FOCUSED LITERATURE SEARCH

NANOTUBES, NANOPORES, NANOCLUSTERS AND OTHER FOUNDATIONS FOR NANOSENSORS

Ab Initio Study of Deformed Carbon Nanotube Sensors for Carbon Monoxide Molecules
da Silva, L.B.; S.B. Fagan; R. Mota, Univ. Federal de Santa Maria, Santa Maria, RS, Brazil.
Nano Letters, Vol 4 No 1, p 65-67, 2004

Deformed single-wall carbon nanotubes (SWCNT) are investigated through ab initio simulations as sensors to detect the presence of chemical gases. Though the viability of using undeformed SWCNT devices has been demonstrated for many molecules, some toxic gases, such as carbon monoxide, are not detectable by these sensors. The authors propose an alternative method using radial deformation, which induces fundamental changes to the electronic properties of SWCNT and allows functionalization of the tube surface to detect the presence of carbon monoxide molecules.

Ab Initio Study of Doped Carbon Nanotube Sensors
Peng, Shu and Kyeongjae Cho, Stanford Univ., Stanford, CA.
Nano Letters, Vol 3 No 4, p 513-517, 2003

Recent advances have demonstrated the viability of using carbon nanotubes (CNTs) to detect the presence of chemical gases such as NO2, NH3, and O2, leading to the design of a new breed of sensor devices based on intrinsic CNTs. Though the devices are capable of detecting small concentration of molecules with high sensitivity under ambient conditions, they are limited in that only molecules binding to a carbon nanotube can be detected, e.g., NH3, NO2, and O2. However, many highly toxic gases (such as carbon monoxide), water molecules, and biomolecules cannot be detected using these intrinsic CNT devices. This paper proposes the concept for a new type of nanoscale sensor device that can detect the presence of CO and water molecules. These devices are developed by substitutional doping of impurity atoms (such as boron and nitrogen atoms) into intrinsic single-wall carbon nanotubes or by using composite BxCyNz nanotubes.

Advances in Air Quality Monitoring via Nanotechnology
Baraton, Marie-Isabelle (SPCTS-UMR6638 CNRS, Univ. of Limoges, Limoges, France); Lhadi Merhari (CERAMEC R&D, Limoges, France).
Journal of Nanoparticle Research, Vol 6 No 1, p 107-117, Feb 2004

The authors review the outcome of two European projects whose objective was to provide an alternative approach to air pollution monitoring via cost-effective mobile microstations based on semiconductor sensors and capable of complementing the expensive and bulky conventional air quality monitoring (AQM) stations. Improvement of the sensor sensitivity to detect very low levels of pollutants (CO, NO, NO2, O3) in air was achieved by using metal oxide nanosized particles with both controlled size and surface chemistry, and by adapting the screen-printing process to the nanometer size specificity. The detection thresholds for NO2, NO, and O3 of the nanoparticles-based sensors have been decreased by a factor of 3 to 5 compared to currently commercialized sensors. The lowest detectable concentration of CO has been reduced from 5 to 3 ppm without affecting selectivity. The new sensor prototypes can now meet the criteria for outdoor AQM, whereas the commercial semiconductor and electrochemical sensors still can not.

Application of Microcrystalline and Nanocrystalline Diamond Thin Film Electrodes for the Electrochemical Detection of Trace Metal Ions
Sonthalia, Prerna V. (Michigan State Univ., East Lansing) and G.M. Swain.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 2130-13P.

Diamond thin-film electrodes show promise for the development of sensitive, reproducible, and low-cost field-deployable methods to detect trace metal ions in water supplies. The authors report on the direct determination of Ag(I), Pb(II), Cd(II), Cu(II), and Zn(II), individually and in mixtures, using differential pulse anodic stripping voltammetry and boron-doped microcrystalline and nanocrystalline diamond thin films.

Applications of Composites of Sol-Gels and Functionalized Metal Nanoclusters to Cesium Determinations
Ca, Diep V. (Miami Univ., Oxford, OH); Butler, James A. Cox.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 330-2P.

The authors describe the preparation of a doped sol-gel material for the solid-phase extraction of cesium ion from solution. Preliminary results show that the pore size, ~6 nm, is sufficient to allow facile incursion of cesium ion from contacting liquids but is smaller than the size of the nanoclusters, hence the nanoclusters do not leach from the porous solid. In contrast to liquid-phase reactions between the crown ether and cesium, a color change occurs with the nanocluster suspension. The factor responsible is a change in the surface plasmon wave. The nanocluster self-template cysts within the sol-gel, which allows for free motion in the liquid-filled domains in the material so that the chemistry can be hypothesized to be the same as when suspended in liquids. This paper presents the results of a test of this hypothesis and applications to optical sensing and solid-phase extraction of cesium.

An Asymmetric Polymer Nanopore for Single Molecule Detection
Mara, A, (Johnson & Johnson Pharmaceutical Research and Development, LLC, San Diego, CA), Z. Siwy (Silesian Univ. of Technology, Gliwice, Poland), C. Trautmann, J. Wan, and F. Kamme.
Nano Letters, Vol 4 No 3, p 497-501, 2004

A sensor capable of detecting single DNA molecules is based on a single nanopore prepared in a polymer film by a latent ion track-etching technique. The nanopore sensor is able to discriminate between DNA fragments of different lengths. To develop the sensor, a polymer foil was penetrated by a single heavy ion of total kinetic energy of 2.2 GeV, followed by preferential etching of the ion track. DNA molecules were detected as they blocked current flow during translocation through the nanopore, driven by an electric field. The nanopores are highly stable and their dimensions are adjustable by controlling etching conditions.

Biosensor Funded for Terror War
Johnson, R. Colin.
EE Times, 12 Nov 2003

A novel handheld device for sensing biological and chemical agents is based on a prototype sensor developed at the University of Buffalo. The unit combines an LED with protein-imprinted xerogels

with integrated emission sites (Pixies) and a CMOS detector. The protein-imprinted xerogels with integrated emission sites are nanoscopically porous glasses formed by a molecular-imprinting strategy. The fluorescence from the Pixies changes in intensity in the presence or absence of the molecule that is used to imprint the xerogel. If the molecule is present, it binds to the templated site, and its presence causes a change in the fluorescent molecule, which is detected by the CMOS array. The cost for the sensor device itself [light source, Pixie array, and CMOS chip] is estimated to be less than $50. Professor Albert Titus of the electrical engineering department at the University of Buffalo performed the research with fellow electrical engineering professor Alexander Cartwright and chemistry professor Frank Bright. The prototype device used to prove the concept and persuade the National Science Foundation to fund the handheld device's development was designed to sense oxygen, but the researchers claim that a variety of different chemical and biological agents can be templated by the xerogel process, and they plan to fabricate a core set of the most likely protein-based toxins--staphylococcal, botulinum and shiga toxins--into a single handheld device. The device also indicates the level of concentration of the detected toxin by measuring the intensity of the fluorescence.
http://eetimes.com/at/news/OEG20031112S0034

Biosensors Based on Conductive Nanomaterials
Lin, Y. (PNNL, Richland, WA); J. Wang (New Mexico State Univ., Las Cruces); Y. Tu & Z.F. Ren (Boston College, Chestnut Hill, MA); J. Liu (SNL, Albuquerque, NM).
EMSL Monthly Report, Sep/Oct 2003

Researchers have developed electrochemical sensors and biosensors based on conducting polymer nanowires and carbon nanotubes (CNTs) to construct next-generation chemical sensor and biosensor devices. The first nanostructured conductive material was made by aligning nanowires of a conducting polymer, polyaniline (PANI). Researchers developed a templateless approach for electrosynthesis by conducting polymer nanowires on platinum and gold electrodes. Nanoparticles of an electron transfer mediator, iron (III) hexacyanoferrate (FeHCF), were successfully deposited into the nanowire matrix by an in situ electrodeposition method. The properties of the nanocomposite materials were induced by the combination of a nanoporous-conducting polymer and a mixed valence compound. The nanoporous PANI film has an extremely high-surface area and provides excellent support for uniform dispersion of FeHCF particles in the third dimension. The high-surface area of nanoporous PANI films can also increase the loading capacity for FeHCF particles, which leads to high sensitivity in chemical and biological sensing applications. The usefulness of the nanocomposite materials has been demonstrated with an electrochemical sensor device for H2O2, the detection of which is widely investigated for enzyme-based biosensors. Researchers have also investigated carbon nanotube thin films immobilized on an electrode surface for biosensor development. Carbon nanotube materials can provide strong electrocatalytic activity and minimize surface fouling of the sensors. Biosensors from two fabrication regimes have been investigated: (1) the co-immobilization of CNTs and enzymes on electrode surfaces, and (2) the growth of controlled-density-aligned CNTs for the fabrication of nanoelectrode arrays. In the first regime, the CNTs are either dispersed in solvents (e.g., sulfuric acid, dimethylformamide, dissolved in Nafion solution for electrode coating, or mixed with Teflon as an electrode material for reagentless biosensors). In the second regime, the nanoelectrode arrays consisting of millions of vertically aligned carbon nanotubes, each acting as an individual electrode, were fabricated through a non-lithographic method. With the development of electrocatalytic properties of CNTs, CNT-based biosensors have now been developed for glucose, nerve agents, and alcohol.
http://www.emsl.pnl.gov/new/highlights/200310/

Biosensors Based on Carbon Nanotubes
Lin, Y. (Pacific Northwest National Lab, Richland, WA), W. Yantasee, F. Lu, J. Wang, M. Musameh, Y. Tu, and Z. Ren.
Dekker Encyclopedia of Nanoscience and Nanotechnology. Marcel Dekker, NY. ISBN: 0-8247-4797-6, p 361-374, 2004

Carbon nanotube (CNT) is an attractive material for the development of biosensors because of its capability to provide strong electrocatalytic activity and minimize surface fouling of the sensors. This article reviews the recent successful development of biosensors based on CNT materials. Biosensors from two fabrication regimes have been investigated: 1) the coimmobilization of CNTs and enzymes on electrode surfaces and 2) the growth of controlled-density aligned CNTs for the fabrication of nanoelectrode arrays. In the first regime, the CNTs are either dispersed in solvents [e.g., sulfuric acid, dimethylformamide (DMF)], dissolved in Nafion solution for electrode coating, or mixed with Teflon as an electrode material for reagentless biosensors. In the second regime, nanoelectrode arrays consisting of millions of vertically aligned CNTs, each acting as an individual electrode, have been fabricated through a nonlithographic method. The electrocatalytic properties of CNTs have enabled applications of CNT-based biosensors for the low-potential detections of glucoses, organophosphorous compounds, and alcohol.

Biosensors for Detection of Chemical Warfare Agents
Greenbaum, Elias (Oak Ridge National Lab, Oak Ridge, TN); M. Rodriguez, Jr.; C.A. Sanders.
Dekker Encyclopedia of Nanoscience and Nanotechnology. Marcel Dekker, NY. ISBN: 0-8247-4797-6, p 375 - 388, 2004

Researchers working with primary-source freshwater drinking samples from river waters have developed a tissue-based biosensor detection system that uses naturally occurring aquatic photosynthetic tissue as the sensing material for the detection of chemical antagonists in the water. Sensor readout is based on principles of fluorescence induction by living photosynthetic tissue. The system successfully detects algae in samples and monitors changes in the characteristic fluorescence induction curves when the samples are exposed to potassium cyanide (KCN), methyl parathion (MPt), N(3,4-dichlorophenyl)-N,N-dimethylurea (DCMU), and paraquat. The unique aspect of this approach to real-time water-quality monitoring is that unlike conventional sensing devices, this sensor material is external to the detecting instrument and is continuously refreshed. These biosensors can be used as continuous rapid-warning sentinels for the detection of chemical warfare (CW) agents in drinking water supplies that are exposed to sunlight. For air monitoring, tissue biosensors based on immobilized whole cell photosynthetic microorganisms have been developed for the detection of airborne CW agents and simulants. The sensor read-out also is based on the principles of fluorescence induction by living photosynthetic tissue. Like the cyanobacteria and algae from which they were constructed, the sensors are reasonably robust and mobile. Commercially available handheld fluorometric detector systems were used to measure Photosystem II photochemical efficiency of green algae and cyanobacteria entrapped on filter paper disks. Toxic agents flowing in the gas stream through the sensors can alter the characteristic fluorescence induction curves with resultant changes in photochemical yields. Sarin, tabun, mustard agent, tributylamine (a sarin stabilizer), and dibutylsulfide (a mustard agent analog) have been tested, with upper threshold limits of detectability for tabun, tributylamine, and dibutylsulfide reported.

Biosensors, Nanosensors and Biochips: Frontiers in Environmental and Medical Diagnostics
Vo-Dinh, Tuan, Oak Ridge National Laboratory, Oak Ridge TN.
The 1st International Symposium on Micro & Nano Technology, 14-17 March 2004, Honolulu, Hawaii, 6 pp.

This presentation describes three areas of research related to the development of biosensors, nanosensors, and biochips for chemical, biological and medical analysis: (1) nanostructured plasmonics-based probes for surface-enhanced Raman scattering (SERS) biochemical analysis, (2) nanosensors for in vivo analysis of a single cell, and (3) multifunctional biochips for medical diagnostics.
http://www.ornl.gov/~webworks/cppr/y2001/pres/119772.pdf

Carbon Nanotube Array-Based Biosensor
Chaniotakis, Nikolas A.(Univ. of Crete, Iraklion, Crete, Greece), Sofia Sotiropoulou.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 320-6P.

Aligned carbon nanotubes grown on platinum substrate were used for the development of an amperometric biosensor. The opening and funtionalization by oxidation of the nanotube array allows for the efficient immobilization of the model enzyme, glucose oxidase. The carboxylated open ends of nanotubes are used for the immobilization of the enzymes, while the platinum substrate provides the direct transduction platform for signal monitoring. It is also shown that carbon nanotubes can play a dual role, both as immobilization matrices and as mediators, allowing for the development of a third generation of biosensor systems, with good overall analytical characteristics.

Carbon Nanotube Nanoelectrode Array for Ultrasensitive DNA Detection
Jun Li, Jun (NASA Ames Research Center, Moffett Field, CA), Hou Tee Ng, Alan Cassell, Wendy Fan, Hua Chen, Qi Ye, Jessica Koehne, Jie Han, and M. Meyyappan.
Nano Letters, Vol 3 No 5, p 59 -602, 2003

A nanoelectrode array based on vertically aligned multiwalled carbon nanotubes (MWNTs) embedded in SiO2 has been developed for ultrasensitive DNA detection. Sensitivity was dramatically improved by lowering the nanotube density. Oligonucleotide probes were selectively functionalized to the open ends of nanotubes. The hybridization of subattomole DNA targets can be detected by combining such electrodes with Ru(bpy)32+ mediated guanine oxidation.

Carbon Nanotube Powder Microelectrodes for Nitrite Detection
Liu, Peifanga and Junhua Hu, Wuhan Univ., Wuhan, PR China.
Sensors and Actuators B: Chemical, Vol 84 No 2-3, p 194-199, 15 May 2002

A carbon nanotube powder microelectrode (CNTPME) modified with anodic pretreatment and pre-adsorbed Os(bpy)32+ shows high catalytic activity for nitrite reduction in acidic solutions. The sensitivity and temperature coefficients of the modified electrode, plus the miniaturization potential, make the CNTPME/Os(bpy)32+ a very promising candidate for a nitrite sensor.

Carbon Nanotube Sensors for Gas and Organic Vapor Detection
Li, Jing (NASA Ames Research Center, Moffett Field, CA), Y. Lu, Q. Ye, M. Cinke, J. Han, and M. Meyyappan.
Nano Letters, Vol 3 No 7, p 929-933, 2003

This paper presents a gas sensor for gas and organic vapor detection at room temperature fabricated by the simple casting of single-walled carbon nanotubes (SWNTs) on an interdigitated electrode (IDE). The sensor responses are linear for concentrations of sub ppm to hundreds of ppm with detection limits of 44 ppb for NO2 and 262 ppb for nitrotoluene. The extended detection capability from gas to organic vapors is attributed to direct charge transfer on individual semiconducting SWNT conductivity with additional electron hopping effects on intertube conductivity through physically adsorbed molecules between SWNTs.

Carbon Nanotube Screen-Printed Electrochemical Sensors
Wang, Joseph and Mustafa Musameh.
Analyst, Vol 129 No 1, p 1-2, 2004

Carbon-nanotube (CNT) strips fabricated into screen-printed (SP) electrochemical sensors based on a CNT ink combine the advantages of CNT materials and disposable screen-printed electrodes. These thick-film CNT sensors are mechanically stable and exhibit high electrochemical reactivity.

Carbon Nanotubes and Metal Oxide Nanoribbons: Molecular Modeling
Maiti, Amitesh, Accelrys Inc., San Diego, CA.
Dekker Encyclopedia of Nanoscience and Nanotechnology. Marcel Dekker, NY. ISBN: 0-8247-4797-6, p 461-473, 2004

Two of the most intensely studied nanosystems are carbon nanotubes (CNTs) and metal-oxide nanoribbons. CNTs have been a popular area of research for more than a decade because of the promise of a host of commercial applications, while metal-oxide nanoribbons, particularly those synthesized from inexpensive SnO2 and ZnO, are of great current interest because of their potential applications as chemical sensors for pollutant gas species and biomolecules. The authors illustrate some of the modern techniques of molecular modeling to study technologically important applications of nanosystems, such as displays, electromechanical sensing, and chemical sensing.

Carbon Nanotubes as Electrode Materials for the Assembling of New Electrochemical Biosensors
Valentini, F. (Univ. degli Studi di Roma Tor Vergata, Rome, Italy); S. Orlanducci; M.L. Terranova; A. Amine (Univ. Hassan II Mohammedia, Morocco); G. Palleschi.
Sensors and actuators B: Chemical, Vol 100 No 1-2, p 117-125, 1 June 2004

In an investigation of the electrochemical response of paste electrodes assembled using single-walled carbon nanotubes, the electrodes were prepared using 60% of Carbolex nanotubes mixed with 40% of mineral oil. Before use, the nanotube material was submitted to a sequence of chemical/physical purification steps to obtain samples consisting mostly of single-walled carbon nanotubes (SWNT) to assure the reproducibility of measurements. The SWNT-modified electrodes were used for the investigation of important neurotransmitters (dopamine and DOPAC), biological molecules (catechol and guanine), inorganic electroactive molecules (ferricyanide), and hydrogen peroxide.

Carbon Nanotubes as SAW Chemical Sensors Materials
Penza, M. (ENEA Materials and New Technologies Unit, C.R. Brindisi, Brindisi, Italy); F. Antolini; M. Vittori Antisari.
Sensors and actuators B: Chemical, Vol 100 No 1-2, p 47-59, 1 June 2004

Surface acoustic wave (SAWs) sensors coated by either single-wall carbon nanotubes (SWCNTs) or multi-wall carbon nanotubes (MWCNTs) have been designed, fabricated, and characterized for chemical detection of volatile organic compounds (VOCs) at room temperature. The selectivity to VOCs under test can be controlled by the type of organic solvent used to disperse the carbon nanotubes as sensing materials onto SAW sensors. The authors discuss some sensing mechanisms between chemical species to be detected and the carbon nanotubes.

Chemical Sensing and Catalysis by One-Dimensional Metal-Oxide Nanostructures
Kolmakov, Andrei and Martin Moskovits, Univ. of California, Santa Barbara.
Annual Review of Materials Research, Vol 34 No 1, p 151-180, 2004

Metal-oxide nanowires can function as chemical or biological sensors with the potential to be massively multiplexed in devices of small size. The active nanowire sensor element in such devices can be configured either as resistors whose conductance is altered by charge-transfer processes occurring at their surfaces or as field-effect transistors whose properties can be controlled by applying an appropriate potential onto its gate. Functionalizing the surface of these entities offers yet another avenue for expanding their sensing capability. Charge exchange between an adsorbate and the nanowire can change the electron density in the nanowire, modifying the nanowire's carrier density by external means, such as applying a potential to the gate could modify its surface chemical properties and perhaps change the rate and selectivity of catalytic processes occurring at its surface.

A Colorimetric Lead Sensor Using DNAzyme-Directed Assembly of Gold Nanoparticles
Lu, Yi (Univ. of Illinois at Urbana-Champaign); Juewen Liu.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 2160-15P.

Researchers have developed a method for directed assembly of gold nanoparticles using DNAzymes and demonstrated their use for sensitive and selective detection and quantification of metal ions, particularly lead. The sensor consists of a DNAzyme and its substrate that can hybridize to a 5'-thio-modified DNA attached to gold nanoparticles. The hybridization brings gold nanoparticles together, resulting in a purple-colored nanoparticle assembly. In the presence of lead, the DNAzyme catalyzes specific hydrolytic cleavage, which disrupts the formation of the nanoparticle assembly, resulting in redcolored individual nanoparticles. The detection level can be tuned from 100 nanomolar to over 200 micromolar. The senosor also is selective over many other metal ions. The simple colorimetric DNAzyme-nanoparticle sensor is well suited for on-site, real-time detection and quantification.

CombiMatrix and Cyrano Collaborate on Nanotechnology Based Sensors
Businesswire, 12 Jan 2004

Acacia Research Corporation has announced that its CombiMatrix Group and Cyrano Sciences will collaborate on the development of chemical sensors that merge CombiMatrix's microarray technology with Cyrano's electronic nose technology. CombiMatrix's arrays incorporate thousands of independently addressable micro-electrodes on a semiconductor chip. This array technology has been used for applications in genetic analysis, RNAi drug discovery, biodefense applications, and nanomaterials discovery. This collaboration seeks to expand the applicability of this technology for sensing chemical agents in air and water.

Come to the Light: Photochemistry Research Could Lead to Cleaner Environment, New Sensors
Binghamton Research, p 40-41, Fall 2003

In supramolecular chemical research, Alistair Lees of Binghamton University is finding ways to insert luminescent compounds into the cavities of some large molecules. Because the luminescence of such molecules changes substantially in reaction to their environment, they make excellent sensors. Recently, Lees and his team found a compound that is a good sensor for cyanide. Other compounds are sensitive to hydrocarbon vapors, which could help detect gaseous pollutants.
http://research.binghamton.edu/main/whatshot/inside/InsideRes_03.pdf

Comparative Study of Optical Fluorescent Nanosensors (PEBBLEs) and Fiber Optic Microsensors for Oxygen Sensing
Chen-Esterlit, Zoe; Serban F. Peteu; Heather A. Clark; William McDonald; Raoul Kopelman.
Advances in Fluorescence Sensing Technology IV. Proceedings of SPIE--The International Society for Optical Engineering, Vol 3602, p 156-163, May 1999

Opto-chemical fluorescent oxygen nanosensors referred to as PEBBLE (Probe Encapsulated By Biologically Localized Embedding) sensors were fabricated by immobilizing tris(4,7-diphenyl-1,10-phenanthroline)Ru(II) chloride and tris(1,10-phenanthroline)Ru(II) chloride within a polyacrylamide matrix. PEBBLEs have diameters of 20 to 200 nm and exhibit excellent performance for dissolved oxygen detection. Their performance for oxygen sensing is compared with micrometer-sized (10 to 20 micrometer) optical fiber sensors and free dye in solution.

Complex Catalytic Colloids on the Basis of Firefly Luciferase as Optical Nanosensor Platform
Pastorino, L.; S. Disawal; C. Nicolini; Y.M. Lvov; V.V. Erokhin.
Biotechnology and Bioengineering, Vol 84 No 3, p 286-291, 2003

A layer-by-layer nano-assembly technique was used to develop complex catalytic microparticles on the basis of firefly luciferase (FL). FL films containing 1, 2, or 3 monolayers were assembled on silver electrode QCM-resonators and on 520-nm diameter sulfonated polystyrene latex by alternate adsorption of FL and polycations using electrostatic interactions for the interlayer interaction. The functionality and stability of the biocolloids were demonstrated by monitoring the intensity of the light emission. Researchers examined factors influencing the light emitted upon catalytic activity of FL, such as the number of luciferase layers in the film and polyion layer at the outermost layer.

Congress Funds $2 Million in Omnibus Appropriations Bill for Altair Nanotechnologies' and Western Michigan University's Nanoscience Research

Altair Nanotechnologies, Inc., News Release, 14 Dec 2003

Altair Nanotechnologies, Inc. of Reno, NV, and Western Michigan University (WMU) will share grant funding for their joint development of nanosensors for detecting chemical, biological and radiological agents in the environment. The project is a collaboration involving WMU, Altair Nanotechnologies, and the University of Nevada, Reno. The $2 million was included in the Omnibus Appropriations Bill passed by the U.S. House of Representatives December 9, 2003. WMU and Altair have a joint partnership for seeking Federal support for nanotechnology research and development and will utilize the new grant funding equally. WMU is a national leader in nanobioenvironmental chemistry research and has established the Nanotechnology Research and Computation Center to further this research. Altair owns a proprietary technology for making nanocrystalline materials of unique quality both economically and in large quantities. The company is currently developing special nanomaterials with potential applications in pharmaceuticals, batteries, fuel cells, solar cells, advanced energy storage devices, thermal spray coatings, catalysts, cosmetics, paints, and environmental remediation. Contact: Dr. Subra Muralidharan, WMU, 269-387-3656.

Controlling the Surface Enhanced Raman Effect via the Nanoshell Geometry
Jackson, J.B. (Rice Univ., Houston, TX); S.L. Westcott; L.R. Hirsch; J.L. West; N.J. Halas.
Applied Physics Letters, Vol 82 No 2, p 257-259, 13 Jan 2003

Systematic variation of the internal geometry of a dielectric core-metal shell nanoparticle allows the local electromagnetic field at the nanoparticle surface to be precisely controlled. The strength of the field as a function of core and shell dimension is measured by monitoring the surface enhanced Raman scattering (SERS) response of nonresonant molecular adsorbates (para-mercaptoaniline) bound to the nanoparticle surface. The SERS enhancement appears to be directly due to nanoparticle geometry alone.

Core-Shell Nanostructured Materials for Chemical and Electrochemical Sensors
Zhong, Chuan-Jian, State Univ. of New York at Binghamton.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 640-3.

Research has shown that nanostructured materials can function as chemically-responsive thin films on different sensory platforms, including microelectrode and piezoelectrode sensors, that present interesting opportunities in chemical and electrochemical sensing applications. Recent applications include vapor-phase sensing of volatile organic and nitroaromatic molecules, electrochemical detection of metal ions and toxic species, and optical detection of biologically-relevant analytes. The sensitivity, selectivity, response time, and detection limit of the sensors can be correlated with the electronic conductivity, mass flux, chemical specificity, ligand framework binding and catalytic properties. The author describes a general bottom-up pathway for fabricating nanostructured materials from core-shell nanocrystals of 1 to 20 nm in diameter that entails a single-step assembly process involving interparticle covalent, hydrogen-bonding, or multidentate ligand coordination by molecular wires.

Detection of CO and O2 Using Tin Oxide Nanowire Sensors
Kolmakov, A., Y. Zhang, G. Cheng, and M. Moskovits, Univ. of California, Santa Barbara.
Advanced Materials, Vol 15 No 12, p 997-1000, June 2003

Highly uniform SnO2 nanowires with bulk electronic properties directed by their surface chemistry have been produced by isolating and oxidizing tin nanowires selected from a template-synthesized array. The nanowires act as sensitive, fast, stable, and reproducible gas sensors that can be easily integrated into a multi-component array.

