Symposium on Nano-, Micro-, and Mesoscale Technologies in Science and Engineering
Time: 9.15 a.m - 3p.m, May 13, 1999
Location: Engineering Research Center (ERC) Rooms 427 and 435.

Sponsored by the College of Engineering at UC
The Department of Electrical and Computer Engineering and Computer Science
and the Local Section of the Electrochemical Society

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PROGRAM

9.15-9.20 Welcoming address, M. Cahay, ECECS Dept., University of Cincinnati

9.20-9.30 Opening Remarks: Stephen Kowel, Dean of College of Engineering

Morning Session

9.30-10:30 Invited Talk:

Prof. Ron Andres
Engineering Research Professor
School of Chemical Engineering, Purdue University
West Lafayette, IN 47906

Aerosol Synthesis of Metal Nanocrystals
and Their Self-Assembly Into Electronic Nanostructures
(see attached abstract)

10:30-11-45 Poster Session I (See attached List of Abstracts)

11:45-1.00 Lunch for All contributors: In Roon 435 and outside Room 427ERC

Afternoon Session

1.00-2.00 Invited Talk

Prof. Mark G. Allen
Director, Microsensors and Microactuators Lab.
Georgia Institute of Technology, School of Eletrical and Computer Eng.
Atlanta, Georgia 30332-0250

MEMS at Georgia Tech:
Mechanical Structures, Microsensors and Microactuators

2.00-3.00 Poster Session II (See Attached List of Abstracts)

3.00 Meeting Adjourned

AEROSOL SYNTHESIS OF METAL NANOCRYSTALS AND THEIR SELF-ASSEMBLY INTO ELECTRONIC NANOSTRUCTURES

Ron Andres
Engineering Research Professor
School of Chemical Engineering
Purdue University, West Lafayette, IN 47907

The remarkable success of silicon based microelectronics rests on a continuing decrease in the dimensions of the active devices. Eventually unavoidable physical constraints and rapidly rising manufacturing costs mean that radically different materials, technologies, and approaches must be invented to sustain the evolution of computer technology. A potential solution to this problem is the use of the self-organizing phenomena evident in biological systems to build-up or self-assemble electronic circuits and devices from nanometer size components. One such self-assembly scheme involves the casting of a monolayer film of metal clusters onto a flat solid substrate and the introduction of organic molecules that bond the clusters in the film to each other to form an electronically-conducting superlattice [1]. Such a "linked cluster network" has many attractive properties the foremost being: 1) when the clusters have diameters smaller than approximately 5 nm, low intercluster capacitance gives rise to correlated single electron tunneling in the network even at room temperature; 2) the electronic conductance of the superlattice can be controlled by the choice of the linking molecules which act as tunnel barriers between clusters; and 3) narrow "ribbons" or "wires" of molecularly bonded clusters are mechanically stable and can span relatively large distances [2]. We review techniques developed at Purdue for fabricating electronic nanostructures by this scheme and the current understanding of their conductance characteristics .

The two most common methods for obtaining ultra-small metal particles are the reduction of metal ions in the liquid phase and the condensation of metal atoms in the gas phase. The approach we have taken is the second, i.e. gas phase or aerosol synthesis, followed by thermal annealing of the particles to produce nanocrystals. The bare metal crystals are captured in a liquid solvent and "passivated" by adsorption of a monolayer of organic molecules on their surface facets to produce a colloidal suspension. Size-selective precipitation is then used to refine the particle size distribution and remove excess surfactant molecules. Redispersing the clusters in a solvent that is immiscible in water and casting the colloidal suspension on a water surface produces a close-packed monolayer of clusters that float at the air-water interface after the solvent evaporates. This cluster monolayer is transformed into an electronically-conducting superlattice by displacing the passivation layer around each cluster with linking molecules. Once a uniform linked film has self-assembled on the water surface, it is transformed into a patterned network on the substrate by: 1) lithographically defining areas on the substrate where the energy of adhesion of the cluster film is high and areas where the adhesion energy is low, 2) transferring the intact cluster film from the water surface to the substrate by contacting the film with the patterned substrate, and 3) removal of those portions of the film that are not strongly held to the substrate by solvent rinsing.

The above suite of techniques provide a scheme for synthesizing interesting nanoelectronic structures and devices. Our current understanding of electronic transport in such structures, obtained from experimental measurements using scanning tunneling microscopy and conductance spectroscopy and theoretical modeling using quantuum mechanics is described.

References

[1] Andres et. al., Science 273, 1690 (1996)

[2] Datta et. al., Semicond. Sci. Technol. 13, 1347 (1998)

MEMS at GEORGIA TECH
MECHANICAL STRUCTURES, MICROSENSORS AND MICROACTUATORS

Mark G. Allen, Professor
Microsensors and Microactuators Lab
School of Electrical and Computer Engineering
Georgia Institute of Technology

Micromachining is a branch of experimental microelectronics in which integrated circuit and electronic packaging fabrication techniques are used to create mechanical structures in silicon and other materials, potentially in addition to electronic devices. Due to the manner of their fabrication, micromachined structures share certain attributes with integrated circuits, namely batch fabrication (possibility of realizing arrays and highly interconnected structures), economics (the first one's expensive, but each subsequent one can be cheap), and size (typical sizes range from microns to millimeters). Micromachining can be used to create individual mechanical structures (e.g., piercing structures, optical gratings, etc.); structures which transduce a physical signal into an electrical signal (microsensors); and structures which transduce an electrical signal into a physical signal (microactuators). Systems based on individual micromachined devices, so-called microelectromechanical systems (MEMS), can also be realized.

This talk will give an overview of some of the MEMS projects going on at Georgia Tech in our group, ranging from fabrication technology to microsensors and microactuators to combustion-based power generation on the small scale. In addition to this broad overview, three illustrative projects will be discussed in detail: (1) a mechanical structure project, in which microneedles are used to painlessly pierce skin for transdermal drug delivery; (2) a microsensor project, in which ceramic pressure sensors are demonstrated that can operate in high temperature environments and communicate wirelessly with the outside world; and (3) a microactuator project, in which a fully integrated magnetically actuated micromachined electrical relay is demonstrated.

POSTER SESSION I: 10:30a.m-11.45a.m

In situ Light Scattering Measurements of Cryptosporidium and other Suspended Particles in Water.

Gabriel Dutari V., Virendra Sethi, Pratim Biswas*, Avner Adin**
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Establishing a relationship between turbidity, particle size and concentration would provide the basis for evaluating the effectiveness of particle removal processes. Urgent need arises to develop good detection techniques for the characterization of microorganisms and other particles in water. In this poster, an in-situ laser light scattering (ISLS) to measure the light scattering characteristics of suspensions is presented and measurements using turbidimeter and optical particle counter are compared. Another objective was also to use this in situ measurement technique for establishing transport characteristics particles in water.

Preparations of clay, Cryptosporidium parvum oocyst, monodispersed latex particles and silica particles suspensions were followed by measurements in the light scattering optical setup, turbidimeter and optical particle counter (OPC). The in situ technique mentioned above, was used to estimate the settling characteristics of particles used in the earlier experiments.

The 90 % cut off size for the Cryptosporidium parvum oocyst using OPC was approximately 2.5 micrometers, while microscopic determination resulted 4-6 micrometers. The clay suspension size was approximately 1.9 micrometers, a larger number remained below the detection limit of the instrument. In summary, the optical particle counter measurements undersize the Cryptosporidium parvum oocyst. This discrepancy in sizing may be attributed to its partial transparency. A linear dependency is observed by plotting the scattered intensity, Ivv as a function of number concentration for Cryptosporidium parvum suspensions of 104 oocysts/ml and higher, demonstrating the potential application of ISLS. The turbidimeter readings also correlate well with the number concentrations, again not in the lower range. 5.0 micrometers Silica particles (1.96 g/cc) settle faster and the measured light scattering intensity drops rapidly. Assuming settling of an initially uniform suspension, the settling velocity of the silica ranged 9.26-13.88 micrometers/s, close to theoretical calculations. Preliminary settling velocity findings for Cryptosporidium parvum range 0.068-0.5 micrometers/s. Although the size of the oocyst is larger than the mean size of the clay particles, they settle more slowly. The density differences alone cannot account for the order of magnitude differences in the settling velocity. Other local transport mechanisms may affect the sedimentation rates. Experiments are being performed to clearly elucidate these effects. Increasing the sensitivity of the ISLS measurement system will increase its future application.

Vita: Gabriel Dutari was born in Panama City, Panama. He received his Bachelor in Mechanical Engineering at Universidad Tecnologica de Panama. He is currently working on his M.Sc. in Environmental Engineering at the Department of Civil and Environmental Engineering at UC. His research interests include light scattering techniques for characterization and monitoring of particles in water, water filtration modeling and water filtration pilot plant experiments. He is expecting to graduate by early 2000.

References

[1] Sethi, V., Patnaik, P., Biswas, P., Clark, R.M. and Rice, E.W. (1997). Evaluation of Optical Detection Methods for Waterborne Suspensions. American Water Works Association Journal 89(2): 98-112. Hinds, W. (1982). Aerosol technology : properties, behavior, and measurement of airborne particles. New York, J. Wiley-Interscience publication.

[2] Medema, G. J., Schets, F. M., Teunis, P. F. M., Havelaar, A. H. (1998). Sedimentation of Free and Attached Cryptosporidium oocyst and Giardia Cyst in Water. Applied Environmental Microbiology 64(11): 4460-4466.

Acknowledgment: Special thanks to Jim Goodrich, Robert Clark, Nick Dougan , Jim Owens from USEPA, Cincinnati and Zhong-Min Wang from The Aerosol and Air Quality Research Laboratory, University of Cincinnati for their assistance during this work. This research was supported in part by Dr. Adin's appointment to the Internship Program of the Office of Ground Water and Drinking Water administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and the U.S. Environmental Protection Agency.

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** ORISE, USEPA visiting professor from The Hebrew University of Jerusalem

PHOTOCATALYTIC DEGRADATION OF 4-CHLOROBENZOIC ACID USING TiO2 NANOPARTICLES

Dionysios D. Dionysiou and Makram T. Suidan
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Our work focuses on the photocatalytic purification of industrial and wastewater using TiO2 catalyst and UV radiation. We present some of our recent results for the characterization and evaluation of a TiO2 rotating disk photocatalytic reactor for the degradation of 4-chlorobenzoic acid (4-CBA) in water. The study includes characterization of the TiO2 catalyst, investigation of the mixing characteristics of the reactor, determination of the liquid film thickness on the disk using the potassium ferrioxalate actinometry method and an outflow method, and determination of the photonic efficiencies. We discuss the effect of light intensity, initial contaminant concentration, disk angular velocity, and pH on the photocatalytic degradation of 4-CBA. We present our results for the reaction rate constants determined based on the Langmuir-Hinshelwood adsorption-reaction model and we discuss the importance of the absence of mass transfer limitations at a critical disk angular velocity. We also discuss some of our results for the photocatalytic degradation of 4-CBA using TiO2 nanoparticles in suspension and adsorption characteristics of 4-CBA on TiO2 powders. Finally we discuss the significance of this work along with parallel studies for improving the photocatalytic activity and the properties of the immobilized TiO2 films with the aim of commercializing this technology.

