Center for Nanoscale
Chemical-Electrical-Mechanical
Manufacturing Systems

June 20, 2005

Smalltalk

A Message from the Director…

The Center has experienced a number of exciting activities in the last six months. Momentum couldn't be greater and we are moving forward at a rapid pace.

In February, 23 companies attended the Nano-CEMMS Industry Advisory Board (IAB) meeting. Several of our scientists gave industry an in-depth perspective of the science and engineering that goes into realizing the Nano-CEMMS process. John Rogers, a Founder Professor of Engineering in the University of Illinois departments of Materials Science and Engineering and Chemistry, delivered the keynote address—"Materials and Patterning for Macroelectronics." Detailed technical presentations were: "VLSI Micro and Nano Fluidic Systems" by Paul Kenis, "Nano-manipulation" by Min Feng Yu, "Molecular Gates" by Paul W. Bohn, and, "Multiscale Models" by Narayana R. Aluru. Both the speakers and participants created a dynamic meeting which allowed for observations, recommendations, and developing plans for the future.

Funding for the Center continues to grow in all areas. The National Science Foundation (NSF) allocated $106,000 to the Research Experience for Undergraduates (REU) program. Motorola contributed $30,000 to summer workshops for curriculum development. Nano-CEMMS will work with middle and high school science and math teachers to develop and deliver Motorola Nanotechnology Learning Modules. To date, 1,690 middle school students, high school students, and teachers have been impacted by Nano-CEMMS' outreach programs. The industrial affiliates program is also beginning to take shape.

Many of our of our projects are beginning to work closely in interdisciplinary research groups. As a result, we now have many working test beds that integrate multiple facets of a nanomanufacturing system such as, nanopositioning, sensing, and micro fluidics. In this issue of *Smalltalk*, we'll examine research in the area of molecular gates by Paul Bohn, Mark Shannon, and Jonathan Sweedler and nanoscale inkjet printing by John Rogers.

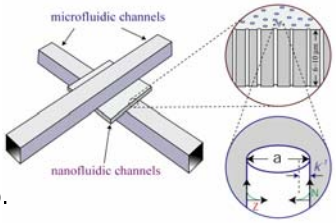
This summer presents many opportunities for the Center, including the NSF Site Visit in June, several teacher programs, and the REU program, as well as continued graduate and undergraduate research.

Dr. Placid M. Ferreira
Director, Nano-CEMMS

Gates to the Future: Molecular Gates

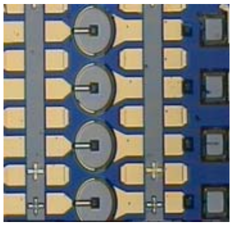
Imagine trying to swim in a bathtub. You would probably hit the sides every time you tried to take a stroke. Swimming in a bathtub is how Professor Mark Shannon explains the workings of molecular gates. "To a molecule, the chance of running into a wall when it is going a long distance in a really narrow environment and the Debye length is squeezing it in—the chance of hitting wall is almost 100%. That is what makes the molecular gate the molecular gate," says Shannon.

Of course, a molecular gate is not *really* a gate. It is an infinite aspect ratio—a micro nanoscale construct. It controls fluid like electronic devices control electrons. The transport is proportional to applied bias (resistor). The transport can be made to move in only one direction (diode) so it is a one way gate. And gain is possible by the introduction of a third pole (transistor).



The gate consists of two microchannels and each one of these channels is the size of a hair. These two "hairs" are crossed and in between there is a little membrane that has holes through it that are nanometer size. The microchannels are super long compared to their width (an ultra high aspect ratio). So, these two conditions—infinitely long and the Debye length squeezing it—have an effect on the charge. As it passes through, whatever is done to the walls affects the flow. Just like in a bathtub. If the bathtub walls were sticky or soft that is going to affect you. The nanofluidics are "all wall". All wall means that the wall of the tube or the pipe controls everything about the object going through.

Molecular gates were developed by a research team led by mechanical and industrial engineering professor Mark Shannon and chemistry professors Paul Bohn and Jonathan Sweedler. The research team initially developed the molecular gate to do sensing applications such as trying to find very few molecules of toxins that may be present in the body. Particularly, they were interested in things like botulism where you have very, very few and very, very few could kill you. Once the team realized all the possibilities of use for the molecular gate, they recognized they could make a manufacturing system out of it.



The active control of fluid transfer accomplishes digital transfer of fluids and solvated molecules which means they can be actively controlled, just like a computer. The gate allows selective gating functions based on mass, size, and affinity of molecules. In other words—it controls which molecules will get let through. Flow selection can be made based on a number of different inputs (chemical composition, size, and mobility). It also can change direction. Gates that open one direction then turn it around and the flow will go in the opposite direction. What is on the wall determines which way it flows.

One objective is to control injections of extremely small amounts. The team hopes to collect extremely small mass samples and to rapidly mix fluid streams. They envision doing gradients, charge separations, rapid reactions, integrating them into a separation system, and creating huge arrays. To date the team has assembled two arrays of gates. But what they can imagine is limitless. When there are more gates, you can do more complex tasks. "By having lots of gates, we can control lots of different molecules and do lots of different things. So we want to make these arrays of gates huge. That's one of the goals of the Nano-CEMMS. We don't want 10 x 10; we don't want 100 x 100; we don't even want 1000 x 1000 which would make a million ; if we could get a billion gates that would be great," says Shannon.