Detection of Single Bacterial Cell Using Bioconjugated Nanoparticles
Zhao, Xiaojun (Univ of Florida, Gainesville) L.R. Hilliard, S. Jin, W. Tan, Y. Wang.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 1740-6.

A new bionanotechnology based on fluorescence immunoassay for the precise and rapid determination of a single bacterial cell using bioconjugated nanoparticles has been developed as an ultrasensitive fluorescence based immunoassay for the detection of Escherichia coli O157:H7 (E. coli O157: H7). The E. coli O157: H7 cells can be detected quickly and accurately using both a fluorescence microscope and a spectrofluorometer without the need for sample amplification or enrichment.

Determinations of Complex Vapor Mixtures in Ambient Air with a Wireless Microanalytical System: Vision, Progress, and Homeland Security Applications
Zellers, Edward T. (Univ. of Michigan, Ann Arbor); et al.
Technical Digest of the IEEE Conference on Technologies for Homeland Security, 13-14 November 2002, Waltham, MA. IEEE, Boston, p 92-95, 2002

The Engineering Research Center for Wireless Integrated Microsystems (WIMS) at the University of Michigan is working to merge sophisticated ensembles of microsensors and microinstruments with embedded microcontrollers and wireless (rf) transceivers employing micromechanical components into functional microsystems occupying volumes of ~1cm3 and operating at a few mW of power. This paper describes one such microsystem, a micro gas chromatograph (uGC), designed to determine the components of complex vapor mixtures at trace levels in the environment. Analytes include vapors of interest for homeland security. Nanoclusters with different thiolate tail groups have been synthesized and tested. Response patterns from an array of four sensors, each coated with a different Au-thiolate nanocluster thin film, provide diverse and sensitive responses to the vapors tested. With expectations of a 5000-fold preconcentration factor, the μGC should have LODs <1 ppb for most vapors of interest.
http://www.eecs.umich.edu/~brown/Publications/Homeland02.pdf

Development and Application of Molecular-Resolution Chemically-Sensitive Nanotube Probes
Lieber, Charles M., Harvard College, Cambridge MA, President and Fellows.
DTIC: ADA419867, 28 pp, Nov 2002

Carbon nanotubes have been developed as probes for molecular resolution atomic force microscopy imaging. Reproducible methods for the preparation of carbon nanotube probe tips by chemical vapor deposition were demonstrated, and approaches for the preparation of controlled diameter carbon nanotubes were defined. The utility of nanotube probes was demonstrated with development of new method of nanofabrication, and with development of novel method for DNA sequence analysis. In addition, semiconductor nanowires have been developed as building blocks for nanophotonics. A new concept for a nanoscale photonic source using crossed nanowires has been demonstrated, and the novel photonic properties of modulated nanowire heterostructures were shown for the first time.
http://handle.dtic.mil/100.2/ADA419867

Development of a Gas Sensor Utilizing Chemiluminescence on Nanosized Titanium Dioxide
Zhu, Yongfa, Jinjun Shi, Zhenyu Zhang, Chao Zhang, and Xinrong Zhang, Tsinghua Univ., Beijing, P.R. China.
Analytical Chemistry, Vol 74 No 1, p 120 -124, 2002

During the development of a gas-sensing mode based on chemiluminescence generated on the surface of nanosized materials, seven nanosized materials were tested, and chemiluminescence was detected from six of them during the catalytic oxidation of organic vapors in air. In a study of the luminescence characteristics of ethanol and acetone vapors passing through the surface of TiO2, the linear range of chemiluminescence intensity versus concentration of organic compounds was 40 to 400 g/mL for ethanol and 20 to 200 g/mL for acetone dissolved in water, respectively. Regenerability and no consumption of sensor substrate signify a long lifetime for the gas sensor.

The Development of Optical Nanosensors for Biological Measurements
Cullum, B.M. and T. Vo-Dinh, Oak Ridge National Laboratory, Oak Ridge, TN.
Trends in Biotechnology, Vol 18 No 9, p 388-393, 1 Sep 2000

This article discusses and documents the basic concepts of, and developments in, the field of optical nanosensors and nanobiosensors. It describes the progression of this field of research from its birth up to the present, with emphasis on the techniques of sensor construction and their application to biological systems. A brief overview of the techniques for fabricating nanometer-sized optical fibers is followed by descriptions of the various types of transducer and bioreceptor molecules presently used for nanosensor and nanobiosensor fabrication.

Development of a Fluorescent Nanosensor for Ribose
Lager, I.; M. Fehr; W.B. Frommer; S. Lalonde.
FEBS Letters, Vol 553 No 1, p 85-89, 9 Oct 2003

Nanosensors were engineered by flanking the Escherichia coli periplasmic ribose binding protein with two green fluorescent protein variants to analyze ribose uptake and metabolism in living cells. Following binding of ribose, fluorescence resonance energy transfer decreased with increasing ribose concentration. Five affinity mutants were generated covering binding constants between 400 nM and 11.7 mM.

Development of a Novel Biosensor System Using Bilayer Lipid Membranes for Monitoring Environmental Pollutants
Koichiro Kawano, Toshiba Corp. Research and Development Center
ISMNT-1: The First International Symposium on Micro & Nano Technology, 14-17 March 2004, Honolulu, Hawaii.

Abstract not available.

Development of Nanosensors and Bioprobes
Vo-Dinh, Tuan (Oak Ridge National Laboratory, Oak Ridge, TN); Guy D. Griffin; Jean Pierre Alarie;

Brian Cullum; Bobby Sumpter; Donald Noid.
Journal of Nanoparticle Research, Vol 2 No 1, p 17-27, Mar 2000

Nanosensors having bioreceptor probes for bioanalysis were fabricated with optical fibers pulled down to tips having distal end sizes of approximately 30 to 60 nm. The fiberoptic nanoprobes were covalently bound either with bioreceptors, such as antibodies, or with other receptors, such as cyclodextrins that are selective for the size and chemical structure of the analyte molecules. The antibody-based nanoprobe was used for in situ measurements of benzopyrene tetrol in single cells.

Direct Detection of Antibody-Antigen Binding Using an On-Chip Artificial Pore
Saleh, Omar A. and Lydia L. Sohn, Princeton Univ., Princeton, NJ.
Proceedings of the National Academy of Sciences, Vol 100 No 3, p 820-824, 4 Feb 2003

The authors describe a rapid and highly sensitive all-electronic technique based on the resistive pulse method of particle sizing with a pore to detect the binding of unlabeled antibodies to the surface of latex colloids. An on-chip pore is used to sense colloids derivatized with streptavidin and measure accurately their diameter increase on specific binding to several different types of antibodies. The technique does not require labeling of the reactants and is performed rapidly by using very little solution, and the pore itself is fabricated quickly and inexpensively by using soft lithography. The device's sensitivity could be enhanced by using a more monodisperse population of colloids or even a solution of highly monodisperse nanocrystals Because this method relies only on the volume of bound ligand, it can be generally applied to detecting a wide range of ligand-receptor binding reactions, including the detection of anthrax and other hazardous biological and chemical agents.
http://www.pnas.org/content/vol100/issue3/index.shtml

Direct Ultrasensitive Electrical Detection of DNA and DNA Sequence Variations Using Nanowire Nanosensors
Hahm, Jong-in and Charles M. Lieber, Harvard Univ., Cambridge, MA.
Nano Letters, Vol 4 No 1, p 51 -54, 2004

Two-terminal silicon nanowire electronic devices have been developed that function as ultrasensitive and selective detectors of DNA. This nanowire-based approach represents a step forward for direct, label-free DNA detection with extreme sensitivity and good selectivity, and could provide a pathway to integrated, high-throughput, multiplexed DNA detection for genetic screening and biothreat detection.

Disposable Carbon Nanotube Modified Screen-Printed Biosensor for Amperometric Detection of Organophosphorus Pesticides and Nerve Agents
Lin Y. (Pacific Northwest National Lab, Richland, WA), F. Lu, and J. Wang.
Electroanalysis, Vol 16 No 1-2, p 145-149, 2004 (Special Issue: Nanotechnology)

A disposable carbon nanotube-based biosensor was successfully developed and applied to the detection of organophosphorus (OP) pesticides and nerve agents. The biosensors using acetycholinesterase (AChE)/choline oxidase (CHO) enzymes provided a high sensitivity, large linear range and low detection limits for the analysis of OP compounds.

Dual-Chemiresistor GC Detector Employing Monolayer-Protected Metal Nanocluster Interfaces
Cai, Q.Y.; E.T. Zellers.
Analytical Chemistry, Vol 74, p 3533-3539, 2002

Researchers synthesized and tested two gold-thiolate monolayer-protected (nano)clusters as interfacial layers on a dual chemiresistor vapor sensor array. Responses (changes in dc resistance) to each of 11 organic solvent vapors were rapid, reversible, and linear with concentration at low vapor concentrations, becoming sublinear at higher concentrations. Limits of detection (LODs) range from 0.1 to 24 parts per million and vary inversely with solvent vapor pressure. When configured as a GC detector and used to analyze 0.5-L preconcentrated samples of the 11-vapor mixture, the array provides LODs of less than or equal to 700 parts per trillion for most vapors, comparing favorably with those from an integrated array of polymer-coated surface acoustic wave sensors configured and tested similarly. Scaling the active device area down by a factor of 16 has no significant effect on sensitivity.
http://www.wimserc.org/downloads/etznanoAC02.pdf

Electrical Properties of Solid-State Nanopore Sensors
Golovchenko, Jene A. and Daniel Branton, Harvard College, Cambridge, MA.
DTIC: ADA417079, 3 pp, Sep 2003

This final report documents support from the Office of Naval Research in developing a solid state single molecule sensor. The sensor uses a voltage-biased nanopore in an insulating membrane that separates two pools of conducting salt water. The biased nanopore attracts and translocates charged biopolymers like DNA. The ionic current that flows through the pore is sensitive to the presence of single molecules and can be used to measure their passage.
http://handle.dtic.mil/100.2/ADA417079

Electroanalytical and Bioelectroanalytical Systems Based on Metal and Semiconductor Nanoparticles
Katz, Eugenii and Itamar Willner (Hebrew Univ. of Jerusalem, Jerusalem, Israel); Joseph Wang (New Mexico State Univ., Las Cruces).
Electroanalysis, Vol 16 No 1-2, p 19-44, Jan 2004

Metal nanoparticles provide three important functions for electroanalysis: (1) the roughening of the conductive sensing interface, (2) the catalytic properties of the nanoparticles permitting their enlargement with metals, and (3) the amplified electrochemical detection of the metal deposits and the conductivity properties of nanoparticles at nanoscale dimensions that allow the electrical contact of redox-centers in proteins with electrode surfaces. These unique functions of nanoparticles were employed for developing electrochemical gas sensors and electrochemical sensors based on molecular- or polymer-functionalized nanoparticle sensing interfaces, and for constructing different biosensors, including enzyme-based electrodes, immunosensors, and DNA sensors.

Electrochemical Sensors Based on Functionalized Nanoporous Silica
Lin, Y., W. Yantasee, and G.E. Fryxell, Pacific Northwest National Lab, Richland, WA.
Dekker Encyclopedia of Nanoscience and Nanotechnology. Marcel Dekker, NY. ISBN: 0-8247-4797-6, p 1051-1062, 2004

This article reviews the successful development of solid-state, mercury-free electrochemical sensors by using nanostructured materials. Specifically, thiol- or acetamide phosphonic acid-functionalized nanoporous silica materials have been incorporated in carbon paste electrodes for the detection of uranium, and the simultaneous detection of lead/mercury and copper/lead/cadmium. Thiol-functionalized mesoporous silica thin film has been immobilized on gold electrode arrays for the detection of lead ions. The electrochemical sensors based on functionalized nanoporous silica yield reproducible measurements with excellent detection limits (at a few ppb of metal ions) and require little or no regeneration of electrode materials.

Electrochemical Toxicity Sensors
Rusling, James F., Univ. of Connecticut, Storrs.
Dekker Encyclopedia of Nanoscience and Nanotechnology. Marcel Dekker, NY. ISBN: 0-8247-4797-6, p 1063-1072, 2004

Covalent DNA adducts of activated molecules (e.g., styrene, benzo[a]pyrene, napthylamines) with DNA bases are important biomarkers of cancer risk in humans exposed to toxic molecules. Conventional toxicity evaluation of new chemicals proceeds from microbiological testing to animal testing and is expensive and time consuming, hence simple, inexpensive chemical screening protocols that could be used at early stages of commercial consideration would be very useful. One such scheme could be based on enzyme bioactivation of the chemicals with detection of DNA damage from the resulting metabolites. Sensors built on this principle could be used to screen chemicals and metabolites that clearly damage DNA.

Electrochemical Investigation of Lead(II) in a Polymerized Crystalline Colloidal Array Sensor Material Containing Benzo-18-Crown-6-Ether
Geary, Caroline D. (Univ. of Pittsburgh, Pittsburgh, PA); S.A. Asher, C.E. Reese, S.G. Weber.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 450-8.

In nanosystems research, the complexation between 18-crown-6 and lead(II) has been applied to both sensors and display devices. Electrochemical experiments have been carried out on this system with lead(II) in aqueous solution containing an excess of 18-crown-6. Using a square wave waveform with different experimental timescales, stoichiometry, binding constants, and rate constants have been determined at 25 degrees C for the system with both nitrate and perchlorate anions at a Hg/C electrode. Results indicate that there is an anion effect on the rate constants. Electrochemical experiments also have tested the binding of lead(II) with benzo-18-crown-6 immobilized in a polymerized crystalline colloidal array (PCCA) using a mercury film on gold electrode in contact with the PCCA.

Electrochemical Oxidation and Detection of Chlorinated Phenols: A Comparison of Boron-Doped Microcrystalline and Nanocrystalline Diamond Thin-Film Electrodes
Mutaaga, Grace W. (Michigan State Univ.); Natasha Tasheva; Greg M. Swain.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 2120-16P.

Electrically conducting microcrystalline and nanocrystalline diamond thin-film electrodes for the detection of chlorinated phenols show promise due to their low background current, good responsiveness, and lack of fouling. Cyclic voltammetric results demonstrate that diamond exhibits good responsiveness and resists fouling during the electrochemical oxidation of phenol and chlorinated

phenols. The diamond electrode performance was evaluated in terms of the linear dynamic range, limit of quantitation, response variability, and response stability. Both types of diamond exhibited good response variability, stability, and response reproducibility.

Electromechanical and Chemical Sensing at the Nanoscale: Molecular Modeling Applications
Maiti, Amitesh, Accelrys Inc., San Diego, CA.
Molecular Simulation, Vol 30 No 4, p 191-198, 15 Apr 2004

Of the potential application areas commonly associated with nanotechnology, sensors based on carbon nanotubes (CNT) and metal-oxide nanoribbons are among those closest to commercial reality. The author reviews some recent molecular modeling investigations (First-Principles Density Functional Theory (DFT), classical molecular mechanics, and Green's-function-based tight-binding transport) on CNT-based electromechanical sensors and the gas-sensing properties of SnO2 nanoribbons.

Electron Transfer of Redox Enzymes to Inorganic Electrodes
Zhang, Shuguang, Massachusetts Inst. of Technology, Cambridge.
DTIC: ADA419613, 4 pp, 2003

This project was undertaken to develop a protein and peptide-based nanowire and nanoswitch with defined length and properties for a broad spectrum of application in nanobiotechnology. The nanowires were used to develop a novel enzyme/conductive matrix in which the activity of redox enzymes could be controlled by direct electron transfer to inorganic electrodes. Synthetic peptide structures were investigated as linking agents between target enzymes and conductive electrodes. The direct coupling of nanocrystals to amino acids, peptide, and proteins was carried out through several methods. One approach was to couple the nanocrystals to peptides and proteins directly, but the yield was very low and become prohibitively expensive. The successful alternative was first to couple the nanocrystals to amino acids and then to make peptides and proteins through chemical synthesis.
http://handle.dtic.mil/100.2/ADA419613

Electro-Oxidation and Amperometric Detection of Chlorinated Phenols at Boron-Doped Diamond Electrodes: A Comparison of Microcrystalline and Nanocrystalline Thin Films
Muna, Grace W., Natasha Tasheva, and Greg M. Swain, Michigan State Univ., East Lansing.
Environmental Science & Technology, Vol 38 No 13, p 3674-3682, 2004

The electro-oxidation and amperometric detection of phenol and chlorinated phenols, the latter coupled with flow injection analysis (FIA) and high performance liquid chromatography (HPLC), has been accomplished using boron-doped microcrystalline and nanocrystalline diamond thin-film electrodes. Cyclic voltammetric studies were performed to evaluate the redox response of phenol, 2-chlorophenol, 3-chlorophenol, 4-chlorophenol, and pentachlorophenol (PCP) in phosphate buffer, pH 3.5, as a function of the potential scan rate and cycle number. The diamond electrode performance for the amperometric detection of these contaminants in FIA-EC and HPLC-EC was evaluated in terms of the linear dynamic range, limit of quantitation, sensitivity, response precision, and response stability. Both electrode types exhibited good sensitivity, response reproducibility, and response stability for all the analytes, and could be used from days to weeks in measurement after a periodic soak in distilled 2-propanol to maintain optimum performance. The researchers also tested the HPLC-EC assay for the determination of 2-chlorophenol in a contaminated soil sample.

Electrospun Nanofibrous Membranes for Highly Sensitive Optical Sensors
Wang, X., C. Drew, and S.-H. Lee; K.J. Senecal; J. Kumar (Univ. of Massachusetts Lowell); L.A. Samuelson (Natick Soldier Center, U.S. Army Soldier & Biological Chemical Command, Natick, MA).

Nano Letters, Vol 2 No 11, p 1273-1275, 2002

Electrospun nanofibrous membranes can be used in the fabrication of highly responsive fluorescence quenching-based optical sensors for metal ions (Fe3+ and Hg2+) and 2,4-dinitrotoluene (DNT). A fluorescent polymer, poly(acrylic acid)-poly(pyrene methanol) (PAA-PM), was used as a sensing material. Optical chemical sensors were fabricated by electrospinning PAA-PM and thermally cross-linkable polyurethane latex mixture solutions. The sensors showed high sensitivities due to the high surface area-to-volume ratio of the nanofibrous membrane structures.

Engineers Think Big by Designing Small
University of Michigan at Ann Arbor, News Release, 5 Sep 2002

Nanotechnology investors and experts converged on Ypsilanti, MI, September 8-12 for COMS 2002, the 7th International Conference on the Commercialization of Micro and Nano Systems. Held at the University of Michigan's NSF-sponsored Engineering Research Center for Wireless Integrated Microsystems (ERC-WIMS), the conference explored how the miniaturization of sensors and actuators will introduce a new era of solutions for consumers, engineers, doctors, and environmentalists, including devices such as integrated environmental monitors. Environmental scientists currently rely on laboratories full of large and complex equipment to analyze samples brought back from the field. Wireless MEMS technology could shrink these laboratories down to the size of a chip and make them deployable exactly where they are needed. These mini-laboratories could provide instantaneous biohazard warnings or be incorporated into industrial pollution controls. The University of Michigan is developing a low power environmental cube that will contain a variety of sensors, including a microgas analyzer capable of recognizing the top 40 pollutants on the EPA's air toxics list. The device, which will occupy less than two cubic centimeters of space, is designed to detect pollutants with a sensitivity of about one part per billion. MEMS technology still has significant technical hurdles to overcome, including designing improved power sources and low power controllers for the devices, and developing generic microsystem packages.

Environmental and Sensing Applications of Molecular Self-Assembly
Fryxell, G.E., R.S. Addleman, S.V. Mattigod, Y. Lin, T.S. Zemanian, H. Wu, J.C. Birnbaum, J. Liu, and X. Feng.
Dekker Encyclopedia of Nanoscience and Nanotechnology. Marcel Dekker, NY. ISBN: 0-8247-4797-6, p 1125-1135, 2004

Research in the last decade has shown that matter can be manipulated and measured at the nanometer scale in structures of honeycombed pores, spheres, icosahedra, nanotubes and nanorods, and self-assembled structural hierarchies. The purpose of this article is to show how understanding the structural and chemical properties of these novel new materials can be applied to the synthesis of nanostructured hybrid materials that can address needs in the areas of drinking water purification, environmental remediation, and enhancing the sensitivity of analytical methods for detecting heavy metal contamination.

Environmental Pollution Monitoring Using Eco-Sensor Based on Bilayer Lipid Membranes
Mizuho Murahashi, Japan Advanced Inst. of Science and Technology.
ISMNT-1: The First International Symposium on Micro & Nano Technology, 14-17 March 2004, Honolulu, Hawaii.

Abstract not available.

Environmental Technologies at the Nanoscale
Masciangioli, Tina; Wei-Xian Zhang (Lehigh Univ.).
Environmental Science & Technology, Vol 37 No 5, p 102A-108A, 2003

Maintaining and improving soil, water, and air quality represent some of the most formidable challenges facing global society in the 21st century. Pollutants from such diverse sources as oil and chemical spills, pesticide and fertilizer runoff, abandoned industrial and mining sites, and airborne gaseous and particulate matter from automobiles exacerbate the situation on a daily basis. Detecting and treating existing contaminants and preventing new pollution are among the challenges. The aggregate financial burden for improving air, water, and soil quality is truly staggering. This paper describes a prospective solution, nanotechnology, to these immense environmental problems.
http://www.nano.gov/html/res/GC_ENV_PaperZhang_03-0304.pdf

Fabrication and Characterization of Carbon Nanoparticles for Polymer Based Vapor Sensors
Quercia, L. (ENEA, Portici (NA), Italy); F. Loffredo; B. Alfano; V. La Ferrara; G. Di Francia.
Sensors and actuators B: Chemical, Vol 100 No 1-2, p 22-28, 1 June 2004

Vapor sensors have been fabricated and characterized with carbon nanoparticles obtained by flame synthesis. Electrochemically prepared porous silicon with a 40% porosity has been used as the substrate for the carbon growth. The carbon structures seem to be composed of units whose size ranges from 5 to 20nm. Composite thin films have been realized using mainly poly(methyl-methacrylate) (PMMA) as polymeric insulating matrix. Thin films of the composite are used to realize chemiresistor sensing devices. The characteristics of the sensors responses to volatile organic compounds (VOCs) are related to filler types that optimize the sensing device and show the importance of the filler characteristics.

Fabrication of Solid-State Nanopores with Single-Nanometre Precision
Storm, A.J. (Delft Univ. of Technology, Delft, The Netherlands); J.H. Chen; X.S. Ling; H.W. Zandbergen; C. Dekker.
Nature Materials, Vol 2 No 8, p 537-540, Aug 2003

This paper reports a new technique for fabricating silicon oxide nanopores with single-nanometer precision and direct visual feedback, using state-of-the-art silicon technology and transmission electron microscopy. First, a pore of 20 nm is opened in a silicon membrane by using electron-beam lithography and anisotropic etching. After thermal oxidation, the pore can be reduced to a single nanometer when it is exposed to a high-energy electron beam. This fluidizes the silicon oxide, leading to a shrinking of the small hole due to surface tension. When the electron beam is switched off, the material quenches and retains its shape. This technique greatly increases the level of control in the fabrication of a wide range of nanodevices.

Fiber-Optic Nitric Oxide-Selective Biosensors and Nanosensors.
Barker, Susan L.R. (Univ. of Michigan, Ann Arbor); R. Kopelman; M.A. Cusanovich.
Analytical chemistry, Vol 70 No 5, p 971-976, 1998

Both micro- and nanosensors for nitric oxide have been prepared with cytochromes c', and their response is fast, reversible, and linear up to 1 mM nitric oxide. The detection limit is 20 microM, making the sensor useful for some biological samples. While sensors have been prepared based on the fluorescence of the cytochromes c', optodes with greatly enhanced signal-to-noise ratios have been made by labeling the cytochrome c' with a fluorescent dye.

A Fluorescence Nanosensor for Cu2+ on Silica Particles
Brasola, E. (Univ. di Padova, Padova, Italy); F. Mancin; E. Rampazzo; P. Tecilla; U. Tonellato.
Chemical Communications (Camb). Vol 24, p 3026-3027, 21 Dec 2003

A fluorescence nanosensor for Cu2+ ions has been obtained by surface functionalization of silica particles with trialkoxysilane derivatized ligand and fluorescent dye.

A Fluorescent PEBBLE Nanosensor for Intracellular Free Zinc
Sumner, J.P. (Univ. of Michigan, Ann Arbor); J.W. Aylott; E. Monson; R. Kopelman.
Analyst, Vol 127 No 1, p 11-16, 2002

In the development and characterization of a fluorescent optical PEBBLE (Probe Encapsulated By Biologically Localized Embedding) nanosensor for the detection of zinc, a ratiometric sensor has been fabricated that incorporates two fluorescent dyes. One dye is sensitive to zinc and the other acts as a reference. The sensing components are entrapped within a polymer matrix by a microemulsion polymerization process that produces spherical sensors of 20 to 200 nm. The response time for the PEBBLE is less than 4 seconds and the sensor is reversible and photostable. These sensors are capable of real-time inter- and intra-cellular imaging and are insensitive to interference from proteins.

Future Watch: Smart Dust -- Mighty Motes for Medicine, Manufacturing, the Military and More
Hoffman, Thomas.
Computerworld, 24 Mar 2003

"Smart dust" devices are tiny wireless microelectromechanical sensors (MEMS) that can detect everything from light to vibrations. Thanks to recent breakthroughs in silicon and fabrication techniques, these "motes" could eventually be the size of a grain of sand, though each would contain sensors, computing circuits, bidirectional wireless communications technology, and a power supply. Technical obstacles to widespread commercial adoption include design challenges in fusing MEMS and electronics onto a single chip, reducing the several semiconductors needed today to operate these motes down to a single semiconductor, and deploying wireless motes that aren't tethered to power sources, such as electrical outlets or batteries. Nanotechnologies may eventually have a huge impact on society, which helps explain why the Defense Advanced Research Projects Agency began funding aspects of this work at the University of California, Berkeley, in 1998. The goal for researchers is to get these chips down to 1mm on a side. Current motes are about 5mm. The cost of motes has been dropping steadily. Prices range from $50 to $100 each today, and they are likely to fall to $1 within five years.

Researchers are attacking the power problem in part by focusing on so-called low-power ad hoc routing protocols, which figure out how to get a message from one mote to another using the least amount of energy. Research on this kind of power is ongoing at UC Berkeley, MIT, and the University of California, Los Angeles. UC Berkeley is working on fuel cells that can "scavenge" energy to make smart-dust devices run longer. Scavenging can involve drawing off the ambient vibration energy generated by an industrial machine or gathering energy from low levels of light.

Gas Sensing Properties of Nano-ZnO Prepared by Arc Plasma Method
Dong, L.F., Z.L. Cui, Z.K. Zhang.
Nanostructured Materials, Vol 8 No 7, p 815, 1997

Abstract not available.

Gas-Sensitive Properties of Thin and Thick Film Sensors Based on Fe2O3-SnO2 Nanocomposites
Kotsikau, D., M. Ivanovskaya, and D. Orlik (Belarusian State Univ., Minsk, Belarus); M. Falasconi (Univ. of Brescia, Brescia, Italy).
Sensors and Actuators B: Chemical, Vol 101 No 1-2, p 199-206, 15 June 2004

The authors examine the influence of phase composition, structural peculiarities, and grain size of Fe2O3/SnO2 nanocomposites prepared by sol-gel technology on gas-sensitive properties of the corresponding gas sensors. The characteristics of thin film sensors were obtained with regard to NO2 and C2H5OH. This paper includes a discussion of the mechanisms of the processes that determine the gas-sensitive behavior of the composites.