Vita: Dionysios D. Dionysiou was born in Cyprus. He received his Diploma in Chemical Engineering from the National Technical University of Athens, Greece, and his M.S. degree in Chemical Engineering from Tufts University. He is currently working on his Ph.D. in the Department of Civil and Environmental Engineering under the Supervision of Professor Makram T. Suidan. His research interests include photocatalytic purification of drinking water and industrial wastewater, preparation of TiO2 powders and immobilized TiO2 films with sol-gel methods, preparation of perovskite materials for hydrogen separation, crystallization from solutions and interfacial crystallization for the preparation of deicing crystals, effect of ionic and non-ionic surfactants for the stabilization of colloidal systems used in construction products, and the production and purification of enzymes in biochemical processes.

Acknowledgment: We are grateful to Suez-Lyonnaise Des Eaux, France, for the financial support.

SPECTROSCOPIC INVESTIGATION OF CdSe SELF-ASSEMBLED QUANTUM DOT STRUCTURES

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Quantum dots in the CdSe/ZnSe semiconductor system display intriguing new physics and have the potential for promising new applications due to their zero-dimensional confinement. We use micro-photoluminescence (μ-PL), nano-photoluminescence (n-PL), and micro-Raman (μ-Raman) spectroscopy to study CdSe self-assembled quantum dot structures. A 3-monolayer thickness of CdSe was MBE grown on a ZnSe epilayer on the (001)-oriented GaAs substrate. CdSe dots formation is strain driven due to a large lattice mismatch (7%) between the CdSe and ZnSe layers. To prevent dot growth after initial dot formation, a thin ZnSe capping layer is deposited on the CdSe layer after waiting times ranging from 0 to 300 sec. PL measurements reveal sharp emission peaks, originating from individual CdSe quantum dots, superimposed on a broad emission. The ensemble characteristics of these sharp emission peaks were investigated to gain insight on the size and number density using a series of samples with different times between growth and capping. The μ-PL along with μ-Raman scattering from samples with different interruption times show unexpected results in contrast to the Ostwald ripening behavior expected in the evolution of dots. By measuring the quenching of the PL with increasing sample temperature, we find compelling evidence that the PL emission from these samples results from two different kinds of states. These results elucidate a new and interesting regime in the formation of quantum dot structures, and new information about the exciton states associated with these quantum dots.

Vita: Heesuk Rho was born in Seoul, Korea. He received his M.S. in 1996 from the Physics Department of the University of Cincinnati. He is currently working as a Ph.D. candidate under Prof. Howard Jackson in the same department. His research is focused on optical characterization of CdSe self-assembled quantum dot structures. He is also interested in measurements of stress distributions in SiGe photoelastic waveguide structures and in Cr-doped sapphire fibers embedded in a glass matrix.

Acknowledgment: We acknowledge support by the NSF (DMR-9705443, ECS-9412772, 9705064) and ARO (DAAG55-97-1-0378).

Elements of Multigrid: An Efficient Approach to Solve Poisson-Type Equations

Nobunaka Matsuno and Thomas Beck
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Iterative relaxation methods have been widely used to solve boundary value problems (such as Poisson and Poisson-Boltzmann type equations) for the past few decades. Although numerical solution of these equations is simple in principle, critical slowing down (CSD) in computational time is often observed for larger systems. The multigrid technique adopts iterative relaxation on multiple levels, and significantly increases the speed of convergence [1, 2].

We will show one and three-dimensional Poisson Solvers utilizing multigrid techniques. In the discussion, the basic elements of the multigrid method will be explained, and performance comparisons between the basic iterative method and the multigrid method will be shown.

Additionally, an application of the multigrid technique to specific biophysical problems will be discussed as an example. The example includes the study of ion transport channels in three-dimensional volume by solving the self consistent Poisson-Nernst-Planck (PNP) Equations.

Vita: Nobunaka Matsuno was born in Kani-city, Japan. He received his Bachelor and Master's degrees in Chemistry from Butler University, Indianapolis, Indiana in 1994 and 1997, respectively. He is currently working on his Ph.D. in the Department of Chemistry at UC under the supervision of T.Beck.

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[1] A. Brandt, Math Comp.31, 333 (1977).

[2] W. Braggs, Multigrid Tutorial, 1987 Lancaster Press.

MICROELECTRODE ANALYSIS OF ENVIRONMENTAL BIOFILMS IN WASTEWATER TREATMENT RESEARCH

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For the past 7 years our lab has been using microelectrodes (5-10 mm. tip diameter) to study biofilms in engineered biological systems used in the treatment of wastewater. The research has focused on operationally important parameters such as dissolved oxygen (DO), pH, ammonia, nitrate, sulfide, and redox potential. This tool allows us to investigate the mechanisms and function of biofilms in-situ. We present here the detailed theory behind their operation and the process of making these microelectrodes. The electrodes are described by their sensing module, response time, lifetime, stability of signal, selectivity, and detection limit. All the electrodes are manufactured in our lab, and are not commercially available except for the DO microelectrode.

The DO microelectrode is an amperometric electrode of whalen type. The fabrication is described in Fu, 1993. The sulfide (S-2) microelectrode is a solid state ion selective electrode. Under alkaline conditions it measures sulfide, and at neutral pH, where biological sulfide reduction occurs, it measures total dissolved S. The redox microelectrode is a solid state electrode with platinum wire, and it measures the oxidation-reduction potential against the SHE. The construction of the sulfide microelectrode is described in Yu, et al., 1998.

The pH, ammonia, and nitrate microelectrodes use liquid ion-selective membranes and measure potential difference. The original work in our lab is described in Zhang, 1994. Further modifications have been made to extend the lifetime and improve the selectivity of the microelectrodes (DeBeer, 1997). The construction of these microelectrodes is the focus of my work.

Vita: Gudny Palsdottir is a PhD candidate in the Department of Civil and Environmental Engineering. A native of Iceland, she came to the United States in the fall of 1989 and began her undergraduate studies at Florida Tech., in Melbourne Florida. She finished a BS degree in Environmental Engineering in March 1993, and a MS from the same department in December 1995. She joined the biofilm engineering research group of Professor Paul L. Bishop at the University of Cincinnati in fall of 1995. Her research focuses on the investigation of loss of nitrification in a trickling filter under various operating conditions; possible causes and remedies.

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Yu, T., Bishop, P. L., Galal, A., and Mark, Jr. H. B. (1998) Fabrication and evaluation of a sulfide microelectrode for biofilm studies (Chapter 19) In: Polymers in Sensors: Theory and Practice N. Akmel and A. M. Usmani (Ed.) American Chemical Society, Washington, DC. pp. 231-247.

Zhang T. C. (1994) Influence of biofilm structure on transport and transformation processes in biofilms. Ph. D. dissertation. Univ. of Cincinnati, Cincinnati, Ohio, U.S.A.

Application of Microsensors in Environmental Biofilm Systems

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Oxygen, ORP, pH, Ammonium, Nitrate and Sulfide microsensors were fabricated and evaluated in our lab. They were applied in studies of the distribution of dissolved oxygen, ammonium, nitrate, sulfide, pH and redox potential in environmental biofilms with stratified microbial communities.

Heterotrophic, nitrifying and sulfate reducing biofilms were developed in laboratory-based rotating drum reactors fed with synthetic wastewaters containing different COD and nutrition levels according to the specific requirements of bacteria. The typical thickness of the biofilm was 1-2 mm.

All the microsensors used in the studies had tip diameters of less than 5um except for the sulfide microsensor which had a tip diameter of 15um. The extremely small size of the microsensors allows the measurement of DO, ammonium, nitrate, sulfide, pH and ORP profiles within the biofilms without considerable disturbance to the biofilms. Results from these studies show stratification of the biofilm community structures and their correspondent functions [1, 2, 3].

Vita: Ms. Jin Li obtained her B.S. degree in Environmental Engineering in 1994 and M.S. degree in Chemical Engineering in 1996 from Zhejiang University, Hangzhou, China. Ms. Li became a research assistant in the Department of Civil and Structural Engineering in HongKong Polytechnic University in 1996. Currently, Ms. Li is a Ph.D candidate and research assistant in the Department of Civil and Environmental Engineering under the supervision of Dr. Paul Bishop. Her research is focused on the microelectrode and fluorescent in situ hybridization studies of nitrifying biofilm, biodegradation of toxic organic compounds (AO7) and their effects on microbial population dynamics in nitrifying biofilms. Ms. Li is also a trainee in multidisciplinary biotechnology research sponsored by the National Institute of Environmental Health Science.

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[1] Fu, Y.C. (1993) Characterizing oxygen profiles and determining oxygen diffusivity in biofilm during biodegradation of azo dye. Ph.D dissertation, University of Cincinnati, Ohio, USA

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Acknowledgment: This project is supported by grants from the National Institute of Environmental Health Sciences(NIEHS), National Institute of Health(NIH), and the United States Environmental Protection Agency(EPA).

Development of a generic microfluidic bio-sensor

Mike Dotson, Supaporn Kradtap, Shobha Purushothama, Kevin Schlueter
Ajith Wijayawardhana, H. Brian Halsall, Allan R. Pinhas, William R. Heineman
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Small volume enzyme immunoassays are attracting attention because of their advantages of low detection limits and inherent selectivity. The goal of this research project is to develop microbead-based assays compatible with MEMS devices and technologies. The microscopic magnetic beads will be covered with dendrimers (tree-like molecules) with many termini. The capture antibody will be attached to the dendrimer termini by means of the streptavidin-biotin bond. The antibody chosen will be specific to the target of interest. The captured target is labelled with a secondary antibody conjugated to an enzyme. The product of the enzymatic reaction is detected by electrochemical oxidation. The immunoassay method is very selective due to the specific interaction between target and antibodies. Electrochemistry has the dual advantage of being a sensitive method with low detection limits and lends itself to miniaturisation. Immunoassay methods are at present being developed for mouse proteins as model analytes. To safely simulate potential bio-warfare agents 'bug-beads' are used. The bug bead is very similar in size and composition to potential targets and serves as a harmless simulant. Attachment of dendrimer to the bead surface will increase the surface area of capture and will enable detection of small amounts of target in large, complex sample volumes.

Vitae:

Mike Dotson: Received his B.S. and M.S. degrees from Furman University. At present he is a doctoral candidate working on a novel synthetic route to PAMAMR dendrimers. This route is less time consuming and enables better control of number of generations and terminal group functionality.