Education and Outreach Update

Programs and People in Nanotechnology

This is shaping up to be a very busy summer for the Center's Education and Human Resource Development area. The planned activities cut across the various constituents of the Center, all working together to lend their particular expertise. The various programs and the people involved in these programs are focused on building the nanotechnology workforce of the future.

Graduate Students – Fifty-three graduate students are working on Center research this summer. The Graduate Student Group meets regularly to present the research from their various labs and to promote cross-collaboration. They are working hard on the poster session and demonstrations for the annual NSF site visit.

Undergraduates – Fourteen undergraduates from seven universities and colleges around the country are engaged in hands-on research within the Center this summer. Working with graduate student mentors, they are actively involved in design, implementation, and testing projects under the direction of eight Nano-CEMMS professors. Before the summer ends, the students will write research papers and present their findings at a seminar.

Teachers – Two workshops for middle and high school teachers will be held during the month of July. Both sessions are intended to familiarize teachers with nanoscale concepts so they can return to their classrooms with new information. Our ultimate goal is to interest the students in new careers in nanoscale science and engineering. During the workshops, teachers will conduct hands-on experiments in the Center's various labs, working with faculty, graduate students, and undergraduate students as they learn to deal with small-scale phenomena. They will also spend a week working on curriculum development.

Middle and High School Students – Center staff will deliver 20 sessions in 10 different camp programs this summer. The sessions include thought-provoking presentations and discussions about nanotechnology, societal changes resulting from nanotechnology, economic opportunity, and working in nanotechnology. The students will engage in multitudes of hands-on activities that will get them thinking like nanoscientists.

Curriculum Development – In May, Nano-CEMMS received a generous grant from Motorola Corporation to develop several new learning modules. This development effort has already started and involves middle school and high school teachers who will lead curriculum design, high school students who will experiment with various methods, undergraduate students who will facilitate design, and graduate students and faculty who will provide content expertise.

For more information about the Nano-CEMMS education program, visit http://www.nano-cemms.uiuc.edu/content/education.

Nanoscale Inkjet Printing

Your favorite gadgets from movies and science fiction are not that far away. Picture a wall display with reconfigurable wallpaper or medical devices such as smart band aids. Those are the kinds of possibilities that interest John Rogers' research group, consisting of Rogers, two graduate students, and a post-doctoral researcher.

The Rogers Research Group looks at organic, plastic, polymer-based materials that behave like conventional silicon electronic material but which are inherently flexible and printable. The Group designs materials that you can actually put in an inkjet and print directly onto a sheet of paper or plastic and build up circuits. It is a printing-based approach to fabricating electronic systems which could offer the cost benefits of large area high-speed printing systems to achieve low cost electronics on unusual substrates like plastics or paper. The key application they are shooting for initially is flexible displays—organic, light emitting displays fabricated on a very thin sheet of plastic— for cell phones or PDAs.

The ink effort seems to be going quite well. To date, researchers have achieved classes of inks that have good electronic properties and demonstrated them on the first generation fluidic printheads. They've been able to print individual transistors that work pretty well. The goal is to improve performance by tailoring the materials and geometries of those transistors and printing interconnected arrays of transistors to perform logic function and computation and display-type switching arrangements. They have printable insulators (polymer-based materials), printable semi-conductors (single-walled carbon nanobube film), and printable electrodes (conducting polymers). So, the group has the three key types of inks that would allow them to produce a complex circuit. The current resolution they have achieved is 1:5 microns. That's not bad for a display type device but it is not good enough for a microprocessor. The hope is to scale the resolution to feature sizes much smaller than a micron, into the nanoscale regime because in plastic transistors, just like silicon transistors, smaller is better.

Once there are a set of inks that work, in order for progress in the types of circuits that can be produced, better printheads must be developed that have finer patterning resolution capabilities. The researchers have some ideas for the nanoscale inkjet tool. The design of the tool depends on the inks and their properties so it makes sense for them to be involved, since the geometry and operation of the printhead depends on what kind of viscosities the inks have and what kind of temperatures they can be subjected to before they degrade.

Rogers affirms that the Center has been great for this research, "We're pretty good at the materials and device design but in terms of all the mechanical engineering and the fixturing, details of fluid flow and nanopores, modeling the flow, and scheduling droplets through the microfluidic printhead—all these things are really outside our group's range of expertise and it is the interdisciplinary aspect of the Center that enabled us to make good progress on a project that has this massive scope and high technical degree of difficulty. We've found the Center has stimulated all kinds of collaborations that just wouldn't have happened otherwise."

For more information:

Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems

University of Illinois at Urbana-Champaign

2134 Mechanical Engineering Laboratory
105 South Mathews Avenue, MC-244
Urbana, IL 61801
217.265.0093

nano-cemms@uiuc.edu
http://www.nano-cemms.uiuc.edu