Gold Nanoparticle-Based Sensing of "Spectroscopically Silent" Heavy Metal Ions
Kim, Youngjin, Robert C. Johnson, and Joseph T. Hupp, Northwestern Univ., Evanston, IL.
Nano Letters, Vol 1 No 4, p 165-167, 2001

This paper describes a simple colorimetric technique for the detection of small concentrations of aqueous heavy metal ions (e.g., lead, cadmium, and mercury). Functionalized gold nanoparticles are aggregated in solution in the presence of divalent metal ions by an ion-templated chelation process, which causes an easily measurable change in the absorption spectrum of the particles. The aggregation also enhances the hyper-Rayleigh scattering (HRS) response from the nanoparticle solutions, providing a more sensitive method of detection. The chelation/aggregation process is reversible via addition of a strong metal ion chelator, such as EDTA.

Gold Nanoparticles and Catalytic DNA Produce Colormetric Lead Sensor
University of Illinois News Release, 15 May 2004

Detecting the presence of hazardous lead paint could become as simple as pressing a piece of paper against a wall and noting a color change. Scientists at the University of Illinois at Urbana-Champaign have developed a highly sensitive and selective biosensor that functions in much the same fashion as a strip of litmus paper. The researchers report their discovery in a paper that has been accepted for publication in the Journal of the American Chemical Society. The colorimetric sensor is based on DNA-gold nanoparticle chemistry, and could be used for sensing a variety of environmental

contaminants. Using gold nanoparticles laced with DNA, chemistry professor Yi Lu and graduate student Juewen Liu are able to hybridize the nanoparticles into aggregate clusters that have a characteristic blue color. In the presence of a specific metal ion, the catalytic DNA will break off individual gold nanoparticles, resulting in a dramatic color shift to red. The intensity of the color depends upon the initial concentration of contaminant metal ions. By applying the DNA-gold nanoparticle solution to a substrate, the researchers can create a biosensor that functions in the same manner as litmus paper. The colorimetric sensors eliminate the need for additional instrumentation, and are well suited for on-site, real-time detection and quantification. Lu is working with colleagues at the National Science Foundation's Nanoscale Science and Engineering Center for Directed Assembly of Nanostructures (a partnership among Illinois, the Rensselaer Polytechnic Institute, and Los Alamos National Lab) to further develop the biosensor technology. The ultimate goal is to develop a microchip array with different color schemes for simultaneously detecting many different metal ions. Funding was provided by the Department of Energy and the National Science Foundation.

Helium Detection via Field Ionization from Carbon Nanotubes
Riley, D.J., M. Mann, D.A. MacLaren, P.C. Dastoor, W. Allison, K.B.K. Teo, G.A.J. Amaratunga, & W. Milne, Univ. of Cambridge, Cambridge, UK.
Nano Letters, Vol 3 No 10, p 1455-1458, 2003

The design for a novel, high-efficiency detector for neutral atoms such as helium is based on multiwalled carbon nanotubes (MWNTs), grown by chemical vapor deposition on a steel support wire. Application of a positive bias to the MWNTs generates electric fields sufficient to field-ionize passing gas-phase atoms. The detector has proved to be capable of ionizing and detecting helium gas under ultrahigh vacuum conditions.

High Reflectivity Bragg Reflectors Based on a Gold Nanoparticle/Teflon-Like Composite Material as a New Approach to the Organic Solvent Detection
Convertino, A. (ISMN-CNR, Rome, Italy), A. Capobianchi, A. Valentini, E.N.M. Cirillo.
Sensors and actuators B: Chemical, Vol 100 No 1-2, p 212-215, 1 June 2004

A new optical sensing element for organic solvents based on a polymeric distributed Bragg reflector (DBR) can be easily interfaced with optical fibers. The DBR is a periodic stack of alternating Teflon-like and gold nanoparticle/Teflon-like composite layers showing high reflectivity in the optical telecommunication spectral range and sensing properties due to the peculiar absorbing properties of the composite layers. The swelling of the composite layers in presence of organic vapors causes a DBR periodicity change, which results in the shift of the high reflectivity window.

A Highly Sensitive and Selective Surface-Enhanced Nanobiosensor
Haes, Amanda J. and Richard P. Van Duyne, Northwestern Univ Evanston IL.
Molecularly Imprinted Materials: Sensors and Other Devices, 2-5 April 2002, San Francisco, California. Materials Research Society Symposium Proceedings, Vol 723, p133-138, 2002
[DTIC: ADP013612, 6 pp]

Nanosphere lithography (NSL)-derived triangular Ag nanoparticles were used to create an extremely sensitive and specific optical biological and chemical nanosensor. Using simple UV-vis spectroscopy, biotinylated surface-confined Ag nanoparticles were used to detect streptavidin down to one picomolar

concentrations. The system was tested for nonspecific binding interactions with bovine serum albumin and was found to display virtually no adverse results. The extremely sensitive and selective response of the Ag nanoparticle sensor indicates an exciting use for biological and chemical sensing.
http://handle.dtic.mil/100.2/ADA412559

If It Walks like a Duck: Nanosensor Threat Assessment
Chachis, George C.
Unattended Ground Sensor Technologies and Applications V. Proceedings of SPIE--The International Society for Optical Engineering, Vol 5090, p 341-347, Sep 2003

The paradox of nanosensors is that the smaller the device is, the more useful it is, but the smaller it is, the more vulnerable it is to a variety of threats. Networked nanosensors are more likely to fall prey to a wide-range of attacks, e.g., jamming, spoofing, Janisserian recruitment, Pied-Piper distraction, as well as typical attacks computer network security. Thus, unattended sensor technologies call for network architectures that include security and countermeasures to provide reliable analysis.

Instrumentation for the Interfacial Analysis for Biosensor Microsystems Containing Genetically Engineered Proteins
Hellinga, Homme W., Duke Univ Medical Center, Durham, NC.
DTIC: ADA408298, 3 pp, Oct 2002

The combined use of an atomic force microscope and ellipsometer allows determination of the structure of immobilized protein layers (thickness, orientation, surface concentration, homogeneity), kinetics of layer formation, transport properties of ligand between bulk and protein layer, and stability of the protein layer as compared to solution stability. Researchers have characterized monolayers formed by covalent attachment of E. coli periplasmic binding proteins to glass and other substrates and found that the orientation of these proteins can be controlled precisely. The monolayers retain their ability to respond to analytes with a ligand-mediated hinge-bending conformational change.
http://handle.dtic.mil/100.2/ADA408298

Integrated Nanoscale Silicon Sensors Using Top-Down Fabrication
Elibol, O.H., D. Morisette, D. Akin, J.P. Denton, & R. Bashira, Purdue Univ., West Lafayette, IN.
Applied Physics Letters, Vol 83 No 22, p 4613-4615, 1 Dec 2003

Though carbon nanotubes and silicon nanowires have been demonstrated as single molecule biosensors, the fabrication methods used for creating these devices typically are not compatible with modern semiconductor manufacturing techniques and their large-scale integration is problematic; however, recent advances in microelectronic fabrication techniques have resulted in the realization of nanowire-like structures. The authors report a method to fabricate silicon nanowires at precise locations using the new techniques and discuss the sensitivity of the resulting devices to changes in the composition of ambient gases.
http://www.ece.purdue.edu/~bashir/projects/papers/Elibol_APL_2003.pdf

Intelligent Polymerized Colloidal Array Sensors for Chemical Detection

Asher, Sanford A. (Univ. of Pittsburgh, Pittsburgh, PA); V. Alexeev; A.V. Goponenko; I.K. Lednev; A.C. Sharma; J.P. Walker; M.M. Ward.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 390-2.

A novel photonic crystal hydrogel material can detect a variety of analytes in aqueous media. The sensor material comprises ~90% water containing polyacrylamide hydrogel, lightly crosslinked with bisacrylamide, with an embedded photonic crystal of monodisperse highly charged polystyrene colloids, which self-assembles into a crystalline colloidal array. The material is then functionalized with a molecular recognition agent, which can allow it to sense glucose in bodily fluids or to detect ultralow concentrations of metal cations.

Langmuir-Blodgett Silver Nanowire Monolayers for Molecular Sensing Using Surface-Enhanced Raman Spectroscopy
Tao, Andrea, Franklin Kim, Christian Hess, Joshua Goldberger, Rongrui He, Yugang Sun, Younan Xia, and Peidong Yang.
Nano Letters, Vol 3 No 9, 1229-1233, 2003

The authors report on a Langmuir-Blodgett technique used to assemble monolayers (with areas over 20 cm2) of aligned silver nanowires ~50 nm in diameter and 2 to 3 m in length. These nanowires are close-packed and aligned parallel to each other, and the resulting monolayers serve as excellent substrates for surface-enhanced Raman spectroscopy (SERS) for molecule-specific sensing of compounds such as thiol and 2,4-dinitrotoluene.

Layer-by-Layer Fabrication of a Nanocomposite for the Electrocatalytic Determination of Biochemical Compounds
Perdue, Robbyn K. (Anderson Univ.); Anna M. Kijak; James A. Cox (Miami Univ., Oxford, OH).
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 2120-11P.

The incorporation of dirhodium centers into polyoxometalates results in nanoscale anionic species that can mediate electrochemical oxidations and reductions. This paper reports the synthesis of a new compound, dirhodium phosphomolybdic acid. When immobilized on electrode surfaces with a previously reported analog, dirhodium phosphotungstic acid, they both can be organized by the layer-by-layer electrostatic deposition method on glassy carbon initially modified with a monolayer of p-aminobenzoic acid. The resulting electrode is a well-defined nanocomposite. The resulting assembly mediated the oxidation of L-methionine.

Liquid Polymer Nano-PEBBLEs for Cl- Analysis and Biological Applications
Brasuel, M.G., T.J. Miller, R.Kopelman, and M.A. Philbert, Univ. of Michigan, Ann Arbor.
Analyst, Vol 128 No 10, p 1262-1267, Oct 2003

The first nanometer-scale anion sensing fluorescent spherical nanosensors, or PEBBLEs (probes encapsulated by biologically localized embedding) have been developed for the intracellular monitoring of chloride. The general scheme for the polymerization and introduction of sensing components creates a matrix that allows for the utilization of the highly selective ionophores used in poly(vinyl chloride) and poly(decyl methacrylate) ion-selective electrodes. PEBBLEs were delivered into C6 glioma cells to monitor intracellular chloride levels.

A Micromachined Calorimetric Gas Sensor: an Application of Electrodeposited Nanostructured Palladium for the Detection of Combustible Gases
Bartlett, Philip N. and Samuel Guerin, Univ. of Southampton, Highfield, Southampton, UK.
Analytical Chemistry, Vol 75 No 1, p 126 -132, 2003

This paper describes a study demonstrating that the electrochemical deposition of nanostructured metal (palladium) films offers a promising approach to the fabrication of micromachined calorimetric gas sensors for combustible gases.

Magnetic Relaxation Switches Capable of Sensing Molecular Interactions
Perez, J.M. (Center for Molecular Imaging Research, Boston, MA); L. Josephson; T. O'Loughlin; D. Hogemann; R. Weissleder.
Nature Biotechnology, Vol 20 No 8, p 816-820, Aug 2002

Biocompatible magnetic nanosensors have been developed that act as magnetic relaxation switches (MRS) to detect molecular interactions in the reversible self-assembly of disperse magnetic particles into stable nanoassemblies. With four different types of molecular interactions (DNA-DNA, protein-protein, protein-small molecule, and enzyme reactions) as model systems, scientists showed that the MRS technology can be used to detect these interactions with high efficiency and sensitivity using magnetic relaxation measurements, including magnetic resonance imaging. The magnetic nanosensors can be used in homogeneous assays, as reagents in miniaturized microfluidic systems, as affinity ligands for rapid and high-throughput magnetic readouts of arrays, as probes for magnetic force microscopy, and potentially for in vivo imaging.

Metal Ion Sensor with Catalytic DNA in a Nanofluidic Intelligent Processor
Strategic Environmental Research & Development Program, Conservation CS-1265, 1 pp, July 2002

This project aims to create a highly selective and sensitive miniaturized sensor for bioavailable lead (Pb^{2+}) by combining two recent advances: (1) catalytic deoxyribonucleic acid (DNA) that is reactive only to Pb^{2+} and which can be tagged to produce fluorescence and (2) nanoscale fluidic molecular gates that can manipulate fluid flow and perform molecular separations on tiny volumes of material. This work will develop both the chemistry needed to combine Pb^{2+}-specific catalytic DNA with the molecular gates and the protocol for separating, sensing, and quantifying Pb^{2+} in a complex matrix. Building on the capability of microfabricated, capillary electrophoresis columns in polydimethylsiloxane to precisely control fluidic movement, a three-dimensional arrangement of these channels will be used to induce a sample to pass through a molecular gate consisting of a thin polymeric membrane. Specific recognition elements that cause a measurable response in the presence of a particular species will be incorporated into these channels. In this case, the interior of the channels will be chemically modified to bind a unique sequence of DNA, obtained through in vitro selection, that is highly selective toward Pb^{2+}. It will cleave an associated strand of substrate DNA in the presence of Pb^{2+}. Tagging the substrate DNA with a fluorophore allows for detection of the substrate DNA fragments, thus providing a sensitive optical signal for the presence of Pb^{2+}. This research will combine these scientific advances into a miniaturized sensor that is capable of remote, selective, and sensitive detection of the presence of Pb^{2+}. This SEED Project began in FY 2002. Contact: Dr. Donald Cropek, U.S. Army Corps of Engineers, Construction Engineering Research Lab, Champaign, IL, 800-872-2375, Ext. 7445 or 7430, Donald.M.Cropek@erdc.usace.army.mil.

Metal Ion Sensor with Catalytic DNA in a Nanofluidic Intelligent Processor
Cropek, Donald M. (U.S. Army Engineer Research and Development Center, Construction Engineering Research Lab, Champaign, IL); Paul W. Bohn; Yi Lu; Jonathan V. Sweedler.
SERDP/ESTCP Partners in Environmental Technology Technical Symposium & Workshop, 2-4 December 2003, Washington, DC. Poster Session Abstracts, p 216, 2003

A selective and sensitive miniature sensor for Pb2+ combines two recent advances: catalytic DNA that is reactive only to Pb2+ and that can be tagged to produce fluorescence only in the presence of the metal, and nanoscale fluidic molecular gates that can manipulate fluid flows and perform molecular separations on tiny volumes of material. Researchers have developed the chemistry needed to combine Pb-specific catalytic DNA with the molecular gates and the protocols for separating, sensing, and quantifying Pb2+ in a complex matrix. This technology immobilizes DNA into the interior of nuclear track-etched nanocapillary arrays of a molecular gate and uses multi-layered microfluidic pre- and post-separation channels, which are fabricated from poly(dimethylsiloxane) (PDMS) in planes above and below the molecular gate. The microfabricated electrophoresis channel is capable of separating Pb2+ from other common divalent metal ions. The pre-separated Pb2+ is selectively brought into contact with the sensing DNA and releases an emissive strand to produce fluorescence. Controllable nanofluidic/microfluidic transfer of Pb2+ during sample injection, separation, and detection was achieved by controlling applied bias, polarity, and electrical field strength. The sensitivity and selectivity of the first generation device for Pb2+ over other metal ions are presented. Successful performance of this sensing platform increases the relevance of this SERDP-funded research (CS-1265) beyond Pb2+ to include creation of field sensors for other substances of interest, such as PCBs, PAHs, and other metals (e.g., Al, Hg, Cd, and depleted uranium).

Metallic Nanocrystallites-Coated Piezoelectric Quartz for Applications in Gas Sensing
Lin, Hong-Ming and Bee-Yu Wei (Tatung Univ., Taipei, Taiwan).
Journal of Nanoparticle Research, Vol 5 No 1-2, p 157-165, Apr 2003

This article reports the gas-sensing capability of nanocrystalline transition of piezoelectric quartz crystals (PQC) coated with Pd and Ag (particles size of 10 to 15 nm) or Pt and Au (20 to 25 nm). The nanocrystalline particles deposited on the quartz substrate adsorbs gaseous pollutants, increasing the weight of the quartz substrate and decreasing its vibration frequency. Transition metals--Pd, Pt, Au, and Ag in particular--show good sensitivity for NH3-detection; the maximum frequency change occurs at 150 degrees C for Pd and Pt and at 100 degrees C for Au and Ag. The sensitivity and stability of these gas sensors can be attributed to physical adsorption of the pollutant gases as a result of van der Waals attraction.

Metal Nanoparticles Protected with Monolayers: Applications for Chemical Vapor Sensing and Gas Chromatography
Grate, Jay W. (Pacific Northwest National Lab, Richland, WA); D.A. Nelson; R. Skaggs; R.E. Synovec; G.M. Gross.
Dekker Encyclopedia of Nanoscience and Nanotechnology. Marcel Dekker, NY. ISBN: 0-8247-4797-6, p 1859-1867, 2004

Metal nanoparticles, in which each particle's surface is coated with a protective organic monolayer, are of particular interest because the surface monolayer stabilizes them relative to aggregation and they can

be taken up into solutions and processed into thin films for device applications. The metal in these monolayer-protected nanoparticles (MPNs) typically is gold and the organic layer is a self-assembled thiol layer. A particularly promising application for these materials is as selective layers on chemical vapor sensors in which the thin film of MPNs on the device surface collects and concentrates gas molecules at the sensor's surface.

Microcantilever Based Chemical Sensors with Enhanced Performance
Tipple, C.A. (Univ. of Tennessee, Knoxville), P.G. Datskos, P. Dutta, N. Lavrik, M.J. Sepaniak.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 2620-3.

Films ranging in type and thickness from self-assembled monolayers of thiolated b-cyclodextrin to thin films (18-400 nm) of physically vapor-deposited cyclodextrins and calixarenes were studied on smooth and nanostructured (de-alloyed) gold-coated microcantilever surfaces. A simple, synchronous, dual laser differential-based system has been developed that exhibits a significant reduction in factors affecting cantilever performance, such as temperature drift, refractive index, flow rate, ionic strength, and mechanical noise. Using this system and employing an array of differently coated cantilevers, researchers have quantified individual components in simple mixtures.

Miniature Radio-Frequency Mobility Analyzer as a Gas Chromatographic Detector for Oxygen-Containing Volatile Organic Compounds, Pheromones and Other Insect Attractants
Eiceman G.A. (New Mexico State Univ., Las Cruces), B. Tadjikov, E. Krylov, E.G. Nazarov, R.A. Miller, J. Westbrook, P.J. Funk.
Journal of Chromatography A, Vol 917, p 205-217, 27 Sep 2001

A high electric field, radio-frequency ion mobility analyzer (RF-IMS) was used as a small detector in gas chromatographic separations of mixtures of volatile organic compounds. The detector was equipped with a 2 mCi 63Ni ion source, and the drift region for ion characterization was 34 mm wide X 20 mm long and 0.6 mm high. Detecting trace amounts of volatile organic compounds--alcohols, aldephydes, esters, ethers, pheromones, and other chemical attractants for insects--is necessary to understand insect response to and field dispersion of these chemicals. New technology created at New Mexico State University has separated and characterized various similar chemicals from these families rapidly and accurately at atmospheric pressure. This breakthrough makes a hand-held, field-portable device of unprecedented sensitivity (picogram detection limits) operating in real time finally possible.

Multiple Bacteria Detection Using Dye-doped Silica Nanoparticle-Antibody Conjugates
Hilliard, Lisa R. (Univ. of Florida); Xiaojun Zhao; Shouguang Jin; Weihong Tan.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 1630-10.

A simple immunoassay has been developed for the simultaneous detection and identification of multiple harmful microorganisms using dye-doped silica nanoparticle-antibody conjugates. The method takes advantage of the fluorescent properties of dye-doped silica nanoparticles. When compared to pure dye, the dye-doped silica nanoparticles are superior biomarkers because each antibody-antigen (Ab-Ag) binding event is linked with 100 to 1000 times more dye molecules. This immunological method can potentially be useful in the testing of food and environmental samples for infectious pathogenic bacteria.

Nano-Engineered Electrochemical Sensors for Monitoring of Toxic Metals in Groundwater
Strategic Environmental Research & Development Program, Conservation CS-1267, 1 pp, July 2002

This fact sheet describes a project whose overall objective is to establish a proof of principle for a new class of sensors that utilize electrically conductive, high surface area sorbent material. The research aims (1) to develop the fabrication technology that combines the desired conductive matrices, mesoporous supports, and adsorptive coatings; (2) to test materials for uptake of aqueous lead (Pb) and mercury (Hg)[Self-Assembled Monolayers on Mesoporous Supports (SAMMS) embedded in a conductive medium concentrates metal ions of interest from aqueous media]; and (3) to demonstrate the sensitivity of the Square Wave Anodic Stripping Voltammetry (SWASV) technique using the novel electrodes to measure aqueous Pb and Hg ion concentrations [application of current releases the trapped species, allowing measurement of the metal ions by SWASV]. This project will develop a novel class of microscale electrochemical sensors for measurement of metal ion concentrations in aqueous streams. The sensors will be based on highly porous, functionally coated electrodes. These materials afford significant capacities for adsorption of metal ions to functional ligands embedded in the electrically conductive coating. Metal ion concentrations will be determined using preconcentration/voltammetry at electrodes impregnated with suitable ligands. Ion-specific chemistry at the modified electrodes can be exploited for the preferential accumulation of metal ions prior to the voltammetric quantification of the surface-bound metal ions. Following the accumulation step, the adsorbed metal ions are reduced by application of a negative-going potential. The reducing current is proportional to the metal ion concentration in solution. This SEED Project began in 2002. Contact: Dr. Thomas Zemanian, Pacific Northwest National Lab, Richland, WA, 509-373-0344, ts.zemanian@pnl.gov.
http://www.serdp.org/research/CS/CS-1267.pdf

Nano-Proprietary: Principles of Remote Detection of Explosives
PrimeZone, 24 Nov 2003

At the Defense Research and Engineering Conference and Exposition sponsored by The American Society of Mechanical Engineers International, Washington, DC, November 17-19, 2003, Dr. Zvi Yaniv (CEO of Applied Nanotech, Inc.) presented a new concept for remote detection of explosives in which airborne nanodetectors are strategically placed to detect the presence of explosives. These nanodetectors--e.g., selective quantum dots, nanoporous silicon particles, bioluminescent molecules--change their optical characteristics in the presence of chemicals embedded in explosives. These changes can be easily detected from a large distance, for example, using usual photomultipliers already utilized in many light-detection applications. Dr. Svi's invited talk was entitled "Current Applications of Nanotechnology and Future Outlook For Security Systems."

A Nanocontact Sensor for Heavy Metal Ion Detection
Tao, N., Arizona State Univ.
Proceedings of EPA Nanotechnology and the Environment: Applications and Implications STAR Progress Review Workshop, 28-29 August 2002, Arlington, VA. EPA 600-R-02-080, p 28-29, Feb 2003

This project exploits the phenomena of conductance quantization and quantum tunneling to fabricate nanoelectrodes for in situ detection of metal ion pollution. The goal is to develop a high-performance and low-cost sensor for initial onsite screening tests of surface and ground water to provide early warning and prevention of heavy metal ion pollution.

http://es.epa.gov/ncer/publications/workshop/nano_proceed.pdf

Nanode Array Sensor Microchips. Phase 2
Dill, Kilian, Combimatrix Corp., Mukilteo, WA.
DTIC: ADA417148, 44 pp, July 2002

The funded proposal has several objectives. The first objective is to expand the fabrication and utilization of large arrays of individually addressable, nanometerscale ultramicroelectrodes (nanodes). The second objective is to expand on the current suite of immunochemical assays that can be monitored by electrochemical, visible, or fluorescent means for a wide range of chemical and biological warfare agents. The researchers also will determine if various particle size (viral, spore, cell) can be detected on the ArrayChip. Lastly, limits of detection will be determined for a list of analytes. Attaining these technical objectives will demonstrate the commercialization of using integrated circuit sensor devices for multiplexed assays.
http://handle.dtic.mil/100.2/ADA417148

Nanoengineered Electrochemical Sensor Based on Mesoporous Silica Thin-film Functionalized with Thiol-Terminated Monolayer
Yantasee, W., Yuehe Lin, Xiaohong Li, G.E. Fryxell, T.S. Zemanian, & V.V. Viswanathan.
Analyst, Vol 128 No 7, p 899-904, 2003

A thiol-functionalized mesoporous silica (SH-FMS) thin film is used as the electrode sensing layer for detection of lead(II) in aqueous solutions by employing a square wave adsorptive stripping voltammetry technique.

A Nanometer Aerosol Size Analyzer (nASA) for Rapid Measurement of High-Concentration Size Distributions
Han, Hee-Siew, Da-Ren Chen, and David Y.H. Pui (Univ. of Minnesota, Minneapolis); Bruce E. Anderson (NASA Langley Research Center, Hampton, VA).
Journal of Nanoparticle Research, Vol 2, p 43-52, 2000

A new fast-response nanometer aerosol-size analyzer (nASA) is capable of scanning 30 size channels between 3 and 100 nm in a total time of 3 seconds. The analyzer includes a bipolar charger (Po210), an extended-length nanometer differential mobility analyzer (Nano-DMA), and an electrometer (TSI 3068). Tests to characterize the soot emissions from the J85-GE engine of a T-38 aircraft have demonstrated that the broad dynamic concentration range of the nASA makes it particularly suitable for studies of combustion or particle formation processes. This paper presents the details of the nASA test, as well as results from calibrations, laboratory tests, and field applications.

Nanometer Size Electrode for Nitric Oxide and S-Nitrosothiols Measurement
Zhang, X.; Y. Kislyak; J. Lin; A. Dickson; L. Cardosa; M. Broderick; H. Fein.
Electrochemistry Communications, Vol 4 No 1, p 11-16, Jan 2002

The authors describe the performance characteristics of a new nitric oxide (NO) nanosensor with a tip diameter of just 100 nm. The new NO integrated ultramicrosensor consists of a single carbon fiber

working electrode combined with a reference electrode. The surface of the working electrode is modified with unique, multi-layered NO-selective membranes.

Nanoparticle Optics for Chemical/Biological Sensing and Surface Enhanced Spectroscopy
Van Duyne, Richard P. (Northwestern Univ., Evanston, IL); A.J. Haes, C.L. Haynes, A.D. McFarland.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 640-4.

The extraordinary sensitivity of the localized surface plasmon resonance (LSPR) mechanism to the nanoenvironment within 0-30 nm of the surface of Ag nanoparticles has allowed researchers to develop a new class of optical nanobiosensors. The LSPR nanobiosensor provides a pathway to ultrasensitive biodetection experiments with extremely simple, small, light, robust, low-cost instrumentation that will greatly facilitate field-portable environmental or point-of-service medical diagnostic applications.