Supaporn Kradtap: Received her B.Sc. degree from ChiangMai University, Thailand and her M.S. degree from the University of Massachusetts at Amherst. She is currently pursuing a doctoral degree. Her research goal is to develop bead-based assays for targets of environmental interest. Upon graduation she would like to work as a lecturer and researcher in Environmental-Analytical Chemistry for a University in Thailand.

Shobha Purushothama: Received her B.Sc. degree from Bombay University in India and her M.S. degree from Western Kentucky University, Bowling Green, KY. She is presently pursuing a doctoral degree. Her research goal is to develop dendrimer bead based assays compatible with MEMS devices.

Kevin Schlueter: Received his B.A. degree from Miami University and his Ph.D. from the University of Cincinnati. He completed a three year immunopharmacology fellowship in the Transplant Division of the Department of Pathology and Laboratory Medicine at the UC Medical Centre. He has served in that department as a post-doctoral researcher in co-operation with the Department of Infectious Diseases and The Holmes Hospital AIDS Treatment Centre in development of analytical methods for HIV therapeutics. Recently, he has been involved as a post-doctoral researcher with the Departments of Psychiatry, Pathology and Laboratory Medicine and the Veteran's Administration Medical Centre Research Division in development of ultrasensitive SPE/GC/MS methods of cocaine and metabolites analysis.

Ajith Wijayawardhana: Received his B.S. degree from Dennison University, and M.S.degree from the University of Utah in Salt Lake City. He is a doctoral student working on the development of sensitive, miniature electrochemical methods of detection.

NSOM CHARACTERIZATION OF PHOTONIC BAND GAP SAMPLE

Aditi Sharma, J.M. Yarrison-Rice* and H.E. Jackson
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D. Naghski and J.T. Boyd
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We will present preliminary results of the characterization of Photonic Band Gap (PBG) samples by Near Field scanning optical microscopy (NSOM). The PBG (analogous to the electronic band gap) refers to a range of photon frequencies that are forbidden to propagate in any direction in the sample. It arises due to a periodic modulation of the dielectric constant and provides unique and novel ways by which to manipulate and influence light propagation. Our samples are 2D optical waveguides that have a region within the waveguide that exhibits a photonic band gap in the visible. The waveguides consists of a guiding core layer of silicon nitride sandwiched between a silicon dioxide buffer layer below and a silicon dioxide cladding layer above. The PBG strip is a triangular lattice of air pores etched through the cladding and core layers. The specific sample we have looked at has 20 such rows of air pores with a pore diameter of 146nm and lattice pitch of 260nm. NSOM is a technique well suited to the study of these samples since it provides the subwavelength resolution necessary for imaging the intensity distribution of light interacting with the PBG lattice. We have used NSOM to probe the interaction of 632.8 nm light with the PBG lattice and have obtained some preliminary intensity images with subwavelength resolution. The calculated photonic band structure of an infinite triangular lattice having the same lattice parameters as our sample will resolution. The calculated photonic band structure of an infinite triangular lattice having the same lattice parameters as our sample will also be presented.

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Vita: Aditi Sharma completed her undergraduate education at the Birla Institute of Technology and Science (BITS), in Pilani, Rajasthan, India. She received a Bachelor in Electrical Engineering and an integrated Master of Science in Physics under the dual degree scheme at BITS. She has completed her MS (Physics) at the University of Cincinnati and is now working towards her Ph.D. in the Department of Physics under the supervision of Dr. H.E. Jackson. Her area of research is using Near Field Scanning Optical Microscopy to study and characterize samples such as Photonic Crystals and Multimode Interference (MMI) devices.

Acknowledgment: This work was supported in part by ARO (DAAG55-97-1-0378).

CHARACTERIZATION OF FLAME-SYNTHESIZED IRON-DOPED TITANIA AND ITS PERFORMANCE AS A PHOTOCATALYST

Catherine L. Almquist, Zhong-Min Wang, Pratim Biswas
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Photocatalysis is a rapidly developing field in environmental engineering for applications of waste treatment and pollution control. The most common photocatalyst is titania, a safe, non-toxic semiconductor material that can photochemically degrade organic compounds to innocuous compounds under UV exposure at room temperature. Because of the low-temperature oxidation conditions, photochemical processes are potentially economically attractive alternatives to the traditional waste treatment and pollution control methods. A disadvantage of titania is that it requires light energy in the UV region (wavelengths 330 nm to 380 nm). Since this range of wavelengths makes up a small fraction (approximately 5 percent) of solar light, photocatalysts that can be activated in the visible light region would increase the fraction of usable solar light energy and would have obvious advantages for practical environmental engineering applications.

Preliminary studies suggest that flame-synthesized iron-doped titania may be photoactivated in the visible light region. Therefore, catalyst characterizations were conducted with respect to surface and optical properties. The flame-synthesized catalysts have higher surface areas than commercial-grade titania and are composed of nanometer-sized primary particles with low internal porosity. The phase compositions and morphologies are dependent upon the flame characteristics.

Flame-synthesized iron-doped titania was further characterized with respect to photocatalytic activity for degrading organic contaminants in aqueous solutions and was compared to that of commercially available titania. Phenol, one of the most stable and highly water-soluble pollutants in industrial waste waters, was used as the analyte to compare the photocatalytic activities of the photocatalysts. In our study, the effects of catalyst concentration, iron:titania ratio, phenol concentration, and pH on photocatalytic activity was investigated.

Vita: Catherine Almquist received her B.S. degree in chemical engineering in 1989 from The Ohio State University, her M.S. degree in chemical engineering from UC in 1997, and is currently working toward her PhD in environmental engineering at UC. In addition, Catherine worked at Battelle Memorial Laboratories (Columbus, Ohio) as a research scientist for seven years, and at Dow Corning (Carrollton, KY) as a chemical engineer for one year. Her current research interests include photocatalysis and the synthesis and characterization of novel flame-synthesized photocatalysts. Upon graduation, Catherine would like to pursue a career in research in either academia or industry.

ELECTROCHEMICAL CONTROL OF SOLID PHASE MICRO-EXTRACTION USING UNIQUE CONDUCTING POLYMER COATED FIBERS

Ozcan Ceylan, Thompson Gbatu, Karen L. Sutton, J. Faye Rubinson
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Conducting polymers represent a class of new materials that have electronic conductivity. Poly(3-methylthiophene) has been used as an electrode material. Having two states which have widely differing conductivity of the polymer makes the material attractive for many technological applications (see Eq. (1)).

Neutral, Insulating Polymer (Undopped)

====== Cationic, Conductive Polymer (Dopped) (1)

Our application is the use of Solid Phase Microextraction (SPME) method with poly(3-methyl thiophene) coated platinum microfiber electrodes to extract arsenate ions from aqueous solution without derivatization.

Extraction of arsenate ions into the polymer film was done by doping the polymer film with the potential of +1.2 V vs. $Ag/AgCl$. Arsenate ions migrated into the polymer film to maintain electroneutrality. Upon reversal of the potential to -0.6 V, the polymer film was converted to its neutral form, and the arsenate ions were expelled into the either Flow Injection ICP-MS through modified injection system by hooking up the auxiliary, reference, and working electrodes in the injection loop or a smaller volume (200 (L) of de-ionized water for analysis using Flow Injection ICP-MS. The optimization of extraction and desorption profile, and the other experimental parameters such as applied potential, concentration, and polymer film properties will be discussed.

Vita: Ozcan Ceylan was born in Sakarya, Turkey. He received his Master Science degree from University of Cincinnati, and Bachelor of Science degree from Yildiz Technical University, Istanbul, Turkey. He is currently working on his Ph.D in the Department of Chemistry at UC under the supervision of H.B.Mark Jr. His research interests are in the area of electroanalytical chemistry. The projects He is currently working on is primarily the application of conducting organic polymers, especially Poly-3-methylthiophene (P-3MT) as electrodes for design and development of sensors for electroactive biological compounds, neurotransmitters, such as catecholamines. In another application of these conducting organic polymers, He is developing a novel extraction technique, which is similar to Solid Phase Microextraction (SPME) for ionic species from aqueous solutions. He is expecting to graduate by June 2000. Upon graduation, he is going back to his country, Turkey, to work as a faculty for Kocaeli University where he had a scholarship. His office is located in room 431 in Rvschl.

PROPAGATION OF A PULSE IN A DEFORMED POLYMER NETWORK

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Polymer networks are three-dimensional structures in which each chain is connected to all others by a sequence of junction points and other chains. The speed of pulse propagation in polymer networks is strongly influenced by their microscopic structure, and therefore the measurement of pulse velocity can be used to understand the structural features at the molecular level. We have developed an experimental technique to measure the speed of a mechanical disturbance propagating through a polymer network in a finite static state of deformation. Experiments on (poly)dimethylsiloxanes have been carried out to relate the propagation velocity to the extent of deformation, the degree of crosslinking, etc. The theory of elastic wave propagation provides the framework for a discussion relating wave velocity to the stress tensor. Combining these measurements with molecular models for the networks allows the estimation of structural parameters of a network such as the degree of crosslinking and the molecular weight between entanglements.

We have investigated the difference in behavior of low molecular and high molecular weight siloxanes. The low molecular weight siloxanes show an elastic response to the mechanical disturbance as it propagates through the network. On the other hand, we see viscoelastic effects for the high molecular weight networks. These observations allow us to determine both the entanglement spacing and the crosslink density. We discuss our results in light of molecular models which invoke the role of entanglements for high molecular weight siloxanes.

Vita: Moitreyee Sinha is from Bengal on the eastern coast of India. She did her undergraduate studies at the Indian Institute of Technology in Kharagpur. There she completed a five year Integrated Masters Course in Physics which imparts a broad-based engineering training in the first two years and focuses on physics in the next three years. She specialised in solid state physics. Her Masters thesis was on dielectric studies at microwave frequencies using a cavity perturbation technique. During that time, she also worked with the Liquid Crystal Division at the Raman Research Institute, Bangalore and with the Solid State and Structural Chemistry Unit at the Indian Institute of Science in Bangalore. In Fall 1994, she joined the PhD program in the Physics Department at the University of Cincinnati. She received her MS degree in June 1996 and is currently working in the field of polymers under the guidance of Dr. Howard Jackson (Physics department) and Dr. James Mark (Chemistry department). Her research interests include understanding relationships between polymer network properties and structure, molecular theory of rubberlike elasticity, acoustic studies, light scattering techniques and mechanical properties of polymer networks. She is working on two projects involving studying elastomers using a pulse propagation technique and Brillouin light scattering. Her career interests are working in related areas of research in industry or in academia.

Acknowledgment:
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Study of the Micromechanics of Load Transfer from Matrix to Fiber in a Ceramic Matrix composite using Fluorescence Spectroscopy

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The conventional techniques for measuring stress and strain in ceramic matrix composites are based on indirect experiments and theoretical models. In recent years a couple of optical techniques have been explored for non-contact and non-destructive evaluation of the stress and strain in materials, such as Raman spectroscopy and fluorescence spectroscopy [1, 2].