Nanoparticle-Structured Electrochemical Sensor for Detection of Metal Ions
Zhong, C.J. (State Univ. of New York, Binghamton); Y. Lin (PNNL, Richland, WA); M.H. Engelhard (EMSL, Richland, WA).
EMSL Monthly Report, Jan/Feb 2004

One class of nanomaterials consists of core-shell-type nanoparticles with metal or oxide nanocrystal cores and organic shell encapsulation. These nanomaterials can be prepared with high monodispersity of size, enhanced stability, and chemical tunability. The use of such materials as building blocks toward a molecularly wired three-dimensional ligand framework could find applications in chemical and biological sensing with enhanced interfacial sensitivity and specificity. Scientists have been exploring a general strategy that entails core-shell manipulation of gold and alloy nanoparticles as building blocks towards responsive or fine-tuned interfacial materials for electroanalytical applications. Nanostructured thin film assemblies derived from gold nanoparticles of 2-nm core size and 11-mercaptoundecanoic acid linker exhibit membrane-like properties. In these films, the hydrogen bonding-linked interparticle channels can be tuned by pH, electrode potential, and metal loading. The films are shown to be electrochemically responsive to copper ions, which involves CO_2^- to Cu^{2+} binding chemistry in a 3-D network. For selective sensing of a target metal ion, the 3-D network can be fine-tuned by incorporating a specially designed ligand. These findings have important implications to the design of nanostructured electrochemical sensors for selective monitoring of metal ions in environmental samples.
http://www.emsl.pnl.gov/new/highlights/200402/

Nano-PEBBLE Ion-Selective Optodes for Real-time Subcellular Chemical Imaging: Is Single Ion Detection Possible?
Kopelman, R. (Univ. of Michigan, Ann Arbor); J.N. Anker, M.G. Brasuel, T.J. Miller, E. Monson, E.J. Park, M.A. Philbert, J. Sumner, R. Tjalkens.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 1700-2.

Ultrasmall, ultrafast, highly sensitive and highly selective PEBBLE (Probe Encapsulated By Biologically Localized Embedding) optical sensors have been produced in hydrophilic, hydrophobic, and amphiphilic bio-compatible matrices to produce ratiometric pH, calcium, potassium, sodium, magnesium, zinc, and chloride nanosensors. While the hydrophilic (polyacrylamide) probes are based on selective fluoro-ionophores, the hydrophobic (poly-decyl-methacrylate liquid polymer) probes

enable highly selective operation via ion correlation (ion exchange or co-extraction). The hydrophobic nanospheres are stabilized (in solution or cell) by appropriate dispersers, as are the amphiphilic (sol-gel) PEBBLE nano-particles.

Nanoscale Fluorescent Sensors for Intracellular Analysis
Lu, J. and Z. Rosenzweig, Univ. of New Orleans, LA.
Fresenius Journal of Analytical Chemistry, Vol 366 No 6-7, p 569-575, Mar-Apr 2000

This paper reviews the fabrication of submicron optical fiber fluorescent sensors and particle-based fluorescent nanosensors and describes the functional characteristics of these miniaturized fluorescent sensors and their applications for quantitative measurement of intracellular analytes.

Nanoscale Fluoroimmunoassays with Lanthanide Oxide Nanoparticles: 'Lab on a Chip'
Koivunen, M.E., S.J. Gee, I.M. Kennedy, and B.D. Hammock, Univ. of California, Davis.
The 227th ACS National Meeting, 28 March-1 April 2004, Anaheim, CA. Abstract ANYL 194, 2004

Lanthanide oxide nanoparticles can be used as fluorescent labels in fast, specific, and sensitive immunoassays performed on microchips or channels. A nanoscale fluoroimmunoassay has been developed for the detection of the herbicide atrazine in environmental samples. Both speed and sensitivity of the assay are markedly improved in this 'lab on a chip' compared with the conventional atrazine ELISA. These high-throughput nanoscale immunoassays can be further improved by using multiple analytes and fluorescent labels in a multiplex format.

Nanoscale Measurements and Nanosensors
Gupta, M.C.
AIP Conference Proceedings, No 615 No 1, p 14-23, 25 May 2002

Advances in scanning probe methods allows information such as mechanical, acoustic, electric, magnetic, thermal, and chemical properties to be determined with nanoscale resolution. Nanosensors based on unique properties of carbon nanotubes are described.

Nanoscale Optical Biosensors Based on Localized Surface Plasmon Resonance Spectroscopy
Haes, Amanda J. and Richard P. Van Duyne, Northwestern Univ., Evanston, IL.
Plasmonics: Metallic Nanostructures and Their Optical Properties.
Proceedings of SPIE--The International Society for Optical Engineering, Vol 5221, p 47-58, Nov 2003

Using localized surface plasmon resonance (LSPR) spectroscopy, a model system of biotinylated surface-confined Ag nanotriangles can detect less than one picomolar up to micromolar concentrations of streptavidin. The Ag nanoparticle-based LSPR nanosensor yields ultrasensitive biodetection with extremely simple, small, light, robust, and low-cost instrumentation. These results represent important new steps in the development of the LSPR nanobiosensor for applications in medical, biomedical, and environmental science.

A Nanoscale Optical Biosensor: The Long Range Distance Dependence of the Localized Surface Plasmon Resonance of Noble Metal Nanoparticles
Haes, A.J., S. Zou, G.C. Schatz, and R.P. Van Duyne, Northwestern Univ., Evanston, IL.
Journal of Physics and Chemistry B, Vol 108 No 1, p 109 -116, 2004

A detailed set of experiments of the long range distance dependence of the localized surface plasmon resonance (LSPR) of surface-confined noble metal nanoparticles coupled with an excellent theory-versus-experiment comparison proves that the sensing capabilities of noble metal nanoparticles can be size-tuned to match the dimensions of biological and chemical analytes. The optimization of the LSPR nanosensor for a specific analyte will significantly improve an already sensitive nanoparticle-based sensor.
http://www.chem.northwestern.edu/~vanduyne/pdf/JpcB108_109-116_2004.pdf

Nanoscale Optical Biosensor: Short Range Distance Dependence of the Localized Surface Plasmon Resonance of Noble Metal Nanoparticles
Haes, A.J., S. Zou, G.C. Schatz, and R.P. Van Duyne, Northwestern Univ., Evanston, IL.
Journal of Physics and Chemistry B, Vol 108 No 22, p 6961-6968, 2004

Silver and gold nanotriangles were fabricated by nanosphere lithography (NSL) and their localized surface plasmon resonance (LSPR) spectra were measured by UV-vis extinction spectroscopy. The short-range (0 to 2 nm) distance dependence of the electromagnetic fields that surround these nanoparticles when resonantly excited can be systematically tuned by changing their size, structure, and composition.
http://www.chem.northwestern.edu/~vanduyne/pdf/JpcB108_6961-6968_2004.pdf

A Nanoscale Optical Biosensor: Real-Time Immunoassay in Physiological Buffer Enabled by Improved Nanoparticle Adhesion
Riboh, J.C. & A.J. Haes (Northwestern Univ., Evanston, IL); A.D. McFarland, C.R. Yonzon, & R.P. Van Duyne.
Journal of Physics and Chemistry B, Vol 107, p 1772-1780, 2003

The authors report major improvements in the localized surface plasmon resonance (LSPR) nanobiosensor. The LSPR nanobiosensor substrate was changed from glass to mica, and a surfactant, Triton X-100, was used in the nanosphere lithography fabrication procedure. These changes increased the adhesion of the Ag nanotriangles by a factor of 9.
http://www.chem.northwestern.edu/~vanduyne/pdf/JpcB107_1772-1780_2003.pdf

Nanosensor for In Vivo Measurement of the Carcinogen Benzo[a]pyrene in a Single Cell
Kasili, P.M.; B.M. Cullum; G.D. Griffin; T. Vo-Dinh, Oak Ridge National Lab., Oak Ridge, TN.
Journal of Nanoscience and Nanotechnology, Vol 2 No 6, p 653-658, 1 Dec 2002

This paper describes the fabrication and the application of an antibody-based fiber-optic nanosensor for in situ measurements of the carcinogen benzo[a]pyrene (BaP) in a single cell.

Nanosensor for In-Vivo Measurement of the Carcinogen Benzo[a]Pyrene in a Single Cell
Kasili, P.M. (Oak Ridge National Lab, Oak Ridge, T); B.M. Cullum; G.D. Griffin; T. Vo-Dinh.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 1330-7.

The authors discuss the fabrication and the application of an antibody-based fiberoptic nanosensor for in situ measurements of the carcinogen benzo[a]pyrene (BaP) in a single cell.

Nanosensor Smells the Faintest Scent
Catchpole, Heather.
ABC Science Online, 3 December 2003

Professor Toyoki Kunitake from the Japan Science and Technology Agency says that nanostructures could be used to make semi-conductors, which in turn could be used to detect molecular levels of substances, including perfumes and other vapors. The researchers made nanometer-thick films of metal oxides using two methods: the sol-gel process and spin coating. The sol-gel process is a way of making ceramic materials with very smooth surfaces. Spin coating applied fluid to a surface and then evaporated the fluid to leave a smooth deposit. The researchers then created flexible shapes with remarkably thin walls by incorporating latex and gold nanoparticles into the nanostructures. Though the research is at a very basic level and production of such nanostructures is still several years off, Kunitake said that his team's technology should offer a cheaper alternative to making ceramic nanofilms because they are able to make them at room temperatures.

Nanosensors and Biochips: Frontiers in Biomolecular Diagnostics
Vo-Dinh T.; B.M. Cullum; D.L. Stokes, Oak Ridge National Lab.
Sensors and Actuators B: Chemical, Vol 74 No 1, p 2-11, 15 Apr 2001

This paper provides an overview of two important technologies: nanosensors and biochips. Various types of nanosensors and biochips have been developed for biological and medical applications, and significant advances have been achieved over the last several years in these technologies. Examples are provided of nanosensors developed for single-cell analysis and applications of biochips for biological sensing of pathogenic agents (e.g., benzopyrene tetrol) and medical diagnostics.

Nanosensors: Design and Application to Site-Specific Cellular Analyses
Cullum, Brian M.; Guy D. Griffin; Tuan Vo-Dinh, Oak Ridge National Lab., Oak Ridge, TN.
Biomedical Diagnostic, Guidance, and Surgical-Assist Systems IV. Proceedings of SPIE--The International Society for Optical Engineering, Vol 4615, p 148-154, May 2002

An antibody-based nanoprobe for in situ measurements within a single cell was targeted to benzopyrene tetrol (BPT), a metabolite of the carcinogen benzo[a]pyrene (BaP) and the BaP-DNA adduct. Nanoprobes were inserted into individual cells of a rat liver epithelial Clone 9 cell line, incubated five minutes to allow antigen-antibody binding, and then removed for fluorescence detection. Prior to measurements, the cells had been treated with BPT. The results demonstrate the possibility of in situ measurements inside a single cell using an antibody-based nanoprobe.

Nanosensors Enable Portable Detectors for Environmental and Medical Applications
Haes, Amanda and Richard Van Duyne, Northwestern Univ., Evanston, IL.
LaserFocusWorld, May 2003

Extrapolation of current data indicates that by optimizing size-and-shape-tunable nanosensor materials, it will be possible to reach sensitivities of a few molecules, perhaps even a single molecule, per nanoparticle sensor element. The extraordinary sensitivity of the localized surface plasmon resonance (LSPR) nanomaterials presents the potential for extremely simple, small, light, robust, low-cost instrumentation that will greatly facilitate field-portable environmental or point-of-service medical diagnostic applications.
http://www.chem.northwestern.edu/~vanduyne/pdf/LFW39_153-156_2003.pdf

Nanosensors for Analysis of a Single Cell
Cullum, Brian M.; Guy D. Griffin; Tuan Vo-Dinh, Oak Ridge National Lab., Oak Ridge, TN.
Biomedical Diagnostic, Guidance, and Surgical-Assist Systems III. Proceedings of SPIE--The International Society for Optical Engineering, Vol 4254, p 35-40, June 2001

Submicron fiber-optic biosensors have been developed and used to measure toxic chemicals within single cells. These sensors are fabricated by pulling the distal end of an optical fiber to a diameter of less than one micron and coating it with antibodies to selectively bind the species of interest. These fibers have been used to selectively measure the concentration of benzo[a]pyrene tetrol, a metabolite of benzo[a]pyrene, within individual cells of two different cell lines: human mammary carcinoma cells and rat liver epithelial cells.

Nanosensors' Niche in Nanotechnology
Carrillo, Daniella L., Frost & Sullivan, Palo Alto, CA.
Chemical Engineering Progress, Vol 99 No 11, p 43S-45S, Nov 2003

Commercialization of nanosensor products has been elusive, but Frost and Sullivan projects that nanotechnology-based detectors, biosensors, and transducers will be commercially available before 2007, with an eventual tremendous impact on the chemical industry. Nanosized temperature sensors likely will have the most penetration in the chemical process industries. Nanosized chemical sensors are projected to completely penetrate the chemical market by 2007, with revenues of $1.3 million/yr, reaching $35.5 million by 2011 due to the emergence of more intelligent, reliable, and cost-effective sensors, coupled with the construction of new, automated plants, which will adapt state-of-the-art sensor technology. Over 50 U.S. companies are actively participating in the production of nanostructured materials, many of which have applications in sensor development. This article identifies many of the commercial firms and university research centers involved in nanotechnology development and application.
http://www.cepmagazine.org/pdf/110333.pdf

Nanosprings Breakthrough Shrinks Size of Sensors
Johnson, R. Colin.
EE Times, 30 Oct 2003

Quantum dots, nanowires, and other nanoscale structures populate the frontier of semiconductor research, collectively aimed at downsizing chip components to the molecular scale. So far piezoelectric materials have been used to fabricate nanowires and nanobelts (ring-shaped nanowires) for experimental nanoscale lasers, field-effect transistors, gas sensors, cantilevers and resonators. But none of these have been "single crystal" and therefore only partially exploit the piezoelectric phenomenon, according to one research scientist--Zhong Lin Wang, director of Georgia Tech's Center for Nanoscience and Nanotechnology and a professor in the School of Materials Science and Engineering--who now claims to have fabricated the world's first single-crystal nanosprings that not only outperform predecessors but also promise to enable single-molecule sensors.
http://www.eetimes.com/story/OEG20031030S0059

Nanostructured Electrochemical Sensor Based on Dense Gold Nanoparticle Films
Yu, Aimin and Zhijian Liang (Max Planck Inst. of Colloids and Interfaces, Potsdam, Germany); Jinhan Cho and Frank Caruso (Univ. of Melbourne, Victoria, Australia).
Nano Letters, Vol 3 No 9, p 1203-1207, 2003

Polyelectrolyte (PE)/gold nanoparticle hybrid films that can be utilized as efficient electrochemical sensors were prepared by infiltrating 4-(dimethylamino)pyridine-stabilized gold nanoparticles into PE multilayers preassembled on indium tin oxide electrodes. Electrochemical experiments indicated that the presence of gold nanoparticles in the PE multilayers could significantly improve the electron-transfer characteristics of the films, which showed high electrocatalytic activity to the oxidation of nitric oxide.

Nanostructured Interfacial Materials for Piezoelectric and Chemiresistor Sensors
Han, Li and Chuan-Jian Zhong, State Univ. of New York at Binghamton.
201st Meeting of the Electrochemical Society, 12-17 May 2002, Philadelphia, PA.

Abstract not available.

Nanotechnology and Homeland Security: New Weapons for New Wars
Ratner, Mark A. (Northwestern Univ.); Daniel Ratner.
Prentice Hall, ISBN: 0131453076, 176 pp, 2003

Nanotechnology offers immense potential for preventing terrorism and other threats to security as well as mitigating their impact. The authors discuss the following nanotechnology focus areas: (1) Sensors: fast, cheap, accurate tests for explosives, radiation, weapons of mass destruction, and food/water contamination; (2) Smart materials: protecting homes, offices, and first responders; (3) Biomedical research: revolutionary treatments for chemical/biological attacks and trauma; (4) Energy generation technologies: ending the world's dependence on oil; and (5) Remediation technologies: healing the effects of environmental damage and ecoterrorism

Nanotechnology: MEMS and NEMS and Their Applications to Smart Systems and Devices
Varadan, Vijay K., Pennsylvania State Univ.
Smart Materials, Structures, and Systems. Proceedings of SPIE--The International Society for Optical Engineering, Vol 5062, p 20-43, 2003

The integration of NEMS (nano-electro-mechanical systems), IDTs (interdigital transducers), MEMS (micro-electro-mechanical-system), and required microelectronics and conformal antenna in the multifunctional smart materials and composites results in a smart system suitable for sending and control of a variety functions, and also can result in novel conformal sensors that can be remotely sensed by an antenna system with the advantage of no power requirements at the sensor site. This paper provides a brief review of MEMS- and NEMS-based smart systems for various applications. Nanotechnology research at Penn State research is based on the use of zeolites over other metal/metal oxides in the microwave field for a high production and uniformity of the product, and biological and mechanical MEMS devices derived from this hybrid composite are presented.

Nanotechnology on a Chip: A New Paradigm for Total Chemical Analysis Systems
Nanotechnology Research Directions: IWGN Workshop Report.
International Technology Research Inst., Loyola College, World Technology (WTEC) Div., p 92, 1999

Sandia National Laboratories is developing a hand-held uChemLab(TM) demonstrator that will analyze for air-born chemical warfare agents and liquid-based explosives agents. The uChemLab(TM) development project brings together an interdisciplinary team of about 50 staff members from throughout the laboratory in areas of expertise including microfabrication, chemical sensing, microfluidics, and information sciences. Although nanotechnology plays an important role in current efforts, most approaches use miniaturized versions of valves, pipes, pumps, separation columns, etc. that are patterned after their macroscopic counterparts. Even though these miniaturized components can work as well as (and sometimes better than) their macroscopic analogs, they simply will not allow for the vision of chemical laboratories in a grain of sand. Nanotechnology will enable a completely new architecture. The ability to build materials with switchable molecular functions could provide completely new approaches to valves, pumps, chemical separations, and detection. Nano-TAS is a fundamentally new approach to allow greater function in much smaller, lower power total chemical analysis systems. Contact person: T.A. Michalske, Sandia National Laboratories.
http://www.wtec.org/loyola/nano/IWGN.Research.Directions/chapter06.pdf

Nanotube Membrane Based Biosensors
Kohli, Punit (Univ. of Florida, Gainesville); Marc Wirtz; Charles R. Martin.
Electroanalysis, Vol 16 No 1-2, p 9-18, Jan 2004

The authors review highly sensitive detection based on electrochemical methods that rely on monodisperse gold and alumina nanotubule membranes with inside diameter approaching molecular dimensions. The analyte species can be detected by measuring a change in trans-membrane current when the analyte is added to the nanotubule-based cell. Another method entails the use of a concentration change based on the nanotubule membrane. Biomemtic ion-gated channels micropore and nanotubule membrane sensors also are reviewed.

Nanotube Sensors
Wirtz, Marc (PPG Industries, Inc., Monroeville, PA); C.R. Martin (Univ. of Florida, Gainesville).
Dekker Encyclopedia of Nanoscience and Nanotechnology. Marcel Dekker, NY. ISBN: 0-8247-4797-6, p 2667-2676, 2004

Nanotube membranes prepared by the template method entails synthesis or deposition of the desired material within the cylindrical and monodisperse pores of a nanopore membrane or other solid. Polycarbonate filters, prepared via the "track-etch" method, and nanopore aluminas, electrochemically prepared from Al foil, have been used as template materials to obtain cylindrical nanostructures with monodisperse diameters and lengths of solid nanowires or hollow nanotubes, depending on the membrane and synthetic method used. One application for these nanotube membranes is in electroanalytical chemistry where the membrane is used to sense analyte species. Membranes containing gold nanotubes with inside diameters that approached molecular dimensions (1 to 4 nm) were used in the work.

Nanotubes Join the Army
Dume, Belle.
PhysicsWeb, 13 Nov 2003

Researchers in the United States have made a nerve agent detector using single-walled carbon nanotubes. Eric Snow and colleagues at the Naval Research Laboratory (NRL) in Washington say that their device is simple to fabricate, extremely sensitive, and intrinsically selective to specific gases. The sensor could be used in industrial and military applications (see J Novak et al. 2003 Appl. Phys. Lett. 83:4026) Researchers found that individual semiconducting single-walled nanotubes show a large change in electrical resistance when exposed to certain gases. This property could be exploited in chemical sensors. To test the device, Snow and co-workers exposed the tubes to DMMP (a chemical similar to the nerve agent Sarin), ammonia, water vapor, and various hydrocarbons using air as the carrier gas. They observed a large increase in the resistance of the sensor as it adsorbed DMMP, but little or no change in resistance when it was exposed to water vapor or hydrocarbons. The nerve gas detector is sensitive to one part per billion of DMMP. The team will work to improve the device's ability to distinguish between different chemicals by incorporating chemo-selective polymers into the sensors. Preliminary demonstrations with a hydrogen-bonding compound have shown that the device can effectively separate out signals from DMMP and ammonia.

Nanotubes Make Miniature Gas Sensors
Dume, Belle.
PhysicsWeb, 10 July 2003

Pulickel Ajayan and colleagues at the Rensselaer Polytechnic Institute in New York state have used carbon nanotubes to make a miniature gas ionization sensor. The researchers say that their detector offers a low-cost, practical alternative to conventional ionization sensors (see A. Modi et al., Nature, 424:171, 2003). Ajayan and colleagues made a simple discharge device in which the cathode is a thin-film array that contains billions of multiwall nanotubes. The anode is an aluminium sheet. Individual nanotubes in the film create very high electric fields near their tips, and the combined effect of all the nanotubes is to increase the overall field and so speed up the gas breakdown process, which means that the gases can be ionized at voltages that are up to 65% lower than in traditional sensors. The highly sensitive device can detect concentrations of gas as low as 10-7 moles per liter, distinguish between different gases in a mixture, and is not affected by temperature or humidity. The device could be incorporated into battery-operated portable sensors for use in environmental, industrial, and security applications.

Nanowire Arrays for Chemical Sensing
Penner, Reginald M., Univ. of California, Irvine.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 950-5.

Arrays of metal nanowires form the basis for a new type of chemical sensor. Sensing occurs when the adsorption of an analyte molecule onto the surface of a metal nanowire causes a change in its resistance. An array sensor for detecting hydrogen gas was constructed by electrodepositing palladium nanowires on an HOPG surface and then transferring the nanowires to a cyanoacrylate film supported on a glass slide. The application of silver contacts to the ends of 10 to 100 nanowires--arrayed electrically in parallel--produced sensors and switches that exhibited a high conductivity state in the presence of hydrogen, and a low conductivity state in the absence of hydrogen. This paper describes a method for incorporating these "portable" metal nanowire arrays into sensors.

Nanowire Nanosensors for Highly Sensitive and Selective Detection of Biological and Chemical Species
Cui, Y. (Harvard Univ., Cambridge, MA); W. Wei; H. Park; C.M. Lieber.
Science, Vol 293 No 5533, p 1289-1291, 2001

Boron-doped silicon nanowires (SiNWs) were used to create highly sensitive, real-time electrically based sensors for biological and chemical species. Biotin-modified SiNWs were used to detect streptavidin down to at least a picomolar concentration range. The capability of these semiconductor nanowires for label-free, real-time detection of a wide range of chemical and biological species can be exploited in array-based screening.

A New Approach to Organic Solvent Detection: High-Reflectivity Bragg Reflectors Based on a Gold Nanoparticle/Teflon-Like Composite Material
Convertino, A., A. Capobianchi, A. Valentini, & E.N.M. Cirillo, Inst. per lo Studio dei Materiali Nanostrutturati CNR - Area della Ricerca di Roma, Rome, Italy.
Advanced Materials, Vol 15 No 13, p 1103-1105, June 2003

The authors present a new sensing element for organic solvents based on a polymeric distributed Bragg reflector (DBR). The periodic stack consists of alternating Teflon-like and gold nanoparticle/Teflon-like layers and shows high reflectivity in the optical telecommunications spectral range. Sensor properties are due to the peculiar absorbing behavior of composite layers, which swell in the presence of organic vapors, causing DBR periodicity change and consequently a high reflectivity window shift.

A New Tool for Eliminating Indoor Air Quality Complaints
Keady, Patricia B. and Tom Halvorsen, TSI Inc., St. Paul, MN.
Journal of Nanoparticle Research, Vol 2 No 2, p 205-208, June 2000

Researchers are studying the toxicology of a new indoor air quality metric, ultrafine particles, on animals and humans. Ultrafine particles are defined as particles smaller than 100 nm diameter; 'nanoparticles,' those smaller than 50 nm diameter, are a subset of ultrafine particles. A battery-powered, portable condensation particle counter (CPC) can be used to quickly identify the source and transport pathways of ultrafine particle contaminants so they can be eliminated or controlled. The CPC condenses isopropyl alcohol on the particles to grow them to an optically

detectable size. The hand-held instrument is fast, has a wide concentration range, and can log data to detect trends and short-term excursions.

NJIT Chemists Pave Way for Cheap, Usable Field Test for Polluted, Toxic, Water, Air, Food
New Jersey Institute of Technology News Release, 31 Mar 2004

Though nanoparticle-size trace chemicals in polluted air or water can be identified through current laboratory processes, the task is expensive and time consuming. Somenth Mitra, Ph.D., professor of chemistry at New Jersey Institute of Technology (NJIT), is working to create a lab on a chip that can identify trace pollutants in the field or at home. With the aid of such a versatile instrument, any worker or homemaker will be able to use a cheap, throw-away sensor--just like the ones drug stores now sell for early pregnancy tests--and quickly learn if a toxic chemical is in the air, food, or water. Mitra presented his data at the American Chemical Society's 227th national meeting in Anaheim, CA, March 31, 2004, in a presentation entitled "Self-Assembly of Nanoparticles for Preconcentration in Environmental Sensing Platforms." Mitra has worked on creating two new methods of concentrating nanoparticles. One method concentrates pollutants in air, depositing nanoparticles from chemical vapors that in turn allow the tiny molecules to assemble themselves directly on the devices. The other approach--which can be used for airborne or liquid pollutants as well as food contaminants--involves a chemical process to create a hard gel. The gel glues together the targeted nanoparticles to form them into distinct micro channels. Scientists often refer to this hard gel process as a "sol-gel synthesis." This latter approach also involves a solid phase extraction in micro channels through which fluid flows on nanoparticles. Mitra has authored four patents.

Novel Nanosensors for Rapid Analysis of Telomerase Activity
Grimm, J.; J.M. Perez; L. Josephson; R. Weissleder.
Cancer Research, Vol 64 No 2, p 639-643, 2004

A novel nanosensor has been developed for rapid screens of telomerase activity in biological samples. The technique utilizes magnetic nanoparticles that, on annealing with telomerase synthesized TTAGGG repeats, switch their magnet state, a phenomenon readily detectable by magnetic readers. High-throughput adaptation of the technique by magnetic resonance imaging allows processing of hundreds of samples within tens of minutes at ultrahigh sensitivities.

A Novel SnO2 Gas Sensor Doped with Carbon Nanotubes Operating at Room Temperature
Wei, Bee-Yu (Industrial Technology Research Inst., Hsinchu, Taiwan); M.-C. Hsu; P.-G. Su; H.-M. Lin; R.-J. Wu; H.-J. Lai.
Sensors and Actuators B: Chemical, Vol 101 No 1-2, p 81-89, 15 June 2004

Single-walled carbon nanotubes (SWCNTs) were added into a SnO2 substrate to develop a new hybrid SWCNTs/SnO2 gas sensor. The SWCNTs/SnO2 layer was fabricated by spin coating using an organometallic solution and then heat-treated. The hybrid sensor detects NO2 concentrations in flowing air at room temperature or N2, by considering alterations in electrical properties. A model is presented to relate potential barriers to electronic conduction in the hybrid material.