Unfortunately, for many ceramic materials of interest, the intensity of Raman lines is pretty low, and the pressure shifts are small. An alternative technique, that of simulated luminescence, has been developed for the measurement of stresses in chromium doped alumina / sapphire, in part because of the well established use of the pressure shift in the fluorescence of Ruby for calibrating the pressure in diamond anvil high pressure cells. The fluorescence lines from sapphire are narrow, intense, and are highly sensitive to applied stress. Also, this is an optical technique and does not require any physical contact with the specimen, and can, therefore, be used remotely. Furthermore, the laser Raman technique coupled with an optical microscope has the added advantage of being highly selective, and capable of probing areas as small as 1 - 2 microns. In this study, the micromechanics of load transfer from matrix to fibers have been studied in a sapphire fiber reinforced glass matrix composite, using the fluorescence spectroscopy. Residual stresses arising from thermal expansion mismatch have been mapped along the fiber length with resolution in microns. Analytical models predicting the stress variation along the fiber length and across fiber cross section have been developed. Variation of stress on the fibers when the composite is subjected to external load has been studied. Effect of matrix cracks on the fiber stress has also been studied at different stages, namely, as the crack advances towards the fibers, and bypasses the fiber leaving the fibers bridging the crack. These results would provide direct insight into the mechanics of fracture of CMCs.

Vita: Debangshu Banerjee graduated from University of Calcutta, India, with Bachelors in Ceramic Technology, and received his Masters degree in Materials Science from Indian Institute of Technology, Kanpur, India. At University of Cincinnati, he has been working towards his Ph. D. degree in the Department of Materials Science and Engineering. His research interests are structural ceramics, and composites. In future, he plans to work as a scientist in an R&D environment.

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Exciton Dynamics in Self-Assembled CdSe Quantum Dots

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Recently, the intense interest in lower dimensional semiconductor nanostructures such as quantum dots has been motivated by the many subtle and profound changes that occur as the dimensionality of these systems is reduced to nearly zero. We have used optical spectroscopies with high spatial, spectral, and temporal resolution to investigate the structure and dynamics of excitons confined to self-assembled CdSe quantum dots grown in a ZnSe matrix. Time- resolved photoluminescence measurements obtained through a 200 nm diameter aperture strongly suggest the existence of *two types* of excitons with lifetimes of $\sim$ 450 ps and 4 ns. Temperature dependent micro-PL measurements also indicate two distinct emissions in these systems: (a) sharp (200 μeV) spectral features superimposed over (b) an broad ($\sim$ 70 meV) emission. Time decays of macro-PL also reveal two distinct lifetimes in these systems. These spatially- and temporally resolved measurements, taken together, indicate that the sharp emissions have a lifetime of 4 ns and result from excitons confined to the quantum dots, whereas the broad feature has a lifetime of 450 ps and may result from a different state in the dot. The origin of the broad emission is not fully understood and is the subject of continuing research.

Vita: Laura Robinson grew up in Memphis, Tennessee (home of THE KING), where she escaped becoming a huge Elvis fan. She received her BS in Physics in 1995 from Bradley University in Peoria, Illinois. After this "playing" in Peoria, she came to Cincinnati and obtained a MS in Physics from UC in 1997. She is currently a GAANN fellow and is working on her Ph.D in Physics under Professor Leigh Smith. Her research interests include magnetically doped semiconductor nanostructures, as well as quantum dot systems. Upon graduation in August 2000, she would like to work in R&D related to semiconductors or optics/optical characterization, preferably in Northern California. She can be contacted via email at laurier@physics.uc.edu.

Acknowledgment: This work was supported by the National Science Foundation (grants DMR-9705443, DMR-9705064, ECS-9412772), the Army Research Office (grant DAAG55-97-1-0378, and the Department of Education (GAANN grant P200A50053-96).

Polymer-based Electrode-less E-field Sensor

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Optical waveguides, also known as dielectric waveguides are the structures that are used to confine and guide the light in the guided-wave devices and circuits of integrated optics. A well known waveguide is an optical fiber which has a circular cross section. In contrast guides of interest to integrated optics are usually planar structures such as planar films or strips.

The guiding of light beams along dielectric layers, first realized experimentally in the early sixties has stimulated the growth of a new class of passive and active components using light guided by films deposited on wafer-like substrates. These optical components provide the advantage of greater bandwidth and immunity from electromagnetic radiation hence making them become sufficiently effective to herald the beginning of a sophisticated technology called integrated optics. Current integrated optics technology is based upon inorganic crystalline LiNbO3. The concept of integrating an electro-optic polymer into a reverse poled Mach-Zehnder modulator to be used as an electrode-less E-field sensor is discussed in this work. The two possible core layers (PMMA and PVK), and the upper cladding layer (HMDS) will be the guide layers. Initial loss measurements carried out in the device is 8db/cm. The final device (Mach-Zehnder modulator) will be constructed using PVK/DR-1 as the core layer as this system is more thermally, mechanically and optically stable compared to the system currently under tests.

Vita: Ram Sivaraman was born in Kerala, India. He received his Masters in Physics from The American College in Madurai, India and his Bachelors in Physics from the Bangalore University, India. He is currently working on his PhD. In the Department of Materials Science and Engineering under the guidance of Dr. S. J. Clarson. His research interests include Electro-optic and Optical Memory Devices.

Computing With Quantum Cellular Automata

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From a physicist's viewpoint, a cellular automaton is defined as a discrete dynamical system. Space, time, and the states of the system are discrete. Each point in a regular spatial lattice, called a cell, can have any one of a finite number of states. The states of the cells in the lattice are updated according to a local rule. That is, the state of a cell at a given time depends only on its own state one time step previously and the states of its nearby neighbors at the previous time step. All cells on the lattice are updated synchronously. Thus the state of the entire lattice advances in discrete time steps [1].

Quantum Computing, described by Quantum Cellular Automata (QCA), is the attempt to process many different computations in parallel, by operating on a collection of superposed states, and then decoding the results of those parallel computations. The great challenge is to find a sufficiently complex system whose evolution is nevertheless both coherent (i.e. unitary) and controllable. It is not sufficient that only some aspects of a system be quantum mechanical, as in solid-state 'quantum dots' [2]. Unlike QCA, quantum dot computing is possible with current technology.

The purpose of a Quantum-Dot Cellular Automaton is to enable scaling down to the molecular size. As transistors become smaller, the quantization of charge in the channel and in the doping layer become significant. When reduced to nanometer scales, current switches may not be the best way to code information. Thus, the effect of miniaturization of MOS circuits will lead to computing on the molecular level [3]. Quantum-Dot computing is one approach to this.

This research will explore interactions between the physical properties of computing systems such as QCA and computational models for algorithm development. In particular, it will explore the relationships between QCA and such computing systems as neural networks and systems based on genetic algorithms. As experimentation with true QCA computing eventually leads to working architectures, the computational models to be developed in this work will eventually be realizable as actual computing machines with computing power much greater than the processors of today.

Vita: Jim Hauser was born in Cincinnati, Ohio. He received a BA in Mathematics in 1983 and a MS in Computer Science in 1996 from the University of Cincinnati. He is currently pursuing a Ph.D. in the Dept. of Electrical & Computer in 1983 and a MS in Computer Science in 1996 from the University of Cincinnati. He is currently pursuing a Ph.D. in the Dept. of Electrical & Computer Engineering and Computer Science at the University of Cincinnati and is a Principal Engineer employed by Harris Corporation in the Broadcast Systems Division. Research interests range from Communications and Digital Signal Processing to VLSI design.

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SIMULATION AND DESIGN AUTOMATION FOR MEMS SYSTEMS

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The purpose of this research is to enhance design capabilities for the rapidly growing field of MEMS (Micro-Electrical Mechanical Systems). Design capabilities have traditionally lagged behind current technology's capabilities. Very good design tools are now emerging for the VLSI designer. However, for the MEMS designer only crude and rudimentary tools exist. Better design tools are necessary for MEMS technology to become as predominant as VLSI technology. The objective of this project is to show how design automation of MEMS systems is enabled using a set of high level behavioral models of basic MEMS devices. This project seeks to define a higher level of abstraction for MEMS design than the levels which are currently available to the designer. The end result will be increased productivity for the designer as well as improved use of the capabilities of MEMS technologies.

This work discusses the results of our investigation into the areas mentioned above. These results have recently been presented at conferences [1,2]. Much of the work concentrates on using mathematical solvers (MATHEMATICA) to create behavioral models of devices. These models aid in the automation of the design process by using these models to generate a physical mask description of a device by describing the device at a behavioral level.

Vita: Dennis Gibson was born in Cincinnati, Ohio. He received his BSEE at the University of KY. He worked as a design engineer for Hitachi for several years before returning to school. He is currently pursuing a Ph.D. in the Dept. of Electrical and Computer Engineering and Computer Science at the University of Cincinnati. His research interests include simulation of analog and mixed-signal devices and MEMS design automation. Upon graduation, he plans to pursue a career as a researcher and instructor at a university. More information on Dennis Gibson and his research can be found at the following website address: http://www.ececs.uc.edu/ dgibson.

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Acknowledgement: This work was supported by the USAF (F33615-96-2-1945) , The University of Cincinnati Summer Fellowship, and The University of Cincinnati Research Challenge Grant.

Enhancement of Superconducting Behavior and Chemical Stability in Metal Doped Cuprates Synthesized by a novel Process

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Bulk $Y_1Ba_2(Cu_{1-x}Fe_x)_3O_{7-d}$ cuprate superconductors synthesized the usual way by reacting oxide precursors at ambient pressure of oxygen (APO) have been extensively studied [1]. Superconducting transition temperature T_c(x) and superconducting volume fraction $V_{sc}(x)$ decline with x and vanish as x = x_c = 0.13. Such samples when given an additional sinter [2] at elevated temperatures (T = 915 C) and pressures (P = 220 atm) of pure O_2, not only show a higher T_c(x) and $V_{sc}(x)$ but permit extending superconductivity to much higher alloying concentrations (x = 1/3) of Fe, thus altering qualitatively the existing Superconducting-Antiferromagnetic phase diagram. Our results on the high pressure oxidized (HPO) samples also reveal that the local structure around Fe differs qualitatively from the one in the APO samples. The chemical stability and enhanced superconducting behavior of the HPO samples derive in part from the changes in local structure. Such samples in a thin film configuration are likely to be of interest in superconducting microwave device applications.

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POSTER SESSION II: 2.00p.m - 3.00p.m

DESIGN, FABRICATION AND TESTING OF A MAGNETICALLY COUPLED ACCELEROMETER

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A magnetically coupled accelerometer has been designed and successfully fabricated using MEMS techniques. The accelerometer works on the principle of electromagnetic induction between two coils. A seismic mass with two supporting beams was fabricated on a silicon wafer by bulk micromachining. A micro-coil was fabricated on the seismic mass before releasing it from the top. A spacer was fabricated and was put between a reference coil fabricated on a silicon wafer and the seismic mass. The force exerted by the acceleration deflects the movable seismic mass. The movement of the mass changes the distance between the coils and hence changes the induced emf in the secondary coils. Static and dynamic responses were studied. The static data were found to be very close to a PSpice model of the coils. For dynamic response, a 2-g test was done and a sensitivity of 0.01 mV/G was found. The coils ware made of gold. A permalloy core was fabricated at the center and around the coil for higher field confinement.

Vita: Saroj Aryal was born in a small village in the southern part of Nepal. He received his MSc degree in Physics from Tribhuvan University, Kathmandu, Nepal. Currently he is working towards his MS degree in the Department of Electrical Engineering and Computer Engineering and Computer Science at UC. He is working under Dr. J. H. Nevin. He is working in the MEMS area. His research interest includes Design, modeling of sensors and actuators, semiconductor and MEMS process development and integration. He is expected to graduate by June of 1999. After completion, he would like work for a company and involve in MEMS design and process development. URL:http://www.mems.uc.edu/ saryal.

SOLID STATE BORON DIFFUSION IN POLYCRYSTALLINE DIAMOND

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This paper presents the results of an experimental study of boron diffusion into polycrystalline diamond in the formation of high quality p-type layers. Dopant was diffused from a solid boron film pre-deposited on the surface of the diamond by thermal evaporation. The choice of boron diffusion source differed from the traditional BN [1] in order to avoid contamination with nitrogen and other undesirable impurities, which form deep levels within the diamond bandgap. Such deep impurities can lead to compensation effects on the boron doping and thereby reduce the quality of the doped diamond layer [2].

A physical system for the rapid thermal processing of diamond was constructed within the facilities of the GaAs ICs and Devices Laboratory at the University of Cincinnati. This system was able to furnish temperatures up to 1700 C and maintain them for a duration up to 15 minutes. The process was conducted under vacuum of about 10-6 Torr. Molybdenum v-groove filaments were used as the heating elements.

First experiments on boron diffusion were performed on several samples grown by Norton Corporation and the Air Force Research Laboratory. Characterization of the samples revealed that the concentration of activated boron atoms was near $10^{17} - 10^{18} cm^{-3}$. The penetration depth of the diffusion was about 0.6 mm after 10 minutes of diffusion at 1600 C. The measured sheet resistance of the samples was about 350 W/square.

Finally, some applications of the boron-doped diamond for high temperature electronic and optoelectronic devices is also discussed.

Vita: Oleh Krutko was born in Krasnoyarsk (of the Former Soviet Union). He received an Engineer Degree (in Electrical Engineering) in 1994 from Sumy State University (Ukraine) and the Candidate of Science Degree (in Physical Electronics) in 1996 from the same school. Currently he is working in the GaAs ICs and Devices Laboratory at the University of Cincinnati under the supervision of Dr. P.B. Kosel. His research interests are wide bandgap semiconductors, high temperature electron devices, optoelectronics, and plasma physics. He expects to graduate with Ph.D. in Electrical Engineering by the end of year 2000.

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TUNNELING PROPERTIES OF HOLES ACROSS HETEROINTERFACES

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We discuss the results of our investigations of hole tunneling through various heterostructures. Our formalism is based on the 6X6 Luttinger-Khon formalism and its recent generalization to heterostructures by Burt [1] and Foreman [2]. We analyze the tunneling properties of holes across abrupt $InP/In_{0.53}Ga_{0.47}As$, $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$, and $Al_{0.3}Ga_{0.7}As/GaAs$ and study the importance of the SO-band on the tunneling coefficients of both heavy- and light-holes. We also report the presence of antiresonances in the transmission coefficients of holes tunneling above quantum wells and discuss their physical origin.

Finally, we discuss how our results can be used to enhance the hole injection efficiency of the emitter-base junction of Pnp Heterojunctio Bipolar Transistors and to calculate the ideality factor of the emitter current versus the applied emitter-base bias.

Some of our results have recently appeared in the literature [3, 4].

Vita: Shashank Ekbote was born in Maharashtra India in Bombay. He received his Master of Technology degree from Indian Institute of Technology, Bombay, India and Bachelor of engineering degree from Govt. Engg. College, Aurangabad, Maharashtra, India. He is currently working on his Ph.D in the Department of Electrical Engineering and Computer Engineering and Computer Science at UC under the supervision of M. Cahay. His research interests include Semiconductor device modeling and simulation, deep sub-micron silicon MOS and Bipolar technology development, numerical modeling of Pnp HBTs, and charge transport in oxide layer of MOS devices. He is expecting to graduate by the end of December 1999. Upon graduation, he would like to work for a semiconductor company with major thrust on research and development of futuristic devices. More information on S. Ekbote research activities and others can be found at the following website address: http://www.ececs.uc.edu/~sekbote. His office is located in Room 679 in ERC.

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LOCALIZATION OF ACOUSTIC WAVES IN RANDOM ELASTIC MEDIA

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The phenomenon of localization of waves propagating through random arrays of inhomogeneities has been the subject of great interest since the introduction of the concept of localization by Anderson in 1958. A great deal of work as been focused on the localization of electron waves in submicron devices leading to a new branch of Physics called mesoscopic physics. Simultaneously, the localization of electromagnetic waves in random arrays of dieletric media has been a subject of great interest since the mid-80's.

In this work, we study the localization of waves propagating in elastic media. More precisely, we investigate the propagation of surface waves (Such as Rayleigh and Love waves) in stratified media in the presence of inhomegeneities. For simplicity, the problem will be treated with two-dimensional scatterers but our analysis, which is based on a robust scattering-matrix approach, could readily be extended to 3D scatterers at the expense of more intensive computer simulations.

Vita: In June of 1998, Brian graduated with a B.S. in Electrical Engineering from the University of Cincinnati. During his senior year, he worked on a senior project under the guidance of Professor Cahay. The topic of this research was the analysis of the coupling between heavy and light holes and the effects of band-mixing on hole tunneling through heterostructures grown by Molecular Beam Epitaxy. He is currently working on his M.S. in the Department of Electrical Engineering and Computer Engineering and Computer Science at UC under the supervision of M. Cahay. He is expecting to graduate by the end of December 1999. Upon graduation, he intends to join a semiconductor company with a strong $R\&D$ division. His goal is to be part of a team that will design, fabricate and simulate advanced submicron devices for both digital and millimeter wave applications.

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DESIGN AND FABRICATION OF A InP/CdS/LaS COLD CATHODE

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We discuss our research efforts on the design and fabrication of a novel cold cathode $InP/CdS/LaS$ multi-layered device structure. We analyze the importance of space-charge effects in the cathode to anode gap region of a recently proposed Metal/CdS /LaS cold cathode using an Ensemble Monte-Carlo (EMC) description of electron transport assuming ballistic injection across the CdS and LaS layers while taking into account the shot noise in the injected current. For some of the biasing conditions considered here, space-charge effects are quite drastic and lead to dynamical effects which are responsible for the onset of current self-quenching similar to the Child-Langmuir regime of operation of thermionic cathodes. The limiting anode current density is found to be much larger than the Child-Langmuir limit. In the presence of strong space-charge effects, large oscillations in the minimum of the electrostatic potential in front of the cathode lead to oscillations in the measured anode current within the tens of GHz frequency range.

Simultaneously, we describe the growth of bulk LaS samples and their characterization using X-Ray Diffraction and micro-Raman Spectroscopy. The Raman scattering observed in LaS with a rocksalt structure is defect induced. As the preparation of our samples has improved, the Raman scattering strength from our samples has decreased remarkably as expected. Nevertherless, clear evidence for broad vibrational modes at about 100 cm^{-1}, 200 cm^{-1} and 250 cm^{-1} is observed and the modes ascribed to the TA, LA and LO modes of the rocksalt phase. A homogeneous solid solution of $La_0.9Eu_0.1S$ composition, examined in ^{151}Eu Mossbauer spectroscopy reveals an isomershift of + 0.22(3) mm/s relative to EuS, reflecting the increased electron density at Eu due to a reduced cell length compared to pure EuS.

Yamini Modukuru received her Master of Science in Physics and Master of Technology in Microelectronics from the Indian Institute of Technology, Bombay, India. She is presently pursuing Ph.D. in Electrical Engineering at the University of Cincinnati under the guidance of Dr. M. Cahay. Her research interests include the modelling, simulation and fabrication of semiconductor devices.

Aashish Malhotra received his Bachelor of Engineering in Electronics and Electrical Engineering from Punjab University, Chandigarh, India and is now pursuing his Master of Science in Electrical Engineering at the University of Cincinnati, Cincinnati, Ohio under the supervision of Dr. M. Cahay. His interests range from industry compatible novel semiconductor devices to ASIC design. More information can be found at the following web site: **http://www.ececs.uc.edu/~amalhotr**.

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Diamond Cold Cathodes

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Emission of electrons from solids into vacuum plays a crucial role in many commercial electronic devices such as the cathode ray tube (CRT) which is used in computer monitors and television sets and in scientific instruments such as high energy electron accelerators and free electron lasers. Electron beam emitters are also important in other devices such as x-ray tubes for medicine and electron microscopes for engineering and biological research. A major impact of negative affinity electron emitters is anticipated in the new future in the production of flat screen high luminosity displays for computers and television.

The technology of electron emission devices has received significant impetus in recent years since the advent of the 'negative-affinity' semiconductors which release the electrons from their conduction band into a good vacuum at low temperatures without the need for additional doping or the application of an external electric field. Since the electrons emitted into vacuum are thermalized at low temperature, their energy spread is small unlike the case of 'hot-electron' emitters, such as heated tungsten wire in conventional thermionic emitters (1000 K). The current density, which can be brought to a focus in an electron beam, is inversely proportional to the energy spread of the electrons at their source, and directly proportional to the source current density.

The large energy bandgap of diamond has the necessary properties to be an ideal material for cold-cathode applications. With its excellent thermal conductivity, low dielectric constant, negative electron affinity, and high electric breakdown it is also well suited for applications in harsh environments and as free-electron lasers and plasma reactors.

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Pnp InP-based Heterojunction Bipolar Transistors: Simulation, Design and Fabrication

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As the epitaxy and fabrication technology for III-V devices continue to evolve, the monolithic integration of multiple types of devices on the same substrate apppears increasingly feasible and attractive for MMIC (millimeter wave integrated circuit) applications. InP-based Pnp heterojunction bipolar transistors (HBTs) are of interest for integration with Npn HBTs in complementary HBT-based circuits. Recently, we reported some of the first numerical simulations of Pnp HBTs in the InP/InGaAs and InAlAs/InGaAs material systems, with a view to reducing device prototyping costs by providing insight into factors limiting device performance [1]. We also have developed an analytical model based on a thermionic-emission-diffusion (TED) model of graded base Pnp HBTs, while incorporating the effects of hole quasi-Fermi level variation in the emitter- base space charge region and the quasi-neutral base and splitting at the emitter-base hetero-interface [2,3]. Currently, we are developing a charge-based Gummel-Poon model based on the TED model, valid over all regions of device operation, incorporating high current effects, which can be used as a large signal model in circuit simulators like SPICE. The fabrication of these high performance Pnp devices is also under way and we present here the preliminary DC characterization results on prototype devices.