NSF Workshop Report on Emerging Issues in Nanoparticle Aerosol Science and Technology (NAST), 27-28 June 2003, University of California, Los Angeles
UCLA Department of Chemical Engineering, 125 pp, 2003

Ultrafine particles present an exceptional challenge for chemical analyses because their mass is small, of the order of attograms. Recent years have seen many advances in on-line analyses of the chemical constituents of ultrafine particles. Most prominent are the advances in particle mass spectrometry, with systems providing data on single particle composition, or size- and composition-resolved data for an ensemble of particles. While much has been accomplished, much is needed to improve our ability our analytical capabilities for the ultrafine particle size fraction. Key areas of research include (1) unbiased sampling of ultrafine particles, both into particle beam systems and for sampling into a liquid stream for subsequent on-line analyses, (2) identification and quantification of organic fraction at the compound or compound-class level, (3) better chemical characterization of light-absorbing particles, (4) means for quantification and calibration, especially for organic compounds, (5) morphological and surface chemistry determinations, (6) fast response systems, (7) systems that can operate under extreme conditions of temperature or pressure, and (8) better and more rapid on-line data reduction schemes. Importantly, the systems must be more accessible, and easier to use. They need to be made smaller in size and lower in weight and cost, especially for targeted needs.
http://www.nano.gov/html/res/NSFAerosolParteport.pdf

NTU Team Develops Molecule-sized Sensor
The Straits Times, Singapore, 4 Mar 2004

A team of researchers in Singapore has developed an electronic sensor the size of a molecule. For starters, the team from Nanyang Technological University (NTU) has created a biosensor that can detect glucose using carbon nanotubes, wire-like conduits about 50,000 times thinner than human hair.
http://www.ntu.edu.sg/pro2/NTUintheNews/TheStraitsTimes/ST-04.03.04.pdf

Optical Biodetectors: Nanosensors Enable Portable Detectors for Environmental and Medical Applications
Haes, A.J.; R.P. Van Duyne, Northwestern Univ., Evanston, IL.
Laser Focus World, 2003, Vol 39 No 5, p 153-155, 2003

The authors discuss a type of optical biosensor that detects changes in local refractive index by monitoring the localized surface-plasmon resonance (LSPR) and extinction maximum of noble metal nanoparticles with UV-visible spectroscopy.
http://www.chem.northwestern.edu/~vanduyne/pdf/LFW39_153-156_2003.pdf

Optical Nanosensors--an Enabling Technology for Intracellular Measurements
Aylott, J.W., Univ. of Hull, Hull, UK.
Analyst, Vol 128 No 4, p 309-312, Apr 2003

Optical nanosensors have been designed to utilize the sensitivity of fluorescence for making quantitative measurements in the intracellular environment. The nanosensor matrix imparts two key benefits: (1) protection of the sensing component from interfering species within the intracellular environment, and (2) protection of the intracellular environment from any toxic effects of the sensing

component. This article discusses recent developments in nanosensor technology and discusses the use of more complex sensing schemes to expand the range of analytes that can be detected and quantified.

Optical Nanosensors and Nanobiosensors
Cullum, Brian M., Univ. of Maryland, Baltimore County.
Dekker Encyclopedia of Nanoscience and Nanotechnology. Marcel Dekker, NY. ISBN: 0-8247-4797-6, p 2757-2768, 2004

As with larger optical sensors, optical nanosensors can generally be classified into one of two different classes: chemical nanosensors or nanobiosensors, depending on the type of recognition element (i.e., chemical or biochemical) used to provide specificity to the sensor. Though both of these classes of optical nanosensors are capable of obtaining quantitative measurements in many different microscopic environments, they have found an ideal application in the analysis of chemical and biochemical species present within living cells. Their small sizes allow them to be inserted and precisely positioned within individual cells to obtain spatially localized measurements of chemical species in real time.

Optical Nanosensors for Chemical Analysis Inside Single Living Cells: 1. Fabrication, Characterization, and Methods for Intracellular Delivery of PEBBLE Sensors
Clark, H.A. (Univ. of Michigan, Ann Arbor); M. Hoyer; M.A. Philbert; R. Kopelman.
Analytical Chemistry, Vol 71 No 21, p 4831-4836, 1 Nov 1999

Spherical optical nanosensors, or PEBBLEs (probes encapsulated by biologically localized embedding), have been produced in sizes from 20 and 200 nm in diameter. These sensors are fabricated in a microemulsion and consist of fluorescent indicators entrapped in a polyacrylamide matrix. A generalized polymerization method has been developed that permits production of sensors containing any hydrophilic dye or combination of dyes in the matrix. The PEBBLE matrix protects the fluorescent dye from interference by proteins, allowing reliable in vivo calibrations of dyes. Sensor response times are less than 1 ms.

Optical Nanosensors for Chemical Analysis Inside Single Living Cells: 2. Sensors for pH and Calcium and the Intracellular Application of PEBBLE Sensors
Clark, H.A. (Univ. of Chemistry, Ann Arbor); R. Kopelman; R. Tjalkens; M.A. Philbert.
Analytical Chemistry, Vol 71 No 21, p 4837-4843, 1 Nov 1999

Optical nanosensors, or PEBBLEs (probes encapsulated by biologically localized embedding), have been produced for intracellular measurements of pH and calcium. This paper examines five varieties of pH-sensitive sensors and three different calcium-selective sensors. Each sensor combines an ion-selective fluorescent indicator and an ion-insensitive internal standard entrapped within an acrylamide polymeric matrix. These PEBBLE sensors are fully reversible over many measurements. The sensors have also been applied to intracellular analysis of the calcium flux in the cytoplasm of neural cells during the mitochondrial permeability transition; specifically, a distinct difference was noted between cells of different types with respect to their response to the toxicant m-dinitrobenzene and measurement of intracellular calcium, the precursor to cell death.

Optical Supramolecules for Chemical and Physical Sensing
Nocera, Daniel G., Massachusetts Inst. of Technology, Cambridge.
DTIC: ADA422046, 13 pp, Apr 2004

This proposal seeks to bring to the Air Force Office of Scientific Research a strategy to use bio-inspired concepts of recognition and signal transduction to unite the areas of optical chemosensing and nanoscience to address diverse chemical and physical sensing needs. Luminescent molecule, supramolecule, or materials have been synthesized for targeted sensing application. An intrinsic component of the program has been to define fundamental parameters that control the nonradiative and radiative energy flows so that the luminescence intensity and lifetime of the optical probe can be used for signal transduction. The following major achievements have been made by the research program: (1) the development of the first microfluidic chemosensor for the detection and monitoring of chemical species on especially small length scales; (2) the development of new optical probes for accurate temperature & and pressure measurements at aerodynamic surfaces; and (3) the development of new materials for an optical diagnostic technique invented to detect and measure turbulence.
http://handle.dtic.mil/100.2/ADA422046

Optochemical Nanosensors for Intracellular Chemical Measurement
Kopelman, R.; M.T. Miller; M. Brasuel; H.A. Clark; M. Hoyer; M.A. Philbert.
Chemical, Biochemical, and Environmental Fiber Sensors X.
Proceedings of SPIE--The International Society for Optical Engineering, Vol 3540, p 198-205, Feb 1999

Fiber-optic ion correlation-based nanosensors for sodium, potassium, and chloride employing a submicron optical fiber 'supertip' have been applied to the monitoring of ion concentrations in single mouse oocytes. These sensors also have been used to monitor the effect of an ion channel-blocking agent. The use of submicron optical fiber multiprobes has been explored to address the challenge associated with single-cell simultaneous measurement of multiple analytes.

PEBBLE Biosensor for the Measurement of Cellular Zinc
Sumner, James (Univ. of Michigan, Ann Arbor); C.A. Fierke, R. Kopelman, N.M. Westerberg.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 2340-3, 2003.

This paper reports on a fluorescent optical PEBBLE (probes encapsulated by biologically localized embedding) nanosensor for the detection of zinc. A ratiometric sensor has been fabricated that incorporates the sensing components within a polymer matrix by a microemulsion polymerization process. The spherical sensors are less than 200 nm in size, which allows for cellular measurements.

Penn Researchers Introduce a New Nanotube-Laced Gel, Create New Means of Aligning Nanotubes
University of Pennsylvania News Release, 1 Mar 2004

Researchers at the University of Pennsylvania have devised a new method for aligning isolated single wall carbon nanotubes and, in the process, have created a new kind of material with liquid crystal-like properties: nematic nanotube gels. The gels could potentially serve as sensors in complex fluids, where changes in local chemical environment, such as acidity or solvent quality, can lead to visible changes in the gel shape. (See M.F. Islam, et al., "Nematic Nanotube Gels," Physical Review Letters, 92(8)27 Feb

04) The researchers embedded isolated nanotubes coated by surfactant into a cross-linked polymer matrix, a gel. The volume of the gel is highly temperature dependent, and the researchers were able to compress it to a fraction of its original size by changing its temperature. The gel network prevented the close contact between parallel nanotubes that produces bundling, and its compression produced concentrations of isolated nanotubes that favor nematic alignment. The condensed gel thus creates concentrations of isolated, aligned nanotubes that cannot be achieved when they are suspended in water. Like liquid crystals, the resulting nanotube gels exhibit beautiful defect patterns revealed by polarized light transmission through the sample that correspond to the particular nanotube alignments. The topology of the defects are, in turn, coupled to the mechanical strains present in the gel. The researchers are now exploring applications for both the technique and the properties of the nematic nanotube gels.

Pesticide Detection on a Chip
University of California, Davis, News Release, 29 Mar 2004

For pesticides and other contaminants, nanotechnology can be applied to make high-throughput tests that are smaller, faster and more sensitive than conventional assays. UC Davis researchers led by Ian Kennedy, professor of mechanical and aeronautical engineering, and Bruce Hammock, professor of entomology, have made fluorescent nanoparticles of lanthanide oxide and europium oxide that can be coupled to biological molecules and used in antibody-based assays for pesticide residues. The nanoparticles also can be sorted magnetically. The researchers are currently investigating carrying out these assays in microdroplets and in microchannels on etched chips. Contact: Ian Kennedy, 530-752-2796, imkennedy@ucdavis.edu.

Photoactivated CdSe Nanocrystals as Nanosensors for Gases
Nazzal, Amjad Y. (Univ. of Arkansas, Fayetteville); Lianhua Qu; Xiaogang Peng; Min Xiao.
Nano Letters, Vol 3 No 6, p 819 -822, 2003

The photoluminescence of high-quality CdSe nanocrystals incorporated into polymer thin films was found to respond reversibly and rapidly to environmental changes upon photoradiation above their absorption onset. Photostimulation is necessary for the response, which likely makes the original dense ligands monolayer on the surface of the nanocrystals permeable to gases by the activation of the vibration modes of the nanocrystal lattice through photon/phonon coupling.

Photochemical Sensing of NO(2) with SnO(2) Nanoribbon Nanosensors at Room Temperature
Law, M., H. Kind, B. Messer, F. Kim, and P. Yang, Univ. of California, Berkeley.
Angewandte Chemie International Edition, Vol 41 No 13, p 2405-2408, 2 July 2002

Abstract not available.

Photonic Crystal Chemical Sensing of Chemical and Biochemical Agents
Asher, S.A. (Univ. of Pittsburgh, Pittsburgh, PA), V. Alexeev, A.V. Goponenko, I.K. Lednev, C.E. Reese, A. Sharlma, J.P. Walker.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 1550-1, 2003

Novel photonic crystal hydrogel materials have been developed to for the visual determination of a wide variety of chemical species in aqueous media. The sensor material comprises a ~90% water-containing polyacrylamide hydrogel lightly crosslinked with bisacrylamide, with an embedded photonic crystal of monodisperse highly charged polystyrene colloids that self-assembles into a crystalline colloidal array. This material is then functionalized with molecular recognition agents. When the molecular recognition agent interacts with the analyte, it actuates a hydrogel volume change that changes the diffraction wavelength. The sensor material has been used to detect glucose in bodily fluids, ultralow concentrations of metal cations, and poisonous species in the atmosphere.

Planned U.S. Sensor Network Targets Terror Threats
Merritt, Rick.
EE Times, 14 July 2003

Government researchers are at work on a nationwide sensor network that someday could provide a real-time early-warning system for a wide array of chemical, biological and nuclear threats across the United States. One agency has published a roster of about 50 biological agents alone (see www.niaid.nih.gov/biodefense/bandc_priority.htm). The multifaceted nature of the threat leads researchers to conclude the network will consist of a suite of different kinds of sensors. More than 50 researchers at Pacific Northwest National Laboratory in Richland, WA, have been developing nanosize preconcentrators for nerve agents, botulism, and other toxins. Sandia hopes to prototype by fall 2004 a sensor that could detect chemicals such as nerve and blister agents, as well as some top-priority industrial toxins. The sensor would use polymer- or gel-coated silicon devices to trap targeted chemicals, then send the agents through fluidic channels to on-chip arrays of surface-acoustic-wave detectors running at up to 500 MHz. A follow-on device would integrate the fluidics, SAWs, and support electronics on a single device. At Oak Ridge National Labs in Tennessee, a team has been working for 18 months on an underlying network architecture for a national sensor network. The team will develop and test the networking architecture over the next year, then follow up with a metro-area trial. The SensorNet project, running on a $3 million budget this year, is seeking $9 million in funding for its next fiscal year. A host of pilot sensor network projects are in field tests, including systems developed by Los Alamos and Berkeley researchers to safeguard crops. The field sensors were originally developed to track the spread of insecticides and fertilizers. Trial sensor networks also are in place in Boston subways, at the San Francisco airport, and on the Miami docks. The Washington subway recently went operational with a chemical-sensor system developed by Sandia and Argonne National Labs in Chicago.
http://www.eetimes.com/article/showArticle.jhtml?articleId=12804243

Polyaniline Nanofiber Gas Sensors: Examination of Response Mechanisms
Virji, Shabnam Jiaxing Huang, Richard B. Kaner (Univ. of California, Los Angeles), Bruce H. Weiller (The Aerospace Corporation, Los Angeles, CA).
Nano Letters, Vol 4 No 3, p 491-496, 2004

A new interfacial polymerization method for the synthesis of polyaniline nanofibers has enabled scientists to develop nanofiber sensors and compare them to conventional polyaniline sensors. This paper describes five different compared response mechanisms: acid doping (HCl), base dedoping (NH3), reduction (with N2H4), swelling (with CHCl3), and polymer chain conformational changes (induced by CH3OH). The polyaniline nanofibers performed better in all cases than conventional thin films.

Polyaromatic Luminescent Nanocrystals for Chemical and Biological Sensors
Botzung-Appert, E. (CNRS, UPR 5031 assoc. l'Univ. J. Fourier et a l'INPG); V. Monnier; T.H. Duong; R. Pansu; A. Ibanez.
Chemistry of Materials (Communication), Vol 16 No 9 p 1609-1611, 2004

Abstract not available.

Polymeric Nanowire Chemical Sensor
Liu, Haiqing, J. Kameoka, D.A. Czaplewski, & H.G. Craighead, Cornell University, Ithaca, NY.
Nano Letters, Vol 4 No 4, p 671-675, 2004

Using a nonlithographic deposition process to form single polymeric nanowire chemical sensors, scientists deposited oriented polyaniline nanowires with diameters of ~100 nm on gold electrodes. The devices showed a rapid and reversible resistance change upon exposure to ammonia gas at concentrations as low as 0.5 ppm. The researchers are working on other polymer materials that are able to detect other gasses.

Porphyrin and Tetrabenzoporphyrin Dendrimers: Tunable Membrane-Impermeable Fluorescent pH Nanosensors
Finikova, O. (Univ. of Pennsylvania, Philadelphia); A. Galkin; V. Rozhkov; M. Cordero; C. Hagerhall; S. Vinogradov.
Journal of the American Chemical Society, Vol 125 No 16, p 4882-4893, 23 Apr 2003

The pH dependencies of the UV-vis and fluorescent spectra of new water-soluble dendritic porphyrins and tetrabenzoporphyrins were investigated. The study results suggest that porphyrin dendrimers can be used as fluorescent pH indicators for proton gradient measurements.

Proceedings: EPA, Nanotechnology and the Environment: Applications and Implications, STAR Progress Review Workshop, 28-29 August 2002, Arlington, Virginia
U.S. EPA, National Center for Environmental Research. EPA 600-R-02-080, 77 pp, Feb 2003

Nanoscale science, engineering, and technology, collectively referred to as nanotechnology, is the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new molecular organization. The U.S. EPA's Office of Research and Development, National Center for Environmental Research (NCER), as part of its Science to Achieve Results (STAR) program, supports research leading to nanotechnology application advances that can improve the cost or performance of capabilities to assess and solve environmental problems. EPA also is interested in predicting and understanding both the positive and negative environmental effects of this new technology and the societal changes it may bring. EPA's objective in the nanotechnology research area is to support innovative research that could help define significant emerging environmental problems. The proceedings covered (in part) the following topics: Nanosensors for Detection of Aquatic Toxins, Real-Time Chemical Composition Measurements of Fine and Ultrafine Airborne Particles, Nanostructured Porous Silicon and Luminescent Polysiloles as Chemical Sensors for Carcinogenic Chromium(VI) and Arsenic(V), and Simultaneous Environmental Monitoring and Purification Through

Smart Particles. For more information on EPA's nanotechnology research, contact either Barbara Karn at 202-564-6824 (karn.barbara@epa.gov), or Nora Savage at 202-564-8228 (savage.nora@epa.gov). http://es.epa.gov/ncer/publications/workshop/nano_proceed.pdf

Ratiometric Optical Nanosensors for Selective Magnesium Ion Imaging in Viable Cells
Park, Edwin J. (Univ. of Michigan, Ann Arbor), Jonathan W. Aylott, Raoul Kopelman.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 820-2.

Probes encapsulated by biologically localized embedding (PEBBLEs) are useful as bioanalytical sensors due to their small size, high sensitivity, matrix biocompatibility, chemical inertness, and ability to make ratiometric measurements. A polyacrylamide matrix has been used in fabricating a fluorescence-based magnesium sensor. An inverse microemulsion polymerization has been used to encapsulate a magnesium sensitive indicator dye, along with a reference dye, in an acrylamide matrix to form PEBBLEs ranging in diameter from 15 to 40 nm. Preliminary studies to monitor changes in magnesium concentration in cells as a result of chemical perturbations have demonstrated that the parameters of these sensors include response times of less than 5 seconds, detection limits as low as 100 micromolar, and reversibility and stability over a 6-hour period with respect to leaching and photobleaching of the dye.

Rice Develops Nanosensor for Precision Chemical Analysis: Nanoshell Sensor Opens Door for New Methods to Examine Single Molecules
Rice University News Release, 10 Jan 2003

Nanotechnology researchers at Rice University have demonstrated the ability to precisely control the electromagnetic field around nanoparticles, opening the door for chemical screening techniques that could allow doctors and chemists to routinely analyze samples as small as a single molecule. The research builds upon a method of molecular analysis called Raman spectroscopy and capitalizes on the tunable optical properties of metal nanoshells, a novel type of nanoparticle invented at Rice. "This result is extremely important because it is the first time that anyone has actually designed and engineered a nanosensor specifically for obtaining chemical information," said nanoshell inventor Naomi Halas, the Stanley C. Moore Professor of Electrical and Computer Engineering. By studying the spectrum of light that an object emits, scientists can decipher which elements are present in the sample, and in some cases, how those elements relate to one another. Raman spectroscopy allows scientists to observe the vibrational states of molecules, giving clues about where and how much molecules bend, for example, and serves as a "fingerprint" for the identification of specific molecules of interest, such as environmental contaminants or chemical or biological toxins. Scientists can boost the Raman light emissions from a sample by a million times or more by placing the sample next to small particles of metal called colloids, but they have never been able to precisely control the electromagnetic state of the metal colloids, so results and interpretations of such studies vary. Rice's research offers scientists a chance to precisely control surface enhanced Raman scattering, or SERS. In the Rice experiments, the researchers were able to dramatically enhance the SERS effect, making it up to a billion times more powerful. Similar in structure to a hard-shelled chocolate candy, nanoshells are layered colloids that consist of a core of non-conducting material covered by a thin metallic shell. By varying the thickness of the conducting shell, the researchers can precisely tune the electric and optical properties of nanoshells. Nanoshells are just slightly larger than the size of molecules, measuring just a few tens of nanometers, or billionths of a meter, in diameter. Contact: Jade Boyd, jadeboyd@rice.edu, 713-348-6778.

Science and Technology of Nanostructures in the Department of Defense
Murday, James S., Naval Research Laboratory, Washington DC.
Journal of Nanoparticle Research, Vol 1 No 4, p 501-505, Dec 1999

The United States Department of Defense has designated nanoscience as a strategic research area to accelerate the expected benefits. This paper provides a brief guide to those DoD funding officers and research scientists actively interested in nanostructures for the miniaturization of information technology devices and for the detection of hazardous chemical and biological agents

Security Technologies Advances in Chemical and Biological Detection Technologies: New Technologies Aid Quicker, More Accurate Chemical and Biological Threat Detection
Frost & Sullivan, 7 Oct 2003

This Technical Insights study from Frost & Sullivan examines the advances in chemical and biological detection for security. It provides information about the security concerns and strategies in various military, commercial, and public sectors and their impact on the development of new technologies, including nanosensors, such as 'smart dust.' The research includes a summary of key patents and list of organizations involved in the design and manufacture of security technologies and their contact information. New biological weapons detectors use biotechnology to tell the difference between pathogens and benign microorganisms based on their genetic makeup. Light detection and ranging systems identify different chemical compositions by zapping living cells with UV light and watching for fluorescence from molecules, but this method is ineffective in distinguishing between biological agents and pollen grains or clouds of smoke. Analogous chips that detect harmful organisms using antibodies sensitive to particular pathogens are under development. Research on biodetectors that correlate a human pathogen with the human cell to which it is harmful is also underway. Current R&D in chemical detection technology for chemical warfare agents is focused on increasing the speed and sensitivity of the instruments, while reducing size and cost. Numerous types of detection equipment of varying sensitivity and specificity are available, and the more advanced ones can detect dangerous concentrations of chemical agents. The report's Table of Contents is available at
http://www.marketresearch.com/map/prod/935288.html

Selective Separation of La3+ and Lanthanum Organic Complexes with Nanometer-Sized Titanium Dioxide and Their Detection by Using Fluorination-Assisted Electrothermal Vaporization ICP-AES with In-Situ Matrix Removal
Li, S., Bin Hu (Wuhan Univ., Wuhan, PR China), Z. Jiang, P. Liang, X. Li, and L. Xia.
Environmental Science & Technology, Vol 38 No 7, p 2248 -2251, 2004

A new method has been developed for the determination of free La3+ and La organic complexes in solution using a nanometer-sized titanium dioxide as solid-phase extractant and fluorination-assisted electrothermal vaporization (FETV)-ICP-AES as sensitive detector. The method was applied for the determination of free ion (La3+) and La complexes in synthetic solutions and soil extracts with satisfactory results.

Sensor Industry Developments and Trends
Adrian, Peter.

Sensor Business Digest, July 2003

According to Sensor Business Digest, revenues for the North American gas sensor market totaled about $754.3 million in 2002. Sensors constructed at the molecular scale have promise for being extremely sensitive, selective, and responsive. DoD has been interested in such sensors for rapidly and accurately detecting small amounts of chemical or biological agents to allow soldiers to defend against chemical or biological attacks. Microfabricated gas sensors that use nanoparticulate metal oxide material have been finding growth opportunities in such areas as automobile cabin air quality monitoring, air pollution monitoring (of such constituents as ozone), as well as fire detection. Carbon nanotube-based sensors have potential for detecting a single molecule of a substance, and tiny sensors (on the order of 1,000 times the size of a MEMS sensor) using carbon nanotube material purportedly offer orders of magnitude less power consumption than a MEMS sensor. Carbon nanotube technology is particularly suitable and promising for chemical detection; sensors suitable for sensing different analytes of interest could be configured in the form of an array to comprehensively monitor multiple analytes. Promising applications for carbon nanotube-based gas sensors include chemical leak detection or industrial chemical process monitoring (e.g., petrochemicals, hydrocarbons, nitrogen dioxide, ammonia, hydrogen, oxygen, carbon monoxide, carbon dioxide, methane, hydrogen sulfide); medical monitoring/analysis (e.g., monitoring anesthesia gases, breath gases, blood gases); biowarfare (e.g., monitoring explosives such as TNT or RDX, or monitoring nerve agents such as GB or VX); gas alarms; and environmental pollution monitoring (including indoor air quality monitoring). The lengthy article provides information about Nanomix, Inc. (Emeryville, CA, 510-428-5300, formerly Covalent Materials, Inc.), a key player in the development of commercial products based on nanotechnology materials and components, notably chemical sensors and high-density hydrogen storage materials.
http://www.sensorsmag.com/resources/businessdigest/sbd0703.shtml

Sensor Research Supported by $1.1 Million Federal Earmark
Binghamton University News Release, 13 Nov 2003

A $1.1 million federal earmark championed by Congressman Maurice Hinchey, NY-22, will support Binghamton University's advanced sensor design and threat detection research as part of the University's overarching initiative to carve out an important niche for itself in the area of small-scale systems research and development. The incorporation of micro- and nano-scale elements into working systems will spell the difference in the 21st century between fanciful pieces and parts and valuable, viable products. Hinchey's earmark, the second federal appropriation received by BU in as many years, is part of a Defense Appropriations conference report that passed the U.S. House of Representatives early in November 2003. The report is expected to pass the U.S. Senate and be signed into law. The earmark is five times larger than the University's first-ever appropriation, which last year targeted $200,000. In combination with other federal and state funding and with the support of cooperative partnerships with other institutions and regional companies, the earmark will enhance the development of small-scale systems research facilities on the main campus, at the Innovative Technologies Complex at the eastern edge of the campus, and at Endicott Interconnect Technologies in Endicott.

Sensors Based on Chemicurrents
Cuenya, B. Roldan and E.W. McFarland, Univ. of California, Santa Barbara.
Dekker Encyclopedia of Nanoscience and Nanotechnology. Marcel Dekker, NY. ISBN: 0-8247-4797-6, p 3527-3537, 2004

Most selective and non-selective solid-state chemical sensors rely on an indirect detection mechanism whereby electronic or electro-optical properties of the device are altered by the substance of interest, allowing for a measurable response; e.g., sensors based on analyte/sensor interactions, which modify capacitance, conductivity, and refractive index. A means of directly monitoring charged carriers produced from gas/surface interactions has been described in which "hot" electrons/holes (e/h) from gas/surface reactions are detected using ultrathin film metal-semiconductor (MS) Schottky diodes. When an adsorbate binds to the surface with a relatively large adsorption energy, the energy may appear as an energetic e/h pair generated at the metal surface; the excited electron may travel ballistically through the thin metal film and transverse the Schottky barrier if the film is thin compared with the ballistic mean free path and if the kinetic energy of the electron is larger than the barrier height. Once injected into the conduction band of the semiconductor, the electron is detected as a "chemicurrent" analogous to the photocurrent in a photodiode. The energetic charge carriers have a ballistic mean free path of tens of nanometers, and thus for small-dimension metal structures, the hot charge carriers persist at energies well above the Fermi level. Using ultrathin metal films on Schottky-barrier MS and metal oxide semiconductor (MOS) diode sensors, researchers have investigated the chemi-electronic phenomena associated with a variety of molecular and atomic interactions with transition metal surfaces (Ag, Au, Pt, Pd) and found distinct differences in the mechanism of signal production between the highly energetic atomic and molecular species and more weakly interacting species, such as xenon and hydrocarbons. This review addresses the basis for the chemical sensitivity of these diode structures, emphasizing the importance of oxide interfacial states in the detection of electronic signals from weakly interacting gases.