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Modeling of High Current Effects:
in Pnp Heterojunction Bipolar Transistors

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This paper describes recent results obtained from an analytical model for simulating the operation of InP-based Pnp Heterojunction Bipolar Transistors (HBTs) in the high frequency range. Pnp HBTs are of interest for use in combination with Npn HBTs in circuits such as push-pull amplifiers where they serve as pull-up transistors or as active loads. The motivation for this work is to more accurately model these devices during high frequency operation to aid in optimizing device performance therefore, allowing us to fabricate higher speed electronic devices. The model employed here is an extension of a previously developed model [1,2] which incorporated a thermionic-emission description of hole injection into the base from the emitter. In particular, in this work the model has been extended to incorporate the effects of high current levels on device performance. This includes the effects of the collector current level on: 1. the base-collector space charge region width and transit time, 2. the base-collector junction capacitance and 3. the base pushout phenomenon. These, in turn, have an effect on the device's current gain and high frequency performance (cutoff frequency) so that the falloff in these performance parameters with collector current level can be predicted. The results obtained from the analytical model will be compared to our experimental results based on an in house fabricated prototype device as well as published experimental results based on fabricated devices by other groups.

Vita: Robert Peddenpohl II was born in Cincinnati, Ohio on June 3, 1976. He received the Bachelor of Science degree in physics from Centre College, Danville, Kentucky, in 1998. He is presently working towards the Masters of Science degree in electrical engineering at the University of Cincinnati. His research interests are in semiconductor device physics, modeling, fabrication and characterization. He is a student member of the IEEE Electron Device Society.

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Simulation and Design of High Frequency Pnp InP-based Heterojunction Bipolar Transistors

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InP-based Pnp Heterojunction Bipolar Transistors (HBTs) are of interest for use in combination with Npn HBTs in circuits such as push-pull amplifiers where they serve as pull-up transistors or as active loads. Because the Npn HBT is superio r in its high frequency capabilities, the Pnp HBT is usually the device whose fr equency performance limits that of the circuit so that there is a strong need to maximize the Pnp's speed. Recently, there have been reports of a novel device f abrication technology which can be used to dramatically reduce the HBT's collect or capacitance and thereby improve its high frequency capability [1]. In this wo rk we employ a commercial device simulator (ATLAS by Silvaco) to explore the ant icipated benefits of adapting this novel fabrication technology to the Pnp HBT. That is, the high frequency limits to the device's current gain will be investig ated as a function of the reduction in the HBT's collector junction area that is expected when the new fabrication technology is employed. Since the collector j unction capacitance scales with the base-collector junction cross-sectional area and contributes to an RC time delay, a reduction in the device's emitter-to-col lector time delay is expected which will increase the device's cutoff frequency. This simulation study will report the predicted effects of the new device techn ology on the device's high frequency performance to evaluate its suitability for enhancing device performance. Also investigated and reported will be any negati ve effects, such as an increase in current crowding or parasitic series resistan ce produced by the new fabrication technology.

Vitae:

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A NEW PULSED-MODE MICROMACHINED FLOW SENSOR FOR AN INTEGRATED MICROFLUIDIC SYSTEM

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A new pulsed-mode micromachined flow sensor for an integrated microfluidic system has been designed, fabricated and characterized in this work. This micro flow sensor has several unique physical and operational characteristics, as a part of the complex of components constituting a generic fully integrated microfluidic system [1] for autonomous bio-chemical analysis. Companion elements include microvalves, micropumps, microreservoirs, microchannels, etc., whose liquid (or gaseous) fluid dynamics must be characterized by these micromachined sensors. In contrast to other thermally-based flow sensors [2], the sensing elements here are located in the microchannel walls in order to prevent clogging by virtue of dead volume or other interference which may cause nucleation of particle deposition. Nevertheless, the single crystalline silicon elements are thermally isolated from the bulk by unique low stress, low temperature-deposited ($< 150\ ^oC$) PECVD SiO_2 which is considerably superior to other electrical and thermal isolation schemes. In essence, the sensor measures liquid flow through the integrated channel sidewall. In order to minimize possible thermally induced effects in the fluid, the elements are pulsed at a fixed current level (say 2mA) for 50 ms intervals at a very low duty cycle.

High resistivity (50 Ohm-cm) silicon results in a highly sensitive element, which easily achieves full operation during the on-cycle, because of the fast time response resulting from miniature size and thermal isolation The electrodes are located outside the channel and thus do not need further electrical passivation, in contrast to earlier in-flow immersion. The thermal field can be made to variously penetrate the boundary layer appropriately. A numerical simulation of the liquid flow field [3] and thermal distribution has been realized using ANSYS 53 and the FLOTRAM CFD option In summary, this micro flow sensor shows very promising results for integrated microfluidic measurements, in a convenient packaging scheme for a multi-level bonded package in an integrated biochemical "lab-on-a-chip," with fast and highly sensitive signals for regulation of microflow in the range of 0.01-10 ml/min.

Vita: Nihat Okulan received the diploma degree in Electrical and Computer Engineering in 1995 from the Hochschule Bremen, Germany. After graduation he joined the MEMS group at the University of Cincinnati, where he is currently pursuing his Ph.D degree. His doctoral research involves analysis, modeling, design, fabrication and characterization of microflow sensors. He has also dedicated a major part of his research to microfluidic systems with particular emphasis on packaging and flip-chip bonding. Further, he is working on gold diffusion and characterization in silicon to increase temperature coefficients to improve device performances of microflow sensors. More information on N. Okulan can be found at the following website address: http://www.mems.uc.edu/ nokulan.

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Si Bulk Micromachined Electrostatic Voltmeter

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With the Micro Electro Mechanical Systems (MEMS) based device schemes on the rise the MEMS based metering schemes also finds its due place in the micro world. The inherently planar nature and yet unresolved friction issues which have resulted in extremely hard rotational movements, limited the performance of MEMS based schemes, compared to their macro counterparts. In this work the micro equivalent of quadrant type electro meter is discussed. The latter was heavily used for high voltage measurements in the past. The advantages of electrostatic instruments such as negligible power consumption, the usage in both a.c. and d.c. circuits and no errors due to frequency, waveform and stray magnetic fields can correctly be utilized in the micro equivalents too. In the proposed meter the possible micromachined configurations are presented along with their relative merits and demerits. The applications of such micromachined voltmeters include anywhere mass, space etc. of present digital and analog macro equivalents play a vital role.

Vita: Sisira K Gamage obtained his bachelor degree in Electrical Engineering from University of Moratuwa, Sri Lanka in 1993 and his masters degree in Physics from Georgia State University, Atlanta, GA in 1997. During his master's degree program he was involved in infrared detector research, particularly in long wave length infrared detection for space applications. His current research activities include MEMS based schemes for metering under the supervision of Prof. H. T. Henderson.

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A NEW MAGNETICALLY ACTUATED MICROVALVE FOR GAS AND LIQUID CONTROL APPLICATIONS

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In this paper, we describe the design, fabrication, and testing of a prototype microvalve which makes use of a novel magnetic microactuator. The target application of this valve is a microfluidic total analysis system (uTAS) which will require precise valving at moderate flow rates.

The completed device consists of three layers, with the bottom two layers making up the normally closed valve. For these valve layers, inlets, outlets, and valve seats made from polyimide are patterned on a glass wafer that is electrostatically bonded to a silicon wafer. This silicon wafer contains a 10 um-thick silicon membrane coated with 7 um of Ni/Fe permalloy. The top layer of the device contains an innovative microactuator, which consists of a new solenoid type inductor and etched through-holes filled with Ni/Fe permalloy for guiding the flux to the valve. The through-holes allow precise control of the air gap in the driving magnetic circuit. By simply adjusting the distance of the membrane from the through holes by bulk micromachining, any desired value of air gap can be achieved. This is important because large air gaps lead to increased power dissipation in the magnetic actuator. Also, because the flux generator is fabricated on the side opposite where actuation occurs, the actuator can be readily connected to driving circuitry without interfering with the actuating device. This is especially important in microfluidic applications which have fluids flowing through valves and channels. The actuator and valve components are separately fabricated and then mounted onto a glass motherboard which contains both fluid flow channels and patterned gold traces for making electrical connections. In addition to providing an easy means for testing, the motherboard will allow for the later attachment of other microfluidic components to create a complete microfluidic total analysis system (uTAS) on a single substrate.

Experiments were performed on the devices to determine a relationship between the flow rate of fluid (both nitrogen and DI water) through the valve and actuator current for a given value of inlet pressure. Preliminary results show that the valves are capable of controlling gas and liquid flow in the range of submicroliters to hundreds of uL/min for applied actuator currents between 0 and 600mA. Because the resistance of the coils is only about 1-ohm, this corresponds to a relatively low power dissipation of between 0 and 350 mW.

We believe that these promising preliminary results, along with the many desirable features of our devices, will allow them to be used both in our intended application and in a variety of other microfluidic applications as well. Although many other types of valves have been reported using shape memory alloy, electrostatic, piezoelectric, or other actuation schemes, we believe that our device with its fully integrated magnetic actuator represents a significant breakthrough in the area of microfluidic components. At the poster session, we plan to present detailed fabrication methods as well as a graphical display of results and appropriate analysis.

Vita: Dan Sadler graduated from the University of Cincinnati Suma Cum Laude in 1996 with a B.S. in electrical engineering. After graduation, he joined the University of Cincinnati's Center for Microelectronic Sensors and MEMS, where he is currently pursuing his Ph.D. in Electrical Engineering. Dan holds the title of Distinguished Graduate Assistant and is supported by a Dean Fellowship. His research interests include fabrication of devices using the UV-LIGA method, magnetic sensors and actuators, and microfluidics.

A NEW MICROMACHINED ELECTROMAGNET WITH ELECTROPLATED Ni/Fe PERMALLOY THROUGH-HOLES

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In this work, we describe a new electromagnet consisting of a micromachined horseshoe type inductor and etched through holes filled with Ni/Fe (89%/11%) permalloy. The through-holes are designed to allow magnetic flux to be easily guided to the device which is being actuated. This device geometry has many important advantages which will make it useful as an actuator in a variety of applications. First, the through-holes allow precise control of the air gap in the driving magnetic circuit. By simply adjusting the distance of the actuating device from the through-holes, any desired value of air gap can be achieved. In addition, because the flux generator is fabricated on the side opposite of where actuation occurs, the electromagnet can be readily connected to driving circuitry without interfering with the actuating device. Finally, because the electromagnet can be fabricated independently, it is flexible in its range of applications. Many magnetic MEMS applications require a good electromagnet, and some areas which this device is expected to impact include microfluidics, micromotors, and resonating devices.

Fabrication of the device consists of two major steps: etching and electroplating of through-holes, and fabrication of the inductor or flux generator. Abbreviated fabrication steps will be described here, while the complete methods will be displayed at the poster session. Basically, through-hole fabrication is achieved by anisotropically etching the backside of the silicon substrate in KOH to reveal a copper seed layer. Then, the holes are plated in a Ni/Fe electrolytic bath. The inductor is then fabricated on the front side using successive metal deposition, lithography, and electroplating steps. Two separate layers of AZ4000 series photoresist are hard-cured to form permanent dielectric insulation layers between the magnetic core and the top and bottom conductor lines.

Although design and fabrication of this generic microactuator are achieved without regard to application, a test structure was required in order to demonstrate and characterize our new magnetic microactuator. For this reason, a simple cantilever beam prototype structure was developed. By measuring the deflection of the cantilever beam as a function of applied actuator current, the performance of the new device was easily evaluated. At the poster session, we will present a graph of beam deflection vs. actuator current and show that these results correspond reasonably well to those obtained from a generated theoretical model.

In conclusion, we believe this novel electromagnet, using its innovative through-hole processing, is an important breakthrough in the area of magnetic MEMS components. It has great potential to be used as an actuator, and its many desirable features will make it an important component in a wide variety of magnetic MEMS device applications.

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Hydraulic / Pneumatic Fouling and Clogging Studies and MEMS System Integration On the "Lab - On - A - Chip"

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The techniques used for preventing hydraulic fouling and clogging in the micro channels are discussed. Results obtained by operating the valves in a digital mode in order to prevent clogging and to control the direction of fluid flow through the channels is presented. Some of the packaging issues and the layout of the micro devices on the "mother board" are discussed. Some other applications such as implantable bio-medical analysis chips and environmental condition analysis chips are discussed.

Vita: Saman Dharmatilleke received his MS degree in physics from the Wichita State University, Wichita Kansas, U.S.A. and Bachelor of Science degree (physics honors) from University of Colombo, Sri Lanka. He is currently working on his Ph.D in the Department of Electrical Engineering and Computer Engineering and Computer Science at UC under the supervision of Prof. H. Thurman Henderson on the immuno sensor project Funded by DARPA. Have been assigned the task of integrating the whole system on a "mother-board" which includes both design and fabrication of the "mother-board". Before coming to UC, he has done research on many fields of engineering, starting from development of an low cost electronic speech recognition system to development of a meso scale steam engine. Also, he has 25 Years of experience in motor vehicle trouble shooting and maintenance (rebuilding of Gasoline and Diesel engines, rebuilding of automatic and manual transmissions and electrical and electronic equipment, etc.).

Optical Characteristics of GaAs MSM Photodiodes Flip-Chip Bonded Upon Micromirrors Using Micromachined Conductive Polymer Bumps

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Using micromachined conductive polymer bumps, GaAs metal-semiconductor-metal photodiodes flip-chip bonded upon silicon micromirrors have been fabricated and characterized. 111-oriented silicon micromirrors and V-grooves were micromachined on bottom silicon wafer. Top wafer has through-holes, contact metal pads, and side alignment pedestals with electroplated copper to align GaAs MSMs. By inserting optical fibers through the V-grooves terminated by silicon micromirrors, optoelectronic multichip module (OE-MCM) structure enables to redirect optical signals passing through the top wafer into GaAs MSMs.

To detect optical signals reflected from the silicon micromirrors, GaAs MSMs, which show a low dark current of about 10 nA and a high responsivity of 0.33 A/W, have been fabricated and flip-chip mounted on the top of OE-MCM substrate. Conductive polymer bumps have been formed on contact pads of GaAs-MSMs using thick photoresist bump-holes as molding patterns. After the OE-MCM substrate is pre-heated to approximately 20 C above conductive polymer melting temperature, diced GaAs MSMs with micromachined conductive polymer bumps are aligned to the side alignment pedestals and flip-chip bonded onto it. The electrical properties of the micromachined conductive polymer bumps have been evaluated with a four-terminal method. This conductive polymer flip-chip bonding technique allows a very low contact resistance (10-20 milliohms), a lower bonding temperature (170 C), and simple processing steps. Optical properties of GaAs MSMs flip-chip bonded upon micromirrors are under investigation using passive pedestal aligning and conductive polymer flip-chip bonding. By using bulk-micromachining, conductive polymer flip-chip bonding, and passive pedestal aligning techniques, optical input/output couplers realized in this work shows high potential to use as a fundamental building block in OE-MCMs.

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Flip-Chip Packaging with Micromachined Conductive Polymer Bumps

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Using micromachined conductive polymer bumps, a flip-chip bonding technique that achieves both a low bonding temperature and a high bumping alignment resolution has been developed and characterized in this work. Recently, the use of flip-chip interconnection technologies has grown in many packaging schemes. This is due to the advantages of improved reliability, lower cost, and higher I/O density in less packaging space. Conventional solder bonding technique is being challenged by conductive polymer flip-chip bonding technique since conductive polymer requires a low bonding temperature as well as fairly simple processing steps. However, currently available screen printing techniques for the conductive polymer bumps have quite a crude bumping alignment resolution (+/- 10 microns).

In this work, commercially available silver-filled thermoplastic conductive polymer bumps have been micromachined by employing thick photoresist bump-holes as molding patterns. UV-based thick photoresist patterning allows a very high bumping alignment resolution (+/- 1 micron) for bumps. The molds have been filled with the conductive polymers and then removed, leaving molded bumps. Selectivity of the conductive polymers over the thick photoresists can be optimized by selecting an appropriate curing temperature. To test thermoplastic conductive polymer flip-chip bonding arrangement, a flip-chip wafer with bumps and a substrate wafer with a metal layer were used. After the substrate was pre-heated to approximately 20 oC above the thermoplastic melting temperature, the flip-chip wafer was flipped, aligned and contacted onto it. The thermoplastic bumps then melted onto the metal layer of the substrate. The electrical and mechanical bonds are completed as the substrate cools below the melting temperature of the thermoplastic materials. Separating the testing assembly, the bumps were left on the side of the substrate wafer as well as the flip-chip wafer. A conductive polymer bump sandwiched between the flip-chip and substrate has a certain amount of so-called contact resistance. This contact resistance is obviously an important parameter that impacts the behavior of devices, if flip-chip bonding is involved in their packaging. To measure the contact resistance of the bumps, a four-terminal structure was designed, fabricated, and flip-chip bonded with the same way mentioned above. In a four-terminal structure, a bump is sandwiched between two metal pad lines crossing each other. A constant direct current is made to flow through two of the contacts from each end of the metal pad lines, and the voltage across the other two contacts is measured with a high-input-impedance voltmeter. The contact resistances measured for 25 um-high bumps with 300 um x 300 um area and 400 um x 400 um area were 15.9 mOhms and 7.6 mOhms respectively. In conclusion, the conductive polymer flip-chip bonding technique developed in this work shows high potential to replace conventional flip-chip bonding techniques for optical or electronic system applications, flip-chip interconnections, and optoelectronic multichip modules (OE-MCMs), since the technique allows a lower bonding temperature (170 C), a very low contact resistance, a high bumping alignment resolution, and simple processing steps.

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An optical MEMS-based fluorescence detection scheme for microchip capillary electrophoresis

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Capillary Electrophoresis (CE) microchips using integrated optics scheme for eventual application to combinatorial chemistry and drug discovery have been designed, fabricated, and tested. The system is composed of microchannels for separation and photodiode for fluorescent light detection combined with a laser diode which induces fluorescent dye. Using standard micromachining techniques, the microchannels were fabricated on borosilicate glass wafers using HF-based etching techniques and direct glass to glass bonding with a cover glass wafers. A metal-semiconductor-metal (MSM) GaAs photodiode was fabricated and mounted over the separation capillary using a conductive polymer flip-chip bonding approach. Multi-mode optical fibers were incorporated on-chip to couple laser light into the detection area. An infrared (IR) laser diode was coupled to the optical fiber. To characterize the fabricated microchannels, both fluidic and electrical tests were performed. Microchannels were leak checked using colored dyes. Resistance measurements of the channels when filled with dilute NaCl solutions confirmed physical continuity for fluid flow. A series of electrical characterization tests yielded I-V characteristics, heat dissipation ability, and current stability and reproducibility at a given potential. Proper operation of the mounted photodetector after interconnection was verified by directly impinging light from a He-Ne laser. An infrared (IR) laser diode stimulated fluorescence, and dark current and light scattering measurements were carried out. Several visible laser source-flourescent dye combinations were employed to generate a fluorescence signal (few nA) detected by the photodiode.

Vita: Arum Han received his B.S. degree in Electrical Engineering from Seoul National University, South Korea in 1993. He is currently working toward the M.S. at the Center for Microelectronic Sensors and MEMS (CMSM), University of Cincinnati, Ohio. His research interests include microchip capillary electrophoresis, microfludic systems, bio-optical sensor systems, micro-total-analysis-systems (u-TAS), and packaging.

A Generic Microfluidic System for Remote Sensors

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This paper describes the development of a generic microfluidic system directed toward realizing electrochemical immunoassay-based bio/chemical detection system, specifically focusing on MEMS-based microfluidic devices and systems on a 2-inch microfluidic system board. The Bio-MEMS team at the University of Cincinnati has been working on the development of a remotely accessible generic microfluidic system for biological and biochemical analysis, based on electrochemical detection techniques. The limited goal of this work is to develop a handheld generic MEMS-based microfluidic system and apply the fluidic system to detect micro-organisms in liquids.

A magnetic bio-bead approach has been adopted for both sampling and manipulating the target bio-molecules. It should be noted that although we are targeting the detection of micro-organisms, this approach is generic and should be applicable to many other analytical situations, including the analysis of liquids such as blood. Thus, the generic system could be used in a variety of small, low-cost, low-power portable chemical and biological analytical instruments. To realize the generic microfluidic system in this work, several new MEMS-based components have been explored and developed for both microfluidic components such as valves, pumps, and flow sensors and for bio-chemical cells such as biofilters and biosensors. In addition, microfluidic system board with microchannels was designed and fabricated on 2-inch Pyrex glass wafers using glass etching and glass to glass bonding technique. All components were mounted on the system board and connected to each other through the microchannels to construct a prototype generic microfluidic system for remote bio-molecule detection.

The preliminary fluidic and bio-chemical experimental results obtained from the realized MEMS-based microfluidic devices, bio-chemical cells and the prototype microfluidic system board, toward realizing a full electrochemical immunoassay-based remote bio/chemical sensor system. The fluidic test on the developed prototype microfluidic system board was monitored in real time and the components showed promising results.