Separate Detection of BTX Mixture Gas by a Microfluidic Device Using a Function of Nanosized Pores of Mesoporous Silica Adsorbent
Ueno, Y. (NTT Lifestyle and Environmental Technology Labs, Atsugi, Kanagawa, Japan), T. Horiuchi, M. Tomita, and O. Niwa; H.-S. Zhou (National Inst. of Advanced Industrial Science and Technology, Tsukuba, Ibaragi, Japan), T. Yamada, and I. Honma.
Analytical Chemistry, Vol 74 No 20, p 5257 -5262, 2002

The authors achieved separate detection of the components of 10 ppm of a benzene, toluene, and o-xylene mixture gas by using mesoporous silica powder incorporated in a microfluidic device. The device consists of concentration and detection cells formed of 3 cm x 1 cm Pyrex plates.

Silver Nanoparticles for Bio-Analytical Applications
Bagwe, Rahul P. (Univ. of Florida, Gainesville); Weihong Tan.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 820-3.

A major impediment to more widespread use of metal nanoparticles for bioanalytical applications is their tendency to aggregate nonspecifically in many aqueous media, generally due to electrostatic interactions. The authors have used reverse microemulsion of AOT/Heptane/water and NP-5/cyclohexane/water to prepare silver nanoparticles. The method subjects microemulsion containing silver nitrate in aqueous core to UV treatment for two minutes to form silver nanoclusters. The particles are then coated with silica shell by adding tetraethylorthosilicate followed by ammonium hydroxide. Silica shell increases surface functionality necessary for bioconjugation. These particles are used for fluorescent detection of biotinylated biomolecules.

Simultaneous Multianalyte Detection with a Nanometer-Scale Pore
Kasianowicz, John J. (NIST, Gaithersburg, MD), Sarah E. Henrickson, Howard H. Weetall, and Baldwin Robertson.
Analytical Chemistry, Vol 73 No 10, p 2268 -2272, 2001

Scientists have demonstrated that the overall range of analytes detectable by single nanometer-scale pores can be expanded using a simple system. Instead of attaching recognition elements to a channel, the elements are covalently linked to polymers that otherwise thread through a nanometer-scale pore. Because the rate of unbound polymer entering the pore is proportional to its concentration in the bulk, the binding of analyte to the polymer alters the latter's ability to thread through the pore, and the signal that results from individual polymer translocation is unique to the polymer type. The method permits multianalyte detection and quantitation.

Single Silver Nanoparticles as Real-Time Optical Sensors with Zeptomole Sensitivity
McFarland, Adam D. and Richard P. Van Duyne, Northwestern Univ., Evanston, IL.
Nano Letters, Vol 3 No 8, p 1057-1062, 2003

Resarchers used dark-field optical microscopy to demonstrate the localized surface plasmon resonance max response of individual Ag nanoparticles to the formation of a monolayer of small-molecule adsorbates. The kinetics of the single nanoparticle response compared well to that of other real-time sensor technologies.
http://www.chem.northwestern.edu/~vanduyne/pdf/NanoLett3_1057-1062_2003.pdf

SnO2 Nanoribbons as NO2 Sensors: Insights from First Principles Calculations
Maiti, Amitesh (Accelrys, Inc., San Diego, CA); J.A. Rodriguez (Brookhaven National Lab, Upton, NY); M. Law; P. Kung; J.R. McKinney; P. Yang (Lawrence Berkeley National Lab, Berkeley, CA).
Nano Letters, Vol 3 No 8, p 1025 -1028, 2003

SnO2 nanoribbons with exposed surfaces have been demonstrated to be highly effective NO2 sensors even at room temperature. The researchers examine the sensing mechanism through first principles density functional theory calculations. The most stable adsorbed species involve an unexpected NO3 group doubly bonded to Sn centers. The study also examined nanoribbon responses to O2 and CO sensing.

Solubilization of Carbon Nanotubes by Nafion Toward the Preparation of Amperometric Biosensors
Wang, J. (New Mexico State Univ., Las Cruces), M. Musameh, and Y. Lin.
Journal of the American Chemical Society, Vol 125 No 9, p 2408-2409, 2003

A well-known perfluorosulfonated polymer (Nafion) has been used to solubilize single-wall and multiwall CNTs. Nafion bears a polar side chain and hydrophobic backbone. The hydrohobic interaction is between the side-wall of CNTs and the backbone of Nafion, while the polar side-chain of the polymer leads to the solubilization of CNTs in polar solvents like aqueous buffer solutions. The Nafion-induced solubilization of CNTs permits various manipulations, including the modification of electrode surfaces and the preparation of biosensors or biofuel cells. The resulting biosensors greatly benefit from the coupling of the efficient electrocatalytic action of CNTs toward hydrogen peroxide and

NADH with the antifouling/discriminative properties of Nafion films. This work is important because it provides a new way for the fabrication of CNT-based biosensors or biofuel cells.

Sorptive Behavior of Monolayer-Protected Gold Nanoparticle Films: Implications for Chemical Vapor Sensing
Grate, J.W., D.A. Nelson, and R. Skaggs, Pacific Northwest National Laboratory, Richland, WA.
Analytical Chemistry, Vol 75 No 8, p 1868 -1879, 2003

Monolayer-protected gold nanoparticle materials were synthesized and characterized for use as sorptive layers on chemical sensors. The researchers investigated the following thiols as monolayer-forming molecules: dodecanethiol, benzenethiol, 4-chlorobenzenethiol, 4-bromobenzenethiol, 4-(trifluoromethyl)benzenethiol, 4-hydroxybenzenethiol, and 4-aminobenzenethiol. Films of selected monolayer-protected nanoparticle (MPN) materials were deposited on thickness shear mode devices and vapor uptake properties were measured at 298 K. Many, but not all, MPN-based sensing layers demonstrated rapid and reversible uptake of vapors, and sorptive selectivity varies with the monolayer structure. The authors discuss the implications for the roles of sorption and transduction in determining the performance of chemical sensors coated with nanoparticle-based films and compare their performance to those of sorptive polymer layers.

Spatial and Spectral Imaging of Single Micrometer-Sized Solvent Cast Fluorescent Plasticized Poly(vinyl chloride) Sensing Particles
Tsagkatakis, I., S. Peper, and E. Bakker, Auburn Univ., Auburn, AL.
Analytical Chemistry, Vol 73 No 2, p 315-320, 2001

Microscale plasticized PVC particles doped with hydrophobic ionophores were prepared by solvent evaporation of aqueous suspensions of sensing cocktails (poly(vinyl chloride), plasticizer, active sensing components, and tetrahydrofuran) and tested as particulate microoptical sensors. These microspheres respond in complete analogy to traditional thin-film-based optodes previously reported in the literature. The introduction of small, spherical, ionophore-based sensing particles that operate on the basis of bulk extraction principles holds the promise of significantly expanding the available microsphere-based analytical assays.

Study of Multi-Wall Carbon Nanotubes Self-Assembled Electrode and its Application to the Determination of Carbon Monoxide
He, Jian-Boa; C.-L. Chen; J.-H. Liu, Hefei Univ. of Technology, Hefei, PR China.
Sensors and Actuators B: Chemical, Vol 99 No 1, p 1-5, 1 Apr 2004

An electrochemical sensor based on multi-wall carbon nanotubes has been developed for the determination of carbon monoxide (CO). The catalytic activation of multi-wall carbon nanotubes microelectrode (MWCNTME) with Pt micro-disk as substrate was investigated in different supporting electrolyte solutions by cyclic voltammetry and constant potential transient method. The result shows that MWCNTME exhibited strong catalytic effect toward the electrochemical oxidation of CO in 0.5 mol/L perchloric acid. Compared with the bare Pt disk electrode, MWCNTME decreases the overpotential and increases the current of CO oxidation.

Subcellular Optochemical Nanobiosensors: Probes Encapsulated by Biologically Localised Embedding (PEBBLEs)
Clark, H.A.; S.L.R. Barker; M. Brasuel; M.T. Miller; E. Monson; S. Parus; Z.-Y. Shi; A. Song; B. Thorsrud; R. Kopelman; A. Ade; W. Meixner; B. Athey; M. Hoyer; D. Hill; R. Lightle; M.A. Philbert.
Sensors and Actuators B: Chemical, Vol 51 No 1, p 12-16, 31 Aug 1998

Stand-alone sensor devices consisting of multicomponent nanospheres with radii as small as 10 nm are prepared from up to seven ingredients and optimized for selective and reversible analyte detection, as well as sensor stability and reproducibility. Encapsulated by biologically localized embedding (PEBBLE), the probe is delivered into a cell by a variety of minimally-invasive techniques, including a pico-injector, a gene gun, liposomal incorporation, and natural ingestion. These remote nano-optodes have been prepared for pH, calcium, magnesium, potassium, and oxygen.
http://elchem.kaist.ac.kr/BK21_SMS.web/2001_nano/07_Sensor/1998_SAB_v51_0012_PEBBLEs.pdf

Submicrometric Lipobead-Based Fluorescence Sensors for Chloride Ion Measurements in Aqueous Solution
Ma, Aihui and Zeev Rosenzweig, Univ. of New Orleans, New Orleans, LA.
Analytical Chemistry, Vol 76 No 3, p 569 -575, 2004

Fluorescence sensing lipobeads are polystyrene nanoparticles coated with a phospholipid membrane that contains a fluorescent indicator for a targeted analyte. The halide-specific fluorescence dye, lucigenin, has been immobilized into the phospholipid membrane of the lipobeads to enable chloride ion detection. The fluorescence intensity of lucigenin decreases with increasing chloride ion concentration due to dynamic quenching. Lipobeads that contained only lucigenin were ineffective as chloride ion sensors due to poor partition of the water-soluble lucigenin molecules into the phospholipid membrane and high leakage rate of immobilized lucigenin molecules to the aqueous solution, so the researchers stabilized the chloride ion sensing lipobeads by co-immobilizing hexadecanesulfonate molecules into the phospholipid membrane.

Submicron Sensors for Ion Detection Based on Measurement of Luminescence Decay Time
Koronczi, I.; J. Reichert; H.-J. Ache; C. Krause; T. Werner; O.S. Wolfbeis.
Sensors and Actuators B: Chemical, Vol 74 No 1-3, p 47-53, 15 Apr 2001

Submicron optochemical sensors for pH and chloride were developed by coating silanized optical fibre tips of ~300 nm diameter and aluminium-coated SNOM fibres of ~50 nm aperture with polymeric membranes containing luminescent indicators. A fibre-optic nanosensor for chloride was made by combining the ion pair for optical transduction with the chloride-carrier tridodecylmethylammonium chloride in a plasticized PVC membrane.

Super Screener
ScienCentralNews, 12 Nov 2003

In the walls of a living cell, pores are tiny holes that connect the outside world to the inside world of the cell. Each pore is designed to admit only one particular element. Several teams of nanotechnology researchers are trying to build artificial pore (nanopore) devices that can mimic natural pores' expert filtering. Artificial pores could serve as ultra-sensitive biosensors to detect and analyze bioterror threats

almost immediately. Eventually, they also might help monitor the water supply, as well as screen for infection in doctors' offices. Lydia Sohn, assistant professor of mechanical engineering at the University of California Berkeley, teamed up with fellow physicist Omar Saleh to make a sensor that worked like a natural pore. They wanted to etch an artificial pore into a silicon wafer, so it could be mass-produced with the same techniques used to make chips for computers. It took Sohn and Saleh nearly four years to make a working sensor because at the nanoscale, what works in the lab doesn't necessarily work in the real world. Finally, Sohn and Saleh succeeded in making a tiny, silicon-based sensor that works like a pore. On a silicon chip, charged particles called ions flow through the pore and create an electric current. If a different molecule enters the pore, the current is reduced, signaling the presence of a new agent. The team's silicon-based approach allows them to put several pores on one chip to make an array to do multiple sensing. Sohn and Saleh have patented their artificial pores, and commercialization is pending. Currently, the U.S. Army is testing them under battlefield conditions. Their research was funded by the National Science Foundation, the Defense Advanced Research Projects Agency (DARPA), the Army Research Office, and the Fannie and John Hertz Foundation.

Surface-Enhanced Raman Spectroscopy with High Spatial Resolution
Huser, T.R., Lawrence Livermore National Lab., CA.
UCRL-ID-151624, 6 pp, Feb 2003

The recent development of new schemes that limit the optical detection volume, and the advent of new, highly quantum-efficient photon detectors has enabled researchers to optically probe biomolecular processes at the single molecule level by observing the fluorescence of specific marker molecules. The requirement to specifically label biomolecules and the fact that fluorescence emission is prone to photodecomposition of the marker molecules have limited this approach to a few well-characterized case studies. Raman scattering is one of few optical techniques that can identify atomic species and determine their chemical bonds by observing their distinct vibrational fingerprints, but it is orders of magnitude weaker than fluorescence. Scientists have developed new optical probes that allow for the non-destructive characterization and identification of organic and inorganic matter at the single molecule level by surface-enhanced Raman spectroscopy. The approach combines confocal Raman microscopy with surface-enhanced Raman spectroscopy (SERS) generated by coating scanning probe microscope (SPM) tips with thin (30-40 nm) gold and silver films. The scanning SERS probe generates an image of the physical structure of a sample together with detailed chemical information about its composition. In a complementary approach, researchers also have used gold or silver nanoparticles to generate SER spectra from single molecules adsorbed to these particles. This project has led to the development of a new capability at LLNL, i.e. the field of optical single molecule detection.
http://www.llnl.gov/tid/lof/documents/pdf/246790.pdf

Symposium C: Bio-Inspired Nanoscale Hybrid Systems
Schmid, Guenter (Univ. Of Essen); U. Simon; S.J. Stranick; S.M. Arrivo.
Proceedings of the Symposium on Bio-Inspired Nanoscale Hybrid Systems, Abstracts. Materials Research Society, Warrendale, PA. p 44-63, Dec 2002. DTIC: ADA414905, 28 pp, Dec 2002

Symposium C, Bio-Inspired Nanoscale Hybrid Systems, provided an extensive overview of the new and advanced approach to synthesize functional materials and to fabricate nanoscale devices using biomolecules as a key building block. In nature, molecular recognition between complex biomacromolecules forms sophisticated meso- and macroscopic architectures with tremendous control over the placement and orientation of nanoscopic building blocks. The advances of nanotechnology

provide new nanoscale structures, including nanoparticles, nanowires, and nanofabricated circuits. The marriage between biomolecules and these new nanostructructures has allowed many scientific breakthroughs and commercial applications. For example, specific interactions between biomolecules can be a major force to build sophisticated 1D, 2D, and 3D architectures. C.A. Mirkin (Northwestern Univ.) demonstrated "biodirected synthesis of functional materials using nanoscale building blocks" where biomolecular interactions such as DNA hybridization is utilized to direct the assembly of nanoparticles to form desired architectures. Several researchers reported various bio-inspired synthesis and assembly results such as the synthesis of metallic nanowires from peptides, DNA-mediated assembly of carbon nanotubes, and 3D assembly of nanoparticles using virus as a template.
http://handle.dtic.mil/100.2/ADA414905

Team Building Wireless 'Electronic Noses' Using Nanoscale Sensors
Virginia Tech, Blacksburg, VA.
ECE Connection, Winter 2004

Virginia Tech Electrical and Computer Engineering researchers in the Wireless Microsystems Laboratory are working to integrate functional nanoscale gas sensors with wireless communications microsystems using a new assembly process that would allow low-cost batch fabrication and the ability to incorporate distinct sensor devices to monitor different chemicals and gases. Their ultra-miniature "electronic nose" would be sensitive to a variety of gas and chemical compositions and incorporate readout, signal processing, and communications circuitry.
http://www.ecpe.vt.edu/news/feb04/enose.html

Technology Conceived in the Cold War Changes with Times at Sionex
Kelly, Matt.
Small Times, 22 Mar 2004

The evolution of Sionex Corporation's (Waltham, MA) chemical sensor technology started with an idea in the mind of a Soviet scientist, studying how electromagnetic fields affected chemical molecules. After the Cold War he relocated to New Mexico State University, where he met a researcher at Draper Laboratory developing new micromachining technology. The two combined their work and some seed capital to launch Sionex in January 2000. In 2003, Sionex unveiled a sensor that can be calibrated to identify explosives, germs, or other materials. Called microDMx, the Sionex platform conducts ionized molecules along a microfluidic channel sandwiched between two plates; one plate subjects the molecules to an RF field, the other a direct-current field. Those fields coax certain molecules to collect against one plate or the other, while the remainder traverse the channel to receptors on the far side. More than 20 manufacturers have beta versions of the platform to see how they can use it in their products. The Sionex platform is housed in casing the size of a cigar box. Gas is pumped into the system through one pipe, through the chip, and then out via another pipe. A computer can be jacked into the side of the box to monitor results. Using software and firmware, the customer can tweak the strength of the fields as desired to test for different molecules. Field-asymmetric ion mobility spectrometry (FAIMS) is the science underlying Sionex's platform. FAIMS is well suited to trace explosives, which typically have negative ions--a relatively uncommon trait, and therefore easy to identify. Contact: 781-693-3300, info@sionex.com.

Tiny 'Nanofingers' to Support Sensors, Other Applications
Ohio State University News Release, 8 Dec 2003

Future sensors may take the form of microscopic finger-like structures developed at Ohio State University, Columbus. Researchers there have found an easy way to carve the surface of inexpensive ceramic material into tiny filaments, creating a platform for devices that detect chemicals in the air. Each filament, or nanofinger, consists of a single crystal of the compound titanium oxide and measures up to five micrometers long and at most 50 nanometers wide. A micrometer is one millionth of a meter, and a nanometer is one billionth of a meter. The new process offers a simple chemical alternative to typical machine-based methods for carving ceramics, explained Sheikh Akbar, professor of materials science and engineering and founding director of the Center for Industrial Sensors and Measurements at Ohio State. Manufacturers often use diamond-edged rotary tools, lasers, or even ultrasound, because ceramics are hard and prone to chipping. The new patent-pending process is unique because it carves uniform filaments on a very small scale. Materials science student Sehoon Yoo discovered the process and is developing it to earn his doctoral degree, with Akbar as his advisor. Yoo's method involves baking the ceramic compound titanium dioxide at high heat inside a cloud of hydrogen gas. The hydrogen reacts with some of the oxygen in the material to create water, and heat binds the atoms of the ceramic together. What's left is a very dense ceramic minus some oxygen atoms -- its then simply titanium oxide -- covered in a uniform array of nanofingers. His work with titanium has advanced to the point that he can turn a penny-sized sample of the material into a rudimentary sensor that detects hydrogen. The process involves no fancy techniques: all you need is a furnace and a cylinder of hydrogen. Contact: Sheikh Akbar, Akbar.1@osu.edu, 614-292-6725.

Toward Large Arrays of Multiplex Functionalized Carbon Nanotube Sensors for Highly Sensitive and Selective Molecular Detection
Qi, Pengfei, Ophir Vermesh, Mihai Grecu, Ali Javey, Qian Wang, Hongjie Dai, Shu Peng, and K.J. Cho, Stanford Univ., Stanford, CA.
Nano Letters, Vol 3 No 3, p 347-351, 2003

Arrays of electrical devices with each comprising multiple single-walled carbon nanotubes (SWNT) bridging metal electrodes are obtained by chemical vapor deposition (CVD) of nanotubes across prefabricated electrode arrays. The ensemble of nanotubes in such a device collectively exhibits large electrical conductance changes under electrostatic gating, owing to the high percentage of semiconducting nanotubes, which leads to the fabrication of large arrays of low-noise electrical nanotube sensors with 100% yield for detecting gas molecules. The authors describe the detection of molecules in a gas mixture as demonstrated with the multiplexed nanotube sensors.

Trace Explosive Detection Systems: Past, Present, Future
Lareau, Richard T. (Transportation Security Administration, TSA/FAA); William J. Hughes.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 1900-1.

Explosives trace detection systems operate by collecting small residues of particles and/or vapors that indicate larger quantities of explosives present in the object or environment. Types of trace detection techniques currently deployed include ion mobility spectrometry, chemiluminescence, and canines. New technologies in trace analysis of explosives include miniaturized (hand-held) systems, trace walk-through portals, and next-generation sensor arrays (e.g., MicroElectroMechanical Systems (MEMS)- and nanotechnology-based sensor platforms). These sensor arrays/systems, currently in the R&D or

prototype stages, are based on micro-cantilever, micro-thermal analysis, lab-on-a-chip, and other miniaturized platforms. Each shows promise for enhanced sensitivity, selectivity, and improved alarm rates, as well as decreased cost, weight, and size. The systems can be designed to detect many types of chemical species, including CW/BW, illegal drugs, and explosives.

Two-Layer Model of Colloidal Gold Bioconjugates and Its Application to the Optimization of Nanosensors
Khlebtsov, N.G. (Russian Academy of Sciences/Saratov State Univ., Saratov, Russia); L.A. Dykman; V.A. Bogatyrev; B.N. Khlebtsov.
Colloid Journal, Vol 65 No 4, p 508-518, July/Aug 2003

Researchers analyzed an optical model of the conjugates of colloidal gold nanoparticles with biopolymers in terms of two-layer spherical particle with the gold core and dielectric coating. To optimize conjugate nanosensors, the researchers studied the problem of determining the optimal particle size for the transformation of the biopolymer adsorption event into the variations in the spectral parameters of extinction and light scattering. Based on the calculations of extinction maximum values and positions, as well as calculated differential extinction spectra, they concluded that a maximal conjugate efficiency corresponds to the core diameters of 40 to 80 nm. The principles of conjugate nanosensor optimization for the polymer shell structure are discussed.

UCLA Physicists Create Single Molecule Nanoscale Sensor; Possible Applications For Medicine, Biotechnology, Detecting Biological Weapons
University Of California - Los Angeles, News Release, 19 June 2003

UCLA physicists have created a first-of-its-kind nanoscale sensor using a single molecule less than 20 nanometers long--more than 1,000 times smaller than the thickness of a human hair--the team reports in the Proceedings of the National Academy of Sciences dated June 24, 2003. The research, led by Giovanni Zocchi, assistant professor of physics at UCLA, is federally funded by the National Science Foundation. Zocchi's nanoscale sensor uses a single molecule to recognize the presence of a specific short sequence in a mixture of DNA or RNA molecules, which is like finding a needle in a haystack. When a target molecule binds to the probe in the sensor, the probe molecule changes shape, and in its new conformation, pulls on the sensor. A single molecule can actually move the sensor, and the motion is detected by an optical technique called "evanescent wave scattering," which analyzes light that leaks out behind a reflecting mirror. This evanescent wave can be used to sense precisely the position of an object beyond the mirror. Instead of detecting the presence of the target, the scientists detect the changing conformation of the probe when the target binds to it. Zocchi's team is the first to report measurements of conformational changes in a single DNA molecule at the nanometer scale. Unlike previous single molecule experiments, which were impractically complicated for large-scale applications, the simplicity of this design lends itself to many applications. A nano sensor based on this technology could potentially detect minute traces of biological weapons, based on a characteristic genetic signature.

Ultrasensitive Biosensors for Molecular Recognition and Manipulation
Tan, Weihong, Florida Univ., Gainesville.
DTIC: ADA410625, 8 pp, Feb 2003

The research objective is to develop novel biomolecule recognition mechanisms and ultrasensitive biosensors for direct, real-time biochemical imaging and sensing. These biosensors will provide a novel tool that permits major advances in the investigation and control of fundamental molecular and cellular physiological processes. There are three aspects of the approach: using nanotechnology and existing sensing mechanisms for nanometer level biosensor development; using molecular beacon DNA molecules for development of new biomolecule recognition mechanisms; and using single molecule microscopy techniques for molecular interaction studies. Over the three years of this grant, the researchers have published 20 papers and filed two patents (one granted and one pending).
http://handle.dtic.mil/100.2/ADA410625

Use of Steady-State Fluorescence Anisotropy with PEBBLE Nanosensors for Chemical Analysis
Horvath, Thomas; Eric E. Monson; James Sumner; Hao Xu; Raoul Kopelman.
Biomedical Nanotechnology Architectures and Applications. Proceedings of SPIE--The International Society for Optical Engineering, Vol 4626, p 486-492, June 2002

Steady-state fluorescence anisotorpy within PEBBLEs can be used for the optochemical sensing of analytes such as Zn2+, O2, and Ca2+. Steady-state fluorescence anisotropy is a non-time resolved method that measures a combination of rotational and fluorescence lifetimes with no need for reference dyes and ratiometic techniques to obtain quantitative results, even when using intensity-based sensor dyes. With PEBBLE nanosensors, the encapsulated dye is localized in a constant rotational environment, in contrast to the use of free dyes, which can be affected by interferents, such as protein binding.

Using Packed Silver Nanowires as Sensitive Explosives Detector
Sanders, Robert, UC Berkeley News, 11 Sep 2003

Minuscule wires a few nanometers across are proving to be versatile electronic components, as demonstrated recently by University of California chemists who used silver nanowires as key elements of a sensitive explosives detector. Researchers led by Peidong Yang, ChevronTexaco assistant professor of chemistry at UC Berkeley and a chemist with the Materials Sciences Division of Lawrence Berkeley National Laboratory, made about a trillion silver nanowires--essentially nanocopic needles--and packed them tightly together in a thin layer, all needles pointing in the same direction, like rafted logs on a river. The layer of ordered nanowires made an ideal site for chemicals to bind for detection by surface-enhanced Raman spectroscopy. A monolayer of silver nanowires makes a sensitive substrate on which to detect molecules like DNT (dinitrotoluene, a cousin to TNT), which is used in making essentially all explosives, including land mines. The explosives emit DNT vapors, which allows for airborne detection. The packed silver nanowires are a better surface for enhanced Raman spectroscopy than a thin layer of silver because the nanowire surface is more ordered and gives a more clearly defined signal, making interpretation of the Raman vibrational spectrum easier. The packed silver nanowires are uniform, reproducible, and suitable for use in air or in liquid. Yang is hoping to miniaturize the laser and other components required by Raman spectroscopy to create a microscopic sensor on a chip for sensitive and specific detection of chemicals. Yang and his team have been able to make flexible sheets of packed nanowires more than three square inches in area (20 square centimeters). The assembly process the team has developed to assemble nanowires over a large area will have a significant impact in nanoscience. The work is funded by the Camille and Henry Dreyfus Foundation, ACS-Petroleum Research Fund, Alfred P. Sloan Foundation, Beckman Foundation, David

and Lucile Packard Foundation, U.S. Department of Energy, National Science Foundation, and Multidisciplinary University Research Initiative of the Air Force Office of Scientific Research.

Voltammetric Detection of Lead(II) and Mercury(II) Using a Carbon Paste Electrode Modified with Thiol Self-Assembled Monolayer on Mesoporous Silica (SAMMS)
Yantasee, W., Y. Lin, T.S. Zemanian, and G.E. Fryxell.
Analyst, Vol 128 No 5, p 467-472, 2003

The anodic stripping voltammetry at a carbon paste electrode modified with thiol-terminated self-assembled monolayer on mesoporous silica (SH-SAMMS) provides a new sensor for simultaneous detection of lead and mercury in aqueous solutions. The overall analysis involves a two-step procedure: an accumulation step at open circuit, followed by medium exchange to a pure electrolyte solution for the stripping analysis. The most sensitive and reliable electrode contained 20% SH-SAMMS and 80% carbon paste.

Wireless Microsensors for Pollutants and Chemical Warfare Agents Using Nanostructured Silicon
Sailor, Michael J., Univ. of California, San Diego.
PITTCON 2003, March 9-14, Orlando, Florida. Abstract 1550-2.

Films and small particles of microporous silicon are used to detect chemicals by measurement of the intensity of reflected light using a local or remote laser probe. The particles contain a periodic porous nanostructure that is generated in an electrochemical etch. The periodic structure generates a Rugate reflector, which displays a sharp maximum in the optical reflectivity spectrum at a wavelength that is controlled by the etch parameters. The intensity and wavelength of reflected light is determined in part by the refractive index of the porous nanostructure, which can be modified by adsorption of vapors or by specific chemical reactions within the chemically modified porous Si matrix to sense materials such as hydrocarbons and nerve warfare agents.

Workshop Report: Nanotechnology Innovation for Chemical, Biological, Radiological, and Explosive (CBRE): Detection and Protection, Recommended Investment Strategy
May 2-3, 2002, Monterey, CA. National Nanotechnology Initiative, 32 pp, 2002

The goal of this workshop was to recommend a plan of action for research and development under the auspices of the U.S. government's National Nanotechnology Initiative aimed at realizing the promise of the great challenges of chemical, biological, radiological, and explosive agent detection.
http://www.wtec.org/nanoreports/cbre/CBRE_Detection_11_1_02_hires.pdf

SBIR AND OTHER GRANTS

Advanced Nanosensors for Continuous Monitoring of Heavy Metals (EPA 2002 STAR Grant)
EPA Grant Number: R830906
Investigators: Omowunmi Sadik (osadik@binghamton.edu, SUNY at Binghamton) & Joseph Wang (New Mexico State Univ.)
Project Period: May 1, 2003 through April 30, 2006
Project Amount: $351,000

This research will utilize novel nanostructured materials in ways that might be exploited in sensing technologies for the detection, identification, and quantitation of metals. The overall objective is to incorporate novel colloidal-metal nanoparticles into a bed of electrically conducting polymers (ECPs) for the development of nanosensors. Specific objectives include the following: (1) Prepare, characterize, and optimize colloidal metal nanoparticles sequestered within conducting polymers using photochemical polymerization. The resulting materials will be tested for the design of metal nanosensors. (2) Design and test the novel nanosensors for the identification, detection, speciation, and quantitation of EPA's priority metal contaminants such as iron, arsenic, nickel, cadmium, mercury, lead, chromium and copper from aqueous streams. (3) Fabricate disposable nanosensors/nanochips using the NMSU Nanofabrication facility and apply the sensor to the analysis of metal ions from aqueous effluents. Preliminary results using custom-designed ECPs showed remarkable metal sensitivity in the parts-per-trillion levels. The nanosensor will be regenerated using a potential step where the applied potential is reversed and the solution reservoir at the outlet of the sensor is changed, thereby providing a continuous and uninterrupted detection of the metals.
http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/6124/report/0

Compound Specific Imprinted Nanospheres for Optical Sensing (EPA 2002 STAR Grant)
EPA Grant Number: R830911
Investigators: Barry K. Lavine (bklab@clarkson.edu) & Janos Fendler (Clarkson Univ.), William Rudolf Seitz (Univ. of New Hampshire)
Project Period: June 1, 2003 through May 31, 2006
Project Amount: $323,000

The objective of the proposed research is to investigate the use of molecularly imprinted polymers as the basis of a sensitive and selective sensing method for the detection of pharmaceutical and other emerging organic contaminants at parts per billion (ppb) levels in aquatic environments. The effects of polymerization conditions including formulation, temperature, and solvent on the size, selectivity, and sensitivity of the molecularly imprinted polymers employed will be determined. Both the sensitivity and selectivity of prototype sensors developed from the molecularly imprinted polymers will be evaluated in a realistic milieu using samples of known buffering capacity, ionic strength, and bivalent metal content. The work described in this proposal, the development of field-based inexpensive, and rapid sensors for the detection and determination of emerging organic and pharmaceutical compounds in water, will have an impact on how the nation will approach the monitoring, regulation, cleanup, and ultimate removal of these contaminants from U.S. waters.

Metal Biosensors: Development and Environmental Testing (EPA 2002 STAR Grant)
EPA Grant Number: R830907
Anne J. Anderson, anderson@biology.usu.edu, Charles D. Miller, Joan McLean
Utah State Univ., Logan
Project Period: May 1, 2003 through April 30, 2006
Project Amount: $336,000

The objectives are to develop and test biosensors and DNA arrays that will detect Cu and Cd specifically and indicate the bioavailability of these metals to a bacterium. The biosensors will be constructed with a root-colonizing bacterium, Pseudomonas putida, KT2440. This bacterium is robust, offers no environmental threat, and its genomic sequence, almost completed, will be released in 2003. Fusions will be generated between the promoters of P. putida genes responding with increased

transcription when exposed to Cu or Cd and the open reading frame of a reporter gene. We will use a reporter encoding for light production to screen for constructs showing increased light emission when exposed to low non-lethal levels of the metals. These promoter-fusion biosensors will be used singly for quantitative assays of Cu/Cd concentration. The response to the metals associated with the different ligands will be assayed to determine how the response relates to total metal concentration and free metal availability. In the laboratory, we will use in situ detection for real-time imaging of the promoter fusion activities while these bacterial sensors are colonizing roots of plants growing in metal-contaminated soils. The fusions will be deployed in plate arrays to permit rapid assessment of Cu and Cd bioavailability. A second detector system will array the KT2440 genes that react to both metals. Differential hybridization of the gene arrays to RNAs extracted from control and sample-exposed P. putida cells will indicate the level of impact of any metals in the samples. We will compare the responses from the promoter fusion constructs to Cu and Cd complexed with different ligands to their responses at the transcriptional level. We will test the sensitivity and specificity of the biosensor plate arrays and the gene arrays using metal-contaminated soils and water from mine and government sources that are undergoing remediation.

m-Integrated Sensing System (m-ISS) by Controlled Assembly of Carbon Nanotubes on MEMS Structures (EPA 2002 STAR Grant)
EPA Grant Number: R830901
Somenath Mitra, somenath.mitra@njit.edu, & Z. Iqbal, zafar.iqbal@njit.edu
New Jersey Inst. of Technology, Newark
Project Period: May 15, 2003 through May 14, 2006
Project Amount: $346,000

The goal of this research is to develop a micro integrated sensing system (m-ISS) on a chip for environmental monitoring. The proposed m-ISS will exploit some of the remarkable nanoscale properties of single wall carbon nanotubes (SWNTs) to provide on-chip concentration via quantum scale adsorption processes to attain the low detection limits necessary for environmental sensing. The integrated system will be fabricated on a chip using micro-electromechanical system (MEMS) technologies, which offer easy miniaturization, and relatively inexpensive mass fabrication. The m-ISS consists of on-line concentration, separation and detection of organic contaminants. A micromachined pump integrated with the system by silicon micromachining will draw air into the detection system, which will comprise a sensor array or a chromatographic separation channel along with the sensor array. The proposed sensing scheme will enhance the sensitivity by concentrating the sample on a microconcentrator prior to detection. As the air containing the organics flows through the m-ISS, the pollutants are trapped within the microconcentrator. By heating the microconcentrator to temperatures up to 300˚C by an in-channel heater, the organics are desorbed as a concentration pulse into the detection system. When configured with the GC column, the m-ISS serves as a real-time GC system. The microconcentrator and the GC column will be fabricated on the same matrix by self-assembly of SWNT by a chemical vapor deposition (CVD)process developed at NJIT. The SWNT will be functionalized by electrochemical and plasma techniques.

A Nanocontact Sensor for Heavy Metal Ion Detection (EPA 2001 STAR Grant)
EPA Grant Number: R829623
Nongjian Tao, taon@fiu.edu
Arizona State Univ., Tempe
Project Period: January 1, 2002 through December 31, 2004

Project Amount: $375,000

This project exploits the phenomena of conductance quantization and quantum tunneling to fabricate nanoelectrodes for in situ detection of metal ion pollution. The goal is to develop a high-performance and low-cost sensor for initial on-site screening test of surface and groundwater to provide early warning and prevention of heavy metal ion pollution. The existing analytical techniques usually require preconcentration of samples to detect trace metal ions, which can be time consuming and prone to cross-contamination. Moreover, many of the sensitive techniques, such as inductively coupled plasma-mass spectrometry, are not suitable for on-site monitoring. In contrast, the nanocontact sensor has the potential of detecting even a few metal ions without preconcentration and is particularly suitable for on-site detecting ultratrace level of heavy metal ions, including radioactive elements. The sensor consists of an array of nanoelectrode pairs on a silicon chip. The nanoelectrodes in each pair are separated with an atomic scale gap, which is achieved with the help of quantum tunneling phenomenon. Electrochemical deposition of even a few metal ions into the gap can bridge the gap and form a nanocontact between the nanoelectrodes, thus triggering a quantum jump in the electrical conductance. The sensor can achieve high specificity by combining several different measurements, such as redox potentials, point-contact spectroscopy and electrochemical potential-modulated conductance changes.

Nanomaterial-Based Microchip Assays For Continuous Environmental Monitoring (EPA 2002 STAR Grant)
EPA Grant Number: R830900
Joseph Wang, joewang@nmsu.edu
New Mexico State Univ., Las Cruces
Project Period: June 1, 2003 - May 31, 2006
Project Amount: $341,000

The proposed effort aims at addressing the challenge of transforming the 'Lab-on-a-Chip' concept to an effective environmental monitoring system and at exploiting the unique properties of nanomaterials for enhancing such chip-based environmental assays. Lab-on-chip technologies can dramatically change the speed and scale at which environmental analyses are performed. The ultimate goal of this project is to develop a submersible microfluidic device, based on the integration of all the necessary sample handling/preparatory steps and nanomaterial-based assays on a cable platform. The new 'Laboratory-on-a-Cable' concept relies on the integration of continuous sampling, sample pretreatment, particle-based separations, and nanotube-based detection step into a single-sealed miniaturized submersible package. Nanoparticle and nanotube materials will be examined towards the enhancement of the separation and detection processes, respectively. Factors governing the improvements imparted by these nanomaterials will be identified, and structural-performance correlations will be established. We will also examine new world-to-chip interfaces toward the goal of effective on-line sample introduction, and will assess the challenges of transforming the new microchip to a continuous monitoring system. The parameters governing the microchip behavior will be optimized and the analytical performance will be characterized and validated.

Nanosensors for Detection of Aquatic Toxins (EPA 2001 STAR Grant)
EPA Grant Number: R829599
Robert E. Gawley, rgawley@miami.edu
Univ. of Miami, Coral Gables, FL
Project Period: March 1, 2002 through February 28, 2005

Project Amount: $350,000

Goal: Design and prepare nanoscale sensors for the detection of marine toxins domoic acid, brevetoxin, ciguatoxin, cylindrospermopsin, and tetrodotoxin. The protein receptor sites for several of these toxins have been characterized, and include two characteristic features. One is an array of amino acid side chains that complement structural features of the toxin, which facilitates and strengthens binding of the toxin into the receptor site. A second feature is a solvent-excluded pocket in which the amino acid side chains are arrayed. This preorganized feature of toxin receptor sites will be mimicked by design of synthetic receptors at the nanoscale (nanosensors). To optimize the sensitivity and the selectivity of the nanosensor, we will employ combinatorial synthesis techniques to optimize binding in libraries of peptidic host molecules immobilized on solid support (polystyrene beads). Unlike side chain arrays in the native (protein) receptors, we will not limit ourselves to L-amino acids, or even to natural amino acids. In this way, we will be able to produce short peptide sequences that wrap around toxins and bind them by providing an array of side chains similar to the native receptor. To mimic the solvent-excluded pocket of protein receptor sites, we will incorporate the combinatorially-designed peptide at the core of a dendritic polymer, still on a solid support. Qualitative evaluation of toxin binding can be done simply with a fluorescence microscope. Quantitative analysis will be done with a specific host after it has been synthesized in bulk.

Nanostructured Porous Silicon and Luminescent Polysiloles as Chemical Sensors for Carcinogenic Chromium(VI) and Arsenic(V) (EPA 2001 STAR Grant)
EPA Grant Number: R829619
William C. Trogler, wtrogler@ucsd.edu, Michael J. Sailor, msailor@ucsd.edu
Univ. of California at San Diego, La Jolla
Project Period: January 1, 2002 through December 31, 2004
Project Amount: $400,000

The chief goal is to develop new selective solid state sensors for carcinogenic and toxic chromium(VI) and arsenic(V) in water based on redox quenching of the luminescence from nanostructured porous silicon and polysiloles. Nanostructured porous silicon, as well as polysilole nanowire coatings, will be chemically modified to enhance binding of the chromate and arsenate anions. Chemical modification to vary the redox potential of the polysilole excited state will also be used as a way to impart chemical selectivity. Both sensor approaches will be combined by encapsulating the polysilole in a nanotextured microcavity between two Bragg stacks constructed from porous silicon. The nanoporous material will readily admit small inorganic analytes, such as chromate and arsenate, and exclude biomolecules that might confound the measurements. Sensors based on silicon wafer and polymer technologies are also readily adaptable to fabrication. The fluorescence quenching detection modality is also manufacturable. The essential electronics requires a blue or UV LED as the excitation source and an inexpensive photodiode detector. Potential applications of such sensors include remote sensing and industrial process control. The focus on chromium(VI) and arsenic(V) detection is dictated by the redox quenching mechanism that is being used, as well as by the importance of chromium(VI) and arsenic(V) as regulated chemicals under the Safe Drinking Water Act.

The Silicon Olfactory Bulb: A Neuromorphic Approach to Molecular Sensing with Chemoreceptive Neuron MOS Transistors (CvMOS) (EPA 2002 STAR Grant)
EPA Grant Number: R830902
Edwin C. Kan, kan@ece.cornell.edu, Bradley A. Minch, Cornell Univ., Ithaca, NY

Project Period: May 1, 2003 through April 30, 2006
Project Amount: $354,000

An ideal microsensor for autonomously monitoring chemical and molecular environmental hazards in both water and air should simultaneously have a high sensitivity, a high selectivity, a large dynamic range, a low manufacturing cost, simple calibration/reset protocols, a long lifetime, field reconfigurability, and low power consumption. We have developed a Si-based neuron MOS transistor with a novel extended floating-gate structure that permits molecular/chemical sensing. The sensor, called a chemoreceptive neuron MOS (CMOS) transistor, is expected to simultaneously meet all of these requirements, and can be fabricated by minor modification or simple postprocessing of conventional CMOS integrated circuits. The modular structure and fabrication of this new device permits us to use CMOS devices optimized for high sensitivity and large dynamic range and affords us complete flexibility in the design and composition of the molecular/ chemoreceptive sites. The performance of the new sensor is expected to be vastly superior to that of existing chemical microsensors, such as the ion-sensitive FET (ISFET) and the CHEMFET, in nearly every important respect resulting from the internal transistor gain and much better isolation between the electronics and microfluidics. We have already established the preliminary process flow and testing of CMOS transistors with generic molecular receptive areas for vapor and liquid sensing (e.g., water, acetone, etc.). In the three-year proposed effort, we expect to be able to develop a complete system, including both a sensor array and the silicon olfactory bulb, that can be fully integrated, perhaps on a single chip, and that will dissipate only a few hundred microwatts of power in total. Such devices could be manufactured in large numbers very inexpensively and deployed rapidly as environmental sensors, running autonomously for long periods of time on either solar power or miniature chemical batteries.

Simultaneous Environmental Monitoring and Purification Through Smart Particles (EPA 2001 STAR Grant)
EPA Grant Number: R829602
Wolfgang M. Sigmund, wsigm@mse.ufl.edu, Chang-Yu Wu, David Mazyck
Univ. of Florida, Gainesville
Project Period: February 10, 2002 - February 9, 2005
Project Amount: $390,000

We are pursuing a multi-disciplinary synthesis of technologies, including self-organized structural control and smart materials with focus on environmental purification and monitoring to create intelligent surfaces and structures that not only sense and interact with their environment, but that can fundamentally alter their own behavior and deactivate themselves as preprogrammed or as desired. The hypothesis we want to test is: will nano-engineered smart particles based on a modular building concept enable simultaneous monitoring and purification of the water and air environment? Approach: Define and synthesize smart particles that purify and monitor by indicating through a simple visible change like color or size. Make particles easily separable by auto-flocculation and/or by magnetic removal. Synthesize ferromagnetic particles with high specific surface area that increase the specific surface area by at least two orders of magnitude compared to current magnetic photocatalysts. Strongly reduce the mass of photocatalyst required for treatment and further improve pollutants mass transfer and exposure to UV-light through magnetically agitated fluidization. Expected Results: Atomic and molecular control of material building blocks and required engineering tools to provide the means to assemble and utilize these tailored building blocks for assembling novel smart particles for environmental applications as purifiers and sensors, which are environmentally benign. Reducing the

amount of photocatalyst and increasing the specific surface area of magnetic photocatalyst composites by two orders of magnitude.

NIRT: Developing a Nanoscale Sensing Device for Measuring the Supply of Iron to Phytoplankton in Marine Systems (NSF Standard Grant)
NSF Award Number 0304523
Start Date Aug 15, 2003
Expires July 31, 2006
Expected Total Amount $903,840
Mark L. Wells (PI), mlwells@maine.edu, 207-581-1476, Carl P. Tripp (Co-PI), Karen Orcutt (Co-PI), D. Whitney King (Co-PI)
Univ. of Maine, Orono

There is no agreement about how to define biologically available Fe, in contrast to the macronutrients nitrogen, phosphorous, or silicon. Current attempts to attain predictive insights to how ocean ecosystems will influence the magnitude of climate change are blocked in large part by this question, along with an extreme shortage of data on Fe distributions in the oceans. There is evidence that Fe availability can be regulated in bulk seawater incubations by small additions of the fungal siderophore desferrioximine B (DFB). The Fe-DFB complex is not readily available to eukaryotic phytoplankton, so that if the quantity of Fe complexed by DFB were measured and calibrated to Fe uptake by phytoplankton, it could yield a novel first order measure of Fe availability. Building from our current research we have developed liposomes that specifically acquire DFB-bound Fe from solution. These devices, 100 nm in diameter, open the way to applying nanotechnology to create a new breed of Fe biosensors in marine waters. The project goals are to 1) optimize these nanodevices by improving their physical robustness, identifying the size/functionality relationship, and examining the efficacy of other DFB-Fe transporter molecules, 2) develop self-reporting capabilities for quantifying Fe uptake by these nanodevices, and 3) to calibrate the capture of Fe by these nanodevices to the Fe uptake by various phytoplankton species. The anticipated final product will be a calibrated nanoscale biosensor for laboratory-scale use that could then be adapted for deploying on remote vehicles.

NIRT: Heterogeneous Integration of Nanowires for Chemical Sensor Arrays (NSF Standard Grant)
NSF Award Number 0303981
Start Date August 1, 2003
Expires July 31, 2007 (Est.)
Awarded Amount to Date $1,200,000
Thomas Mallouk (PI), tom@chem.psu.edu, 814-865-4700, Stephane Evoy (Co-PI)
Pennsylvania State Univ., University Park

"Electronic nose"chemical sensor arrays are used to detect trace analytes in complex mixtures, and are important for environmental, biomedical, process control, and security-related applications. Scaling chemical sensors to nanometer dimensions will open unprecedented opportunities for implementation of electronic nose arrays in and-held devices, remote monitoring, robotics, medical diagnostics, sensor dust, and other novel applications. The proposed project will bring together an interdisciplinary team from three institutions to work on the fundamental problems connected with creating low cost, low power, massively parallel arrays of chemically diverse nanosensors and integrating them with on-chip data processing. While this project focuses specifically on nanosensor arrays, the problems it addresses are generic to the integration of many different kinds of functional nanoscale objects into silicon-based

circuits. Our approach builds on an existing knowledge base of chemical sensor array platforms and data analysis methods, to which our team brings some unique new materials and techniques. Mallouk and Semancik have developed a method for incorporating chemical sensor "stripes"into template-grown metal nanowires. These nanowires connect the lithographic length scale (micron nanowire length)with the nanoscale (30-300 nm diameter and stripe length).The synthetic technique allows the chemical nature of the sensory material to be diverse. We will focus on three different sensor platforms--chemoresistive metal oxides, intrinsically conducting polymers, and conductive polymer composites--which should provide excellent orthogonality in sensor arrays.

The Nano-Precision HARPSS-CMOS Process for RF and Sensory Microsystems (NSF Continuing Grant)
NSF Award Number 0301900
Start Date May 1, 2003
Expires April 30, 2005 (Est)
Awarded Amount to Date $192,053
Farrokh Ayazi (PI), farrokh.ayazi@ece.gatech.edu, 404-385-0866
Georgia Tech Research Corp., Georgia Inst. of Technology, Atlanta

This proposal is aimed at the integration of a high aspect-ratio, sub-100nm vertical airgap MEMS/NEMS technology with a 1um gate-length CMOS process, and the application of the resulting high aspect ratio CMOS-MEMS process to high-performance RF-sensory microsystems, as well as mixed-signal circuits. The implementation of the following two testbeds is proposed as technology demonstrators: 1. The high-performance sensor system testbed: Implementation of a novel CMOS-integrated inertial-grade (sub-ug resolution) acceleration/vibration sensor system with direct digital output. This single-chip sensor system will have 3-4 orders of magnitude higher sensitivity compared to the current state of the art integrated microsystem. It consists of a nano-precision lateral accelerometer and a high-performance mixed-signal interface circuit which utilizes 200um tall vertical poly-poly capacitors, yielding 2 orders of magnitude reduction in the die area. 2. The wireless RF components testbed: Implementation of MEMS-based high-Q on-chip frequency references "over a wide frequency range extending into GHz" integrated with CMOS electronics (MEMS-based VCO). Imagine having a tiny MEMS-CMOS silicon chip that can not only monitor very small changes in the environment, but also can transmit the monitored data real time in digital form to a receiver base, or communicate with a network of wireless sensory nodes. Such wireless sensory nodes can find numerous applications in various forms of environmental monitoring and energy-efficient systems.

Chemical and Biological Sensors based on Porous Silicon Photonic Micro-Systems (NSF Standard Grant)
NSF Award Number 0088060
Start Date September 1, 2000
Expires August 31, 2003
Expected Total Amount $510,000
Y. Fainman (PI), fainman@ece.ucsd.edu, 858-534-0246, Michael J. Sailor (Co-PI)
Univ. of California at San Diego, La Jolla

The goal of the proposed work is to conduct basic research towards the development of high sensitivity chemical and/or biological sensors integrated on a monolithic Si substrate. This multi-disciplinary study will focus on fundamental understanding of nano-scale chemical, biological and near-field optical

interactions, leading to the development of design and implementation methodologies for porous silicon (Psi)-based sensor micro-systems. The proposed micro-systems will use optical transducers based on microfabricated optical sources combined with optimized nanostructured resonant optical filtering devices and photodetectors, allowing label-free detection of analytes with significantly higher sensitivity than existing techniques (e.g. surface plasmon resonance or optical interferometry). This technique will be applicable to a variety of sensing problems in environmental monitoring, medical diagnostics, high-throughput screening, and pharmacogenomics applications. The PIs propose to study two complementary aspects of this emerging technology: (a) investigation of the correlation between the modification of the optical properties of PSi and the concentration of different species introduced in the pores, including nerve agents, solvents, or biological molecules; and (b) design, modeling, fabrication and testing of monolithically integrated near-field meso-optic structures built using micro- and nano-fabrication techniques. The proposed research will not only have a significant impact on the development of on-chip monolitically integrated micro-sensor systems, but also result in the development of basic science and technology of near-field linear and nonlinear optical phenomena in nano-scale and meso-scale structures.

Chemical Sensors Based on Imprinted Polymer Nanoparticles (NSF Continuing Grant)
NSF Award Number 0097409
Start Date August 1, 2001
Expires July 31, 2004
Expected Total Amount $431,642
Gary C. Tepper (PI), gctepper@saturn.vcu.edu, 804-828-6772, Natalia V. Levit (Co-PI)
Virginia Commonwealth Univ., Richmond

This research focuses on the development of a new miniature sensing technology based on chemically sensitive and highly selective polymer nanoparticles interfaced with a microfabricated transduction device. The particles are produced using a unique combination of supercritical fluid polymer processing, UV curing and molecular imprinting and consist of highly networked, monodisperse polymer nanoparticles imprinted for high selectivity to a specific molecular species. The main objective of the proposed research project is to develop and demonstrate the performance parameters of the proposed sensor. This will be accomplished by developing a prototype and experimentally verifying key performance criteria including chemical sensitivity, selectivity, response time and reversibility. If successful, the proposed sensor would provide an unsurpassed level of performance in a field portable instrument. Applications of the proposed sensor technology include environmental characterization, medical diagnostics, process control, intelligent appliances, and military surveillance. Additional applications for the imprinted polymer nanoparticles include chromatography, specialty separations, and filtering.

Application of Quantum Dots to Environmental and Cell Biology (NSF Standard Grant)
NSF Award Number 0102662
Start Date September 1, 2001
Expires August 31, 2005 (est.)
Expected Total Amount $1,001,117 (est.)
Ian M. Kennedy (PI), imkennedy@ucdavis.edu, 530-752-2075, Kit S. Lam (Co-PI), Bruce D. Hammock (Co-PI), Subhash H. Risbud (Co-PI), Valerie J. Leppert (Co-PI)
Univ. of California, Davis

This award will support the application of materials science and engineering to biosystems and environmental biology at the nanoscale. A multidisciplinary team has been assembled to explore the potential for the application of semiconductor quantum dots to environmental immunoassays and cell biology. The unique optical properties that are available via the quantum confinement effect inherent to nanoscale clusters of semiconductor material offer unique possibilities in biosystems research. The emission of light from quantum dots is dependent on the size of the cluster. Hence, it is possible to design clusters of various sizes to emit at a desired wavelength. The visible part of the optical spectrum can be covered by a range of quantum dots whose emissions are spectrally distinct, permitting their use in simultaneous bioassays for environmental pollutants and hazards, as well as replacements of conventional fluorophores in studies of peptide chemistry and binding to cell receptors. In addition, the magnetic properties of quantum dots can be used for the manipulation of biological molecules in magnetic fields. Quantum dots will be synthesized initially by an established method that can produce CdSe clusters capped by ZnS that permits bioconjugation to molecules of interest via a carboxyl group. The usefulness of the quantum dots in environmental bioassays will be explored by applying them to immunoassays that are designed to detect a class of molecules that are important in agriculture, atrazines.

ITR/SI+AP: Active Sensor Networks with Applications in Marine Microorganism Monitoring (NSF Continuing Grant)
NSF Award Number 0121141
Start Date September 15, 2001
Expires August 31, 2004 (Est.)
Expected Total Amount $1,567,861 (Est.)
Aristides A.G. Requicha (PI), requicha@lipari.usc.edu, 213-740-2934, David A. Caron (Co-PI), Maja J. Mataric (Co-PI), Deborah L. Estrin (Co-PI), Gaurav Sukhatme (Co-PI)
Univ. of Southern California, Los Angeles

The proposed research combines networking, distributed robotics, nanorobotics, and microbiology in an effort to develop and apply technology for the in situ, real-time monitoring of microbial populations in aquatic environments, such as the ocean or water supply systems. The application context provides feedback from experiments with realistic systems, and this feedback is essential to the progress of the Information Technology (IT) research proposed here. This project addresses two key challenges for IT during this decade: moving from virtual to physical applications, and moving from macro to micro and nano. The IT focus is on the study of Physically-Coupled Scalable Information Infrastructures (PCSIIs), which effectively "embed the internet". The sensors and actuators in the proposed PCSII must have small physical dimensions, comparable to those of the microorganisms to be monitored. They must be deployed in very large numbers to achieve the unprecedented spatial and temporal resolution necessary to investigate the causal relationships between environmental conditions and microorganisms. Control and coordination of a multitude of such devices of limited and heterogeneous capabilities raise major challenges for networking, distributed coordination and distributed algorithms. Sensing for detection and identification of microorganisms is another challenge, which will be tackled by using nanorobotic Scanning Probe Microscope technology.