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A New Magnetic Bead-Based Filterless Bio-Separator with Planar Electromagnet Surfaces

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In this work, a new filterless micro bio-separator using magnetic beads has been designed, fabricated, and characterized as an essential sampling device for biological detection systems. In realizing a miniature biological detection system, the bio-separator is essential in sampling a target bio-molecule or bacteria from sampling liquids [1, 2]. However, the development of micro bio-separators has been considered as one of the most difficult tasks. Thus, we have newly devised a filterless bio-separator with a planar electromagnet surfaces, which are fabricated using planar serpentine conductors and semi-encapsulated with Ni/Fe permalloy. To improve the capability of bio-separation, the inside walls of the microchannel consist of the planar electromagnets, which will attract or release the magnetic beads that immobilize the target bio-molecules.

To obtain a maximum separation and holding force on the beads to be selected, the parameter to be maximized is the gradient of magnetic field, while maintaining a magnetic field magnitude large enough to ensure nearly complete alignment and saturation of the magnetic dipole [3, 4]. Based on numerous magnetic simulations, thus, a new embedded serpentine conductor structure with a semi-encapsulated planar electromagnet has been chosen. The current applied into a serpentine conductor (10 um width and spacing), produces magnetic fields through the microfluidic channel and forces magnetic beads to move onto the embedded serpentine conductor. The separated magnetic beads are held in the continuous fluid flow of bio buffer solution, if the magnetic force on a magnetic bead is larger than the fluid friction force on the magnetic bead.

The fabricated bio-separator has been characterized and the maximum flow rate at which the DC current holds the beads in the fluid flow has been also measured. The realized filterless bio-separator has a high potential in biomedical or biological detection systems, especially in selective sampling and separating small amounts of bio-molecules such as antigens for on-chip micro total analysis systems (u-TAS) or remote detection systems [5].

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A Micromachined Inter-Digitated Array Electrode Electrochemical Immunosensor for Microfluidic-Based Biochemical Detection Systems

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Recently, there is a strong demand for the development of microfluidic-based remote sensing systems with biochemical sensor for on-bed diagnoses or for remote sensing kits to detect hazardous biological agents quickly. Early detection of such agents can give an alarm to protect human beings from such hazardous agents or help to diagnose diseases more easily. For these reasons, electrochemical enzyme immunoassays have been widely studied and developed to detect low concentration of antigens by means of the antibody-antigen reaction [1, 2, 3]. However, most of them need a hand-assembled immunoassay reaction cuvette and a macro-size electrochemical cell with freestanding electrodes, which causes poor detection reliability and slow response time in a precise detection. To overcome these drawbacks, a micromachined inter-digitated array (IDA) electrodes electrochemical immunosensor on a chip has been designed, fabricated and characterized in this work, as a part of total microfluidic-based remote sensing systems which involve micropumps, microvalves and microchannels.

IDA type immunosensor has basically four electrodes while conventional electrochemical cell has three electrode so called reference, auxiliary and working electrode. There are two working electrodes which form "inter-digitated array" electrodes in order to amplify signal from oxidation-reduction reaction process during immunoassay. IDA type immunosensor, therefore, is usually more sensitive that conventional electrochemical immunosensor [4]. Cyclic voltammetry (CV) was used to evaluate the functionality of this microfabricated immunosensor as an electrochemical cell. p-Aminophenol (PAP) was chosen to be the analyte in the CV study because PAP is the final product in our electrochemical immunoassay that needs to be detected by the sensor. PAP can be electrochemically oxidized and its oxidized species, p-quinoneimine, can be electrochemically reduced easily because PAP and p-quinoneimine form a very good redox couple.

Detected output currents are varying linearly with PAP concentration. The micromachined inter-digitated array (IDA) electrode type electrochemical cell has no deterioration during its characterization, showing a fairly good stability and robustness.

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On-chip DC/DC Boost Power Converter using Micromachined Planar Inductors

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Recently, great emphasis has been devoted to the development of on-chip DC/DC power converters in the field of wireless communications, especially in cellular phones, laptops and other portable applications [1]. The realization of on-chip DC/DC converters has been considered as one of the difficult tasks due to the lack of appropriate planar chip inductors [2]. However recently we have successfully realized micromachined planar inductors using a new LIGA-like micromachining technique [3].

In this presentation, we discuss a DC/DC boost converter that has been designed, implemented and characterized for operation in the driving frequency range of 3 Mhz to 10 Mhz. An input of 2 V was boosted to 6.55 V in the above frequency range for a duty cycle ratio of 50 % and a load of 10 Kohm.

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3-D MICROFABRICATED TOROIDAL PLANAR INDUCTORS WITH DIFFERENT MAGNETIC CORE SCHEMES FOR MEMS AND POWER ELECTRONIC APPLICATIONS

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This paper describes new microfabricated toroidal-type planar inductors with different types of magnetic cores for MEMS and power electronic applications. For the fabrication of these multi-layer three-dimensional inductive components, a new UV-LIGA lithography process for thick photoresist was developed. These micromachined inductors are 4 mm x 1.5 mm x 120 mm and feature a high Q factor, low resistance values (1.5 Ohm and inductance values as high as 14 mH. By altering the design of the magnetic core by introducing an air gap or a spiral shape, the electromagnetic properties of these devices can be affected. These inductive components are fabricated with a CMOS compatible process and can be used as magnetic components integrated with power electronic circuits, for applications as an on-chip DC/DC power converter. The basic scheme of these inductors consists of a permalloy magnetic core and a coil that is wound all around the length of the core. The use of an airgap is expected to increase the value of the saturation DC current and improve the inductance values at high operational frequencies. This is because the effective permeability will maintain higher values at these frequencies while the permeability of the permalloy will be decreasing with frequency.

The spiral type magnetic core introduces airgaps at the magnetic flux path and laminates laterally the magnetic core in order to reduce eddy current losses at high frequency applications. There are 70 coil turns that are distributed evenly around the 9.2 mm of total magnetic core length. The overall size of these devices is approximately 1.5 mm x 4.2 mm. The conductor coils are designed to be 50 um wide and have 50 um spacing between them with a tight form the bottom conductor electroplating molds, followed by Cu electroplating. A layer of photoresist is then spun and hard-cured to provide a good insulation between the coils and the magnetic core. Another UV-lithography is then performed to form the molds for electroplating the core and vias. Finally, the top conductors were electroplated on the top of this layer. Three different kinds of devices have been fabricated and tested with plain, airgap and spiral type magnetic cores. Inductance measurements of the above three inductors (e.g. no-airgap, airgap = 40-100 um and spiral- type) were performed. High inductance values of more than 12 uH are achieved especially for low frequencies, which we can define as the micro-magnetic actuation regime. The measured inductance of the airgap bearing magnetic cores is smaller than the no-airgap inductors. As the frequency increases, the inductance values are decreased as expected due to magnetic core losses. The spiral and airgap type cores maintain higher inductance values tha n the cores with no-airgaps at high frequencies. Overall, these coils show very low resistance values (1-4 Ohm and they are suitable for high current applications and power electronics. The slight difference of the resistance values is interpreted as small fabrication mismatch of the coils for the different inductors. In this work new toroidal type planar inductive components are designed, fabricated and tested. The introduction of an airgap and a spiral type core improves the magnetic characteristics of the devices at high frequencies. The realized inductor has a high inductance value of 14 uH and a low electrical resistance (1-4 Ohm, which results in a Q-factor of up to 1 at 1 MHz.

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A Micro Fluxgate Magnetic Sensor Using Micromachined 3-Dimensional Planar Coils

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This work presents an innovative on-chip fluxgate magnetic sensor cell with ultra high sensitivity and wide operational range at low frequencies. The fluxgate sensor has been designed, fabricated and characterized in this work. The exciting and sensing elements are three-dimensional micro-coils that have been fabricated on silicon wafers. Recently there has been a large demand for the realization of a miniaturized ultra sensitive magnetic sensor system [1, 2] for guiding and vehicle position identification systems. The fluxgate [3] is known as the most sensitive magnetic sensor, which in terms of the range and resolution stands higher than low sensitivity solid-state devices such as Hall effect and magnetostrictive magnetic sensors, and is comparable to ultrahigh sensitive but very expensive quantum effect SQUIDs [4]. The fabrication is based on a newly developed [5] thick photoresist (LIGA-like) conventional UV- lithography process. It consists of a three layer planar fabrication of the fluxgate sensor and coils. The fabrication process starts with thick (30 um) Cu conductor lines electroplated on a silicon oxidized wafer. The electroplating molds patterned on thick (AZ-4000 series) photoresist. Via connections (bottom to top conductors) were patterned on a new layer of photoresist that covered the bottom conductors and then was hard cured to serve as insulator and support for the rest of structure. Next, the Cu via connections were electroplated and so the magnetic Ni/Fe core. Another layer of thick photoresist was spun and new vias were opened before another hard curing was performed. Finally, the top Cu conductors were electroplated to complete the device. The fabrication process of this sensor can follow a CMOS circuit fabrication process. The supporting driving and sensing electronic circuits can then be integrated with the sensor in one chip. The measurements are performed in a magnetically shielded box. The dimensions of the micro -sensor are 0.5mm x 2mm x 10 um, and it has an operational range up to 1.3mTesla, with system sensitivity of 8360 VT- 1. The linearity of Vp-p measurements that was demonstrated during experimental testing, in the range (-500 uTesla) to (+500 uTelsa) proves the good functionality of the sensor. Because of the 3-Dimensional structure of this sensor the range and the sensitivity can be easily controlled with the thickness of the magnetic core and the exciting AC current can be easily adjusted through the thick Cu conductors. In this work a fully integrated micro-fluxgate sensor has been successfully fabricated and tested. The sensors features such as the small size, lightweight, high sensitivity, excellent reliability and robustness make it suitable for numerous applications in areas such as mineral prospecting, position detection, space measurements, and navigation systems.

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Optical Interconnect for Synchronous timing of GaAs-based MCM Video Memory

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Optical fiber communication has been proposed for a number of different areas of application in computers and data processing networks. This is a consequence of the noise immunity and wide bandwidth capabilities of optical fiber links. System design difficulties multiply when data rates increase to the point where the integrated circuit gate delays become a significant fraction of the clock period, and when the distance between synchronously clocked IC's becomes comparable to the product of the signal propagation speed and the clock pulse rise time. In the growth of semiconductor computer chip, metal interconnection has become a bottleneck. Moreover, limitations associated with metal interconnect dominates as the dimensions are scaled down further and chip areas are increased. This project investigates the implementation of an optical interconnect for a high-speed video memory array. High-resolution color display systems demand the information rates of at least 12 Gbit/s for transferring a 4096 by 4096 screen of pixels. Generating random test patterns in three colors requires 36 layers of 4096 by 4096 bit video memory. In order to overcome clock skew problems with synchronously operating such a large array, it is proposed to use optical fiber interconnections of GaAs-based CCD memory chips in a Multi-Chip-Module arrangement.

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