CAREER: Integrated-Optic Nanoparticle Biosensor Arrays (NSF Standard Grant)
NSF Award Number 0134548
Start Date February 15, 2002
Expires January 31, 2007 (Est.)

Expected Total Amount $375,000 (Est.)
Steven M. Blair (PI), blair@ece.utah.edu, 801-581-6903
Univ. of Utah, Salt Lake City

The important problem of detecting in parallel a large number of molecular species from the very small samples typical of most collection procedures remains an elusive goal. This research plan focuses on solving this problem by merging the science of nanophotonics with waveguide biosensors and microfluidics for the development of a new class of molecular detection array. The immobilization of metallic nanoparticles onto discrete zones of an optical waveguide surface makes the parallel detection of a large number of molecular species feasible. In each zone, captured molecules tethered to the nanoparticles preferentially bind to a particular molecular species through an affinity interaction. Strong localization of light about each nanoparticle allows for dramatic improvement in optical signal transduction, thereby facilitating the detection of small numbers of molecules bound within each zone. Microfluidics will be used to deliver small sample volumes to each sensing zone and passive mixing structures will be studied in order to increase the molecular binding probability within each zone.

CAREER: Chiral Ceramic Sensors (NSF Continuing Grant)
NSF Award Number 0134688
Start Date July 1, 2002
Expires June 30, 2007 (Est.)
Expected Total Amount $400,000 (Est.)
Richard L. (PI), Smith smithrl@mit.edu, 617-253-1000
MIT, Cambridge, MA

A variety of technologies (e.g., fuel cells, catalysis, sensors) rely on electrochemical phenomena that occur at ceramic surfaces and interfaces. The overall understanding of these interfaces is immature, in that we generally lack mechanistic and predictive structure-property relations. The ultimate goal of this research is to advance knowledge of the surface properties that are the basis of sensor and catalyst applications. It will be approached within the framework of developing a new class of metal oxide gas sensors, based on chiral (handed) surfaces, capable of detecting and differentiating chiral molecules. The underlying experimental objective is to develop a mechanistic understanding of the interactions between organic molecules and chiral oxide surfaces, which will include surfaces that are chiral on the atomic scale, e.g. Mo8O23(010), and those that are tailored to have chiral nano/microstructures. Surface properties will be investigated through the fabrication and testing of model sensors and temperature programmed desorption spectroscopy, while surface and bulk structure will be interrogated using appropriate probes. This study will advance general understanding of the roles surface and molecular structure play in oxide reactivity (i.e., surface structure-property relations) as well as new and powerful sensor functionalities.

Nanomaterial for Microchip Chemical Sensors (NSF SBIR Phase II)
NSF Award Number 0215819
Start Date September 15, 2002
Expires February 28, 2005 (Est.)
Expected Total Amount $499,994 (Est.)
Stuart Farquharson (PI), stu@rta.biz, 860-528-9806
RTA, East Hartford, CT

This Small Business Innovation Research (SBIR) Phase II Project will develop a novel microchip chemical analyzer that incorporates a new nanomaterial that performs both separation and detection of small quantities of chemicals and biochemicals. Phase I demonstrated feasibility by incorporating a proprietary nanomaterial in 20- by 50-micron channels etched in a glass microchip and performing chemical separation and surface-enhanced Raman spectral analysis of several test chemicals. Phase II will complete development of the microchip chemical analyzer by designing reproducible plastic microchip cards that fit into an integrated micro-fluidics and Raman system. Development will include the following chemicals: p-aminobenzoic acid, phenyl acetylene, adenine, acetaminophen, secobarbitol, cocaine, and related metabolites. The microchip analyzer will have broad commercial value to the agricultural, biotech, chemical agents, environmental, medical and pharmaceutical industries.

SGER: Antibody-Conjugated Nanoparticle Films as Spectroscopic Sensors of Chemical Agents (NSF Standard Grant)
NSF Award Number 0228143
Start Date September 1, 2002
Expires August 31, 2004 (Est.)
Expected Total Amount $100,000 (Est.)
Alexander Wei (PI), alexwei@purdue.edu, 765-494-4600
Sponsor Purdue Univ., West Lafayette, IN

The proposed work will fabricate robust, antibody-conjugated gold nanoparticle films as substrates for surface-enhanced Raman scattering (SERS), a sensitive spectroscopic method with unmet potential for label-free chemical sensing. The SERS activities of the nanoparticle-based substrates will be optimized as a function of interparticle spacing and periodic order. Initial tests will be performed to recognize 2,4-dinitropohenol (DNP) in gas and aqueous environments and in the presence of several other aromatic compounds as a control for selectivity. The demonstration of substrates for selective chemical detection of DNP can be immediately parlayed into the development of Raman-based sensors of chemical warfare agents, including explosives, nerve gases, and mustard gases and vesicants.
The structure-activity relationships are based on theoretical considerations alone and have no experimental precedence. However, the proposed research is hypothesis-driven and addresses both short-term objectives for chemical sensor development and fundamental issues on the plasmonic properties of nanostructured metal films, with subsequent potential for applications beyond chemical and biological sensing.

SGER: Biosensing in the Gas Phase: A New Approach Based on Imprinted Nanoparticles of a Linear Polymer (NSF Standard Grant)
NSF Award Number 0229026
Start Date September 1, 2002
Expires August 31, 2004 (Est.)
Expected Total Amount $93079 (Est.)
Gary C. Tepper (PI), gctepper@saturn.vcu.edu, 804-828-6772
Virginia Commonwealth Univ, Richmond

The objective of this project is to develop a new kind of gas-phase biosensor to simultaneously detect chemical and biological warfare agents entirely in the gas phase and in real time. Recent studies have demonstrated that biological pathogens emit volatile chemical metabolites that potentially can be utilized as a unique gas-phase signature. Therefore, the volatile chemical agents will be detected

directly while the biological species, such as bacteria, will be detected through their volatile metabolites. The PIs will develop nanoparticles possessing synthetic receptor sites targeted to the volatile chemical metabolites of particular biological pathogens. The imprinted particles will be interfaced with a microfabricated transducer and the resulting biochip will be tested under exposure to a variety of vapors including the metabolites. This technology has the potential to reduce or eliminate the costly, labor intensive and time consuming practice of current air sampling and analysis techniques. If successful, a portable, hand-held, gas phase biosensor could be deployed at various high-risk locations to provide real-time monitoring for biological and chemical agents.

Fluorescence-Amplified Nano-Assembly for Sensing Bio-Toxins (NSF SBIR Phase I)
NSF Award Number 0232277
Start Date January 1, 2003
Expires September 30, 2003 (Est.)
Expected Total Amount $99,912 (Est.)
Winston Ho (PI), winstonho@maxwellsensors.com, 562-801-2088
MSI, Santa Fe Springs, CA

This Small Business Innovation Research (SBIR) Phase I project is to develop a novel functional nanostructure for detection/identification of biological warfare agents (BWA). A new class of fluorescence-amplified nano-assembly (FLAN) is proposed for real-time, selective, and ultra-sensitive BWA and toxin assays. The basic concept of this technology is to mimic the cell membrane that certain organisms and toxins initially attack. Living cells quickly recognize and selectively respond towards invasion. The FLAN using three key elements for target detection: 1) molecular recognition, 2) fluorescence transduction, and 3) fluorescence amplification, to provide simple and direct fluorescent assay. The molecular receptors recognize the BWA; the binding causes a change in the local ternary structure, which leads to an amplified fluorescent structure that can be quantified optically. The synthetic nanostructures exhibit bioactivities and high stability. The BWA/FLAN receptor binding is a rapid one-step reaction; it does not require complicated separation and washing steps, labeled fluorophore, or visualization reagents. During the Phase I project, the investigator will design and synthesize functional nanostructures with BWA-specific receptors; develop a FLAN molecular assembly; develop a fluorescence sensing system; and characterize, test, and evaluate its technical merits.

CAREER: Aligned Carbon Nanotube Composite Array as Permeable Membrane for Selective Chemical Separations and Sensing (NSF Standard Grant)
NSF Award Number 0348544
Start Date April 15, 2004
Expires March 31, 2009 (Est.)
Awarded Amount to Date $483,214
Bruce Hinds (PI), bjhinds@engr.uky.edu, 859-257-8311
Univ. of Kentucky Research Foundation, Lexington

This project is aimed at the development of highly selective affinity membranes based on aligned carbon nanotubes embedded in a polymer film. This concept could lead to the development of membranes with enhanced selectivity for numerous applications. The growth of oriented carbon nanotubes by thermal CVD and functionalization of the carbon nanotube tips with carboxylic acid groups have been demonstrated. The carboxylic acid groups at the ends of the carbon nanotubes can be

functionalized, allowing for high selectivity in an affinity membrane. Measurements of transport properties of nitrogen gas and aqueous ionic species through polymer-coated carbon nanotube structures have been performed; these measurements demonstrated the molecular sieving character of the membranes. In terms of the broader impacts, the educational program will include the development of new courses and laboratories aimed at introducing nanotechnology to undergraduates. Success in this research effort will enable a new class of well controlled nanoscale pore structures for selective chemical separations, sensors, drug delivery, and environmental remediation.

NER: Bottom-up Assembly of Nanomechanical Biosensing Arrays (NSF Standard Grant)
NSF Award Number 0304575
Start Date September 1, 2003
Expires August 31, 2004 (Est.)
Awarded Amount to Date $100,000
Christine Keating (PI), keating@chem.psu.edu, 814-865-4700, Theresa Mayer (Co-PI)
Pennsylvania State Univ., University Park

The applicants propose to develop a novel biosensing strategy in which a nanomechanical transducer array is built from the bottom-up, by integrating nanobiosensor elements onto a CMOS chip. Sensing is accomplished by measuring a shift in the resonance frequency of nanowires due to the mass change associated with DNA hybridization. The DNA derivitization will guarantee high detection selectivity, while the nanometer scale dimensions of the resonant cantilevers will provide high sensitivity. This exploratory project will focus on the incorporation of DNA molecules onto the nanowires before alignment and integration and show that their bioactivity is retained, and sensitivity will be demonstrated. The project has the potential to impact several fields including trace detection and biosensing for food safety, national security, forensics and medical diagnostics. Introduction of the nanoscale in these applications is desired for low cost, rugged and miniaturized devices.

Development of Nano-Based Passive Sensors for RF/Wireless Sensing Systems (NSF Standard Grant)
NSF Award Number 0401375
Start Date July 1, 2004
Expires June 30, 2007 (Est.)
Awarded Amount to Date $210,000
Anh-Vu Pham (PI), pham@ece.ucdavis.edu, 530-752-2075
University of California, Davis

The PI is proposing to develop microwave vertically aligned carbon nanotube resonator sensor for remote and wireless chemical detection. The newly developed sensor is the key component in development of a remote wireless sensing system to detect chemical agents. The sensor will consist of an electromagnetic resonator integrated with vertically aligned carbon nanotubes used as a chemical transducer. The carbon nanotube resonator sensor is a passive sensing device and requires no power consumption. Passive sensor and zero power consumption address the challenges in the development of wireless sensor networks that employ numerous sensor nodes. The contactless sensor is important in applications that prohibit the use of wiring. The microwave carbon nanotube resonator sensor exhibits changes in resonant frequency when exposed to gasses. An array of antennas will be designed and incorporated into the carbon nanotube resonator sensor to communicate with a remote wireless reading system. He will develop a remote wireless reading system to probe the sensor. The major tasks of this research include: (1) development of microwave carbon nanotube resonator sensor to detect chemical

agents, and (2) development of a wireless remote sensing system using microwave carbon nanotube resonator sensors up to 20 GHz. Broader Impact: The advancement of sensors is a national need with broad ranges of applications in health care, the food industry, chemical industry, environmental monitoring and national security. The detection of chemical agents remotely is particular importance and a critical element in the development of wireless sensor networks. The remote detection is crucial in applications where wires are prohibited. The underlying sensing mechanism is passive, and such sensors are critical to power management of wireless networks that use numerous sensor nodes. The sensor can be integrated on a printed circuit board for practical applications. The research will enhance the understanding of the interaction occurring between gas molecules, their environment, and microwave electromagnetic signals. The use of emerging carbon nanotube materials will open numerous possibilities for the development of sensors that can detect new toxic and biological agents.

Sensors: Near Infrared Fluorescent Single Walled Carbon Nanotubes as Solution Phase Optical Sensing Materials (NSF Standard Grant)
NSF Award Number 0330350
Start Date January 1, 2004
Expires December 31, 2006 (Est.)
Awarded Amount to Date $324,966
Michael Strano (PI), strano@uiuc.edu, 217-333-2186
University of Illinois at Urbana-Champaign

The goal of this project is to develop a new class of sensing materials for solution phase detection of molecules based on the near-infrared fluorescence of single walled carbon nanotubes. Carbon nanotubes are a part of a select class of electronic materials that fluoresce in the infrared region. Scattering and auto-fluorescence in a wide range of biologically relevant media prohibit accurate fluorescent detection in the visible spectrum. The geometry of single walled carbon nanotubes is unique among molecular probes. They conduct electrons under near-ballistic conditions or over large distances with minimal scattering. This provides the basis for powerful sensing technologies because large areas of the nanotube surface are sensitive to single molecule adsorption events. Adsorbates on the surface of a nanotube can localize valence electrons or conversely donate electron density to the conduction band, and either event is registered as a change in the nanotube optical emission properties. This project will address three technological hurdles towards this goal: (i) understanding the molecule-nanotube surface interactions and their effect on optical properties, particularly polarity induced solvatochromic shifts and charge transfer interactions; (ii) designing adsorbed interfaces to introduce specificity at the nanotube surface towards desired molecules; and (iii) engineering working sensor devices for molecular detection in unconventional media such as highly turbid solutions or biological relevant media.

US-France Cooperative Research: Electrochemical Preparation of Nanowires and Mesowires for Chemical Sensing (NSF Standard Grant)
NSF Award Number 0233371
Start Date February 15, 2003
Expires January 31, 2006 (Est.)
Awarded Amount to Date $18,339
Reginald Penner (PI), rmpenner@uci.edu, 949-824-4768
Univ. of California, Irvine

This three-year award for U.S./France collaboration in chemistry supports annual visits by a U.S. graduate student to France. The project is led by Reginald M. Penner of the University of California at Irvine and Frederic Favier of the University of Montpellier 2. The objectives of the research are (1) the synthesis of nanowires composed of two metals, (2) the development of methods for attaching receptor molecules to the surface of metal nanowires, and (3) the evaluation of nanowires as chemical sensors. The project takes advantage of a method developed by the French investigator for synthesizing metal nanowires. The U.S. investigator brings to the collaboration expertise in electrochemical methods and electrodeposition of nanowires and mesoscale particles. This award represents the U.S. side of parallel proposals to the NSF and the CNRS.

Novel Compact Sensor Based on Surface Enhanced Raman Scattering of Gold Nanoparticle Aggregates and D-Shaped Fibers (NSF Standard Grant)
NSF Award Number 0401206
Start Date April 1, 2004
Expires March 31, 2007 (Est.)
Awarded Amount to Date $210,000
Claire Gu (PI), claire@ee.ucsc.edu, 408-429-0111, Jin Zhang (Co-PI)
Univ. of California-Santa Cruz

The primary objective of this research is to develop and demonstrate a novel sensor based on nanoparticle surface enhanced Raman scattering (SERS) and D-shaped fibers for chemical, biological, and environmental detection with emphasis on understanding both the fundamental principles and critical engineering issues underling the sensor design and operation. The sensor will be highly sensitive, molecular-specific, reliable, label-free, non-invasive, inexpensive, easy to produce commercially using existing technologies, compatible with existing lasers and detectors, and applicable to a large number of molecules of interest. This is made possible by the unique sensor architecture based on a combination of D-shaped fibers and novel SERS substrates, where SERS provides the high sensitivity (106-1015 enhancement factor), molecular specificity, and applicability to a wide range of compounds, while the novel D-shaped fiber provides compactness, reliability, low cost, and ease of production. The proposed research approach to the compact SERS sensor is to deposit a layer of nanoparticle aggregates on top of the polished surface of a D-shaped fiber. Light propagating inside the fiber is coupled to the nanoparticle layer where SERS is employed to detect the sample. The developed sensor will be tested in the detection of several important chemical and biological systems including glucose, proteins, DNA, and bacteria. It can also be useful for in situ detection of chemical warfare agents, explosives, food pathogens, toxins, and blood or tissue proteins.

Carbon Nanotubes FET Platform for Electronic & Sensors Applications (NSF SBIR Phase I)
NSF Award Number 0340484
Start Date January 1, 2004
Expires June 30, 2004 (Est.)
Awarded Amount to Date $99,878
Jean-Christophe Gabriel (PI), jcgabriel@nano.com, 510-428-5302
Nanomix, Inc., Emeryville, CA

This Small Business Innovation Research Phase I project involves the fabrication of a nanoelectronic device research module or kit for use by educational institutions and private sector researchers. The nanoelectronic devices will be used as transducer components in chemical, biological, and photonic

sensors. The kit will have three components: 1) packaged nanotube based field effect transistors (NTFETs); 2) a functionalization test board (FTB) for testing the devices; and, 3) a data acquisition system by which the users control the FTB. The NTFET development will require refinement of the production of reproducible nanotube array devices on 4" silicon wafers. The proposed work involves extending semiconductor manufacturing to produce 1 nm objects with the attendant challenges of imaging, measurement, and process control. The project will optimize the major variables important to the uniform growth of arrays of single-wall carbon nanotubes with the electronic properties necessary for sensor transduction. The work will explore FET geometries and will develop tools and software for nanotube device characterization. The commercial application of this project is a research tool for the electronics market. Commercial availability of the NTFET kit would allow many component makers to study molecular electronic interactions and develop proprietary formulations for NTFET-based sensors.

SENSORS: Nanoparticles-Based Biosensor for Direct Detection of Organophosphate Chemical Warfare Agents and Neurotoxic Pesticides (NSF Continuing Grant)
NSF Award Number 0330189
Start Date October 1, 2003
Expires September 30, 2004 (Est.)
Awarded Amount to Date $375,000
Aleksandr Simonian (PI), als@tamu.edu, 205-826-4000, Theresa Good (Co-PI)
Auburn Univ., Auburn, AL

This project explores enzyme-based biosensors linked to gold nanoparticle scaffolds that permit the direct detection of ultra low concentrations (10-10 M) of organophosphate (OP) neurotoxins in multi-component environments such as ground water, waste water, food, and soil. The primary biosensor element consists of a metal nanosurface, one or more broad-spectrum organophosphate hydrolase-enzyme biorecognition elements, fluorescent decoys that compete specifically for binding with neurotoxins of interest, and an optical system for fluorescence detection. The nanoparticle/molecular interface is designed to alter the optical properties of the fluorescent decoy when bound by the biorecognition element, giving rise to a unique signal that changes when it is released. The development of this technology into a family of robust, sensitive, and discriminating chemical sensors capable of identifying and quantifying OP nerve agents and pesticides involves: (i) the development of appropriate decoys that can compete specifically with different agents, (ii) the selection or modification of enzymes via rational, site-directed mutagenesis to finely tune catalytic enzyme properties (both affinity and substrate specificities); (iii) the development of the optimum sensor platform, both in terms of nanoparticle properties and attachment chemistries and optical systems for light collection; and (iv) the design of detection algorithms for robust sensor performance. Intended applications of the proposed biosensor include the monitoring of soil, air, and/or water quality.

SGER: Aptamer-based Nanogels: Chemosensory Transducers and Sensors for Homeland Security (NSF Standard Grant)
NSF Award Number 0346494
Start Date October 15, 2003
Expires September 30, 2004 (Est.)
Awarded Amount to Date $54,925
Ponisseril Somasundaran (PI), ps24@columbia.edu, 212-854-6851
Columbia Univ., New York, NY

Recent events have necessitated development of advanced sensors for rapid detection of toxins and microbes. It is the principal investigator's aim to develop smart aptamer (oligonucleotides of modest size) based polymeric nanogel platforms that would sense external perturbations and respond appropriately. The work will incorporate DNAzymes (self cleaving aptamers) into nanogels so that they will release a pre-loaded antidote or produce a detectable signal upon binding of a toxin. The interfacial and colloidal properties of the synthesized nanogels will be studied using fluorescence spectroscopy, light scattering studies, and ultra centrifugation, while their delivery processes at the interface between nanogel and ligands will be studied using surface plasmon resonance spectroscopy in real time. This nano-scale research project has been envisioned and conceived as a strongly interactive and collaborative program between the participating PIs in different disciplines, i.e., chemical engineering, biology, and chemistry. It has potential applications in as diverse areas as microelectric circuits, sensors, nanocomputers, cosmetics, and biomimetic devices.

SENSORS: Arrayed Optical Detection of Nanoscale Biomass (NSF Standard Grant)
NSF Award Number 0330110
Start Date September 1, 2003
Expires August 31, 2006 (Est.)
Awarded Amount to Date $500,000
Michal Lipson (PI), lipson@ece.cornell.edu, 607-255-5014, Roberto Panepucci (Co-PI)
Cornell Univ., Ithaca, NY

This Sensor proposal focuses on the ability to detect small amounts of materials, including pathogenic bacteria and biomolecules integral to cell responses. New approaches are proposed to the problems of transducing mass changes and to the problems of on-chip multiplexing and demultiplexing. These ideas are based on concepts developed for advanced MEMS and integrated optic devices. We propose a novel device/instrument for ultra-sensitive detection of molecular amounts of material with applications in pathogen and biochemical detection, medicine, drug discovery, and nanotechnology. The device consists of a silicon-on-insulator based chip that incorporates ultra-sensitive nano-mechanical cantilevers with novel silicon-based passive integrated optics. Passive optical ring-resonators are used for on-chip wavelength multiplexing and demultiplexing of optical signals. The ring-resonators act as filters for different wavelengths, which are guided to different cantilever sensors. The cantilever waveguide is used for motion detection. Mechanical vibrations in the MHz range are encoded on the optical signal by one element of an array of biosensitized cantilever transducers. The one-to-one association of individual wavelengths with mechanical vibrations of different cantilever sensors allows one to address each sensing site. This innovation in transduction strategy allows the use of ring-resonators that do not need external tuning or closed-loop control. This strategy requires inexpensive broadband sources for optical carrier signals. The sensed shift in vibration frequency at each ring resonator/cantilever pair can be detected in parallel on the external device. The principle of operation of the biosensor is based on highly-sensitive, immunospecific attachment of pathogens to silicon nanofabricated structures that measures the mass of the pathogen, as well as its presence. The cantilevers can detect mass in the attograms to picograms range.

SENSORS: Detection of Toxic Chemical Agents by Molecular Imprinting with Nanoparticles and Dendrimers in Ultrathin Films (NSF Standard Grant)
NSF Award Number 0330127
Start Date August 15, 2003
Expires July 31, 2006 (Est.)

Awarded Amount to Date $250,000
Rigoberto Advincula (PI), radvincula@uh.edu, 713-743-9222
Univ. of Houston, Houston, TX

Molecularly imprinted (MI) chemical recognition elements of toxic organophosphorous chemical agents will be investigated. MI techniques will be employed to detect toxic organophosphorous chemical agents using semiconductor nanoparticles (CdS, CdSe, and ZnS), dendrimers of polybenzylphenyl ethers, and electroactive monomers in a three component cross-linking methodology. These materials will be imprinted as films and monoliths and the sensing efficiency evaluated using electrochemical, evanescent wave, acoustic, and fiber optic sensor formats. Quantum dots will have optical, electrochemical, and luminescent properties sensitive to the binding of chemical agents. The dendrimers will enhance the imprinting methodology by forming high surface area and porous cavities as chemical recognition elements. Electroactive polymers will allow controlled cross-linking, selective hydrophobicity, and electrochemical transport control in these materials. It will also influence the photochemical and electrochemical properties of the quantum dots. Combinatorial methods will be used to control composition and target increased specificity, sensitivity, detection limits, and reliability for sensors. Quantitative specific and non-specific binding studies will be made to determine kinetics, mass transport, pre-concentration effects, and equilibration to properly address sensor figures of merit. In terms of the broader impacts, societal benefits should result from protection from chemical agent threats, improved security, and pollution monitoring.

Integrated Sensing: Development of Multifunctional Wireless Sensory Microsystems with Integrated Nanoelectromechanical Devices (NSF Standard Grant, Collaborative Research)
NSF Award Number 0225496
Start Date January 1, 2003
Expires December 31, 2004 (Est.)
Awarded Amount to Date $75,000
Investigator(s) Sanjay Raman (PI), sraman@vt.edu, 540-231-5281
Sponsor Virginia Polytechnic Inst. and State Univ., Blacksburg

Recent advances in nanometer scale science and technology offer novel approaches for the development of ultra-miniature low-power sensor nodes for distributed wireless sensor networks in applications such as environmental monitoring, civil infrastructure monitoring, condition-based maintenance, security, and surveillance. The reduced dimensions and masses of nanoelectromechanical systems (NEMS) are of great interest for highly-sensitive force- and mass-sensing. We propose a novel technology based on assembly of nanostructured nanomechanical sensors rather than their direct machining from the substrate material. Nanomechanical sensing structures will be produced using "bottom-up" synthesis, then surface assembled and integrated with foundry-fabricated monolithic circuits through electrofluidic assembly, allowing on-chip integration of nanomechanical sensors with transduction, readout, processing, and communications circuitry. This approach also offers flexibility and scalability, enabling the assembly of a larger range of functional structures. Leveraging core competencies in NEMS device development and analog/RF/microwave IC design, we will develop a micropower nanosensor-based microsystem containing nanosensor assembly/integration sites, sensor-specific transduction, and read-out electronics.

Integrated Sensing: Development of Multifunctional Wireless Sensory Microsystems with Integrated Nanoelectromechanical Devices (NSF Standard Grant, Collaborative Research)

NSF Award Number 0225439
Start Date January 1, 2003
Expires December 31, 2004 (Est.)
Awarded Amount to Date $75,000
Investigator(s) Stephane Evoy (PI), evoy@ee.upenn.edu, 215-898-7293
Sponsor Univ. of Pennsylvania, Philadelphia

Recent advances in nanometer scale science and technology offer novel approaches for the development of ultra-miniature low-power sensor nodes for distributed wireless sensor networks in applications such as environmental monitoring, civil infrastructure monitoring, condition-based maintenance, security and surveillance. The reduced dimensions and masses of nanoelectromechanical systems (NEMS) are of great interest for highly-sensitive force- and mass-sensing. The researchers propose a novel technology based on assembly of nanostructured nanomechanical sensors rather than their direct machining from the substrate material. Nanomechanical sensing structures will be produced using "bottom-up" synthesis, then surface assembled and integrated with foundry-fabricated monolithic circuits through electrofluidic assembly, allowing on-chip integration of nanomechanical sensors with transduction, readout, processing, and communications circuitry. This approach also offers flexibility and scalability, enabling the assembly of a larger range of functional structures. Leveraging core competencies in NEMS device development and analog/RF/microwave IC design, the researchers will develop a micropower nanosensor-based microsystem containing nanosensor assembly/integration sites, sensor-specific transduction, and read-out electronics.