

# University of Louisville Nanotechnology Fellows Symposium: Extending Engineering Excitement to High School Educators

*Joseph H Lake<sup>12</sup>, Kevin M. Walsh<sup>123</sup>, Bruce W. ALphenaar<sup>123</sup>, Mark M. Crain<sup>12</sup>, Robert S. Keynton<sup>234</sup>, Robert W. Cohn<sup>123</sup>, Michael D. Martin<sup>12</sup>*

**Abstract** – This paper reports on the first annual University of Louisville (UofL) Nanotechnology Fellow Symposium (NTFS) held on July 27th, 2006 at the Belknap Research Building. Educators interested in generating enthusiasm for engineering in secondary schools should find this paper to be of particular interest. This initial offering of the NTFS was open to all secondary school educators in the disciplines of math and science within Jefferson County Kentucky in both the public and private school systems. Eleven teachers attended the event representing six public and three private schools. A very high level of interest was displayed regarding the nanotechnology presentations and the possible implications of the field to current high school students. This paper presents some of the concerns raised regarding student interest in the fields of engineering and engineering research along with other lessons learned from this first offering of the Nanotechnology Fellows Program. Details of the microfabrication lab presented during the symposium are also provided, as this will be used as a blueprint for future examples and classes.

*Keywords:* nanotechnology, high school education, MEMS

## INTRODUCTION

Outstanding engineering education has been a tradition at the University of Louisville's J.B. Speed School of Engineering since its founding in 1923 [1]. The school's curriculum has continually adapted over the years to insure that the graduates entering the work force are prepared to tackle the most challenging engineering and scientific problems of the day. With this history as a backdrop, the school began developing the infrastructure necessary to support the emerging areas of micro and nanotechnology in the late 90's with the opening of the state's first cleanroom facility and has continued to the present with the 2006 opening of the Belknap Research Building with expanded cleanroom and laboratory facilities largely dedicated to Micro/Nanotechnology research. While graduate level research has always been a priority, UofL was one of the first schools in the country to offer a MEMS (MicroElectroMechanical Systems) design-laboratory class specifically tailored to undergraduate students [2,3]. This early exposure to state-of-the-art fabrication technology has been a major driving force in the expansion of the graduate level research program due to the excitement that is kindled in the students. With almost a decade of experience introducing "young" students to this highly technical area, the Micro/Nanotechnology research group at UofL is uniquely positioned to take a leading role in helping to reinvigorate general enthusiasm for engineering and the technical fields at the high school level.

---

<sup>1</sup> Electrical and Computer Engineering Department, University of Louisville

<sup>2</sup> Nanotechnology Core Center, University of Louisville

<sup>3</sup> ElectroOptics Research Institute and Nanotechnology Center, University of Louisville

<sup>4</sup> Department of Bioengineering, University of Louisville

It would seem that there is a general lack of interest in the various fields of engineering with the current generation of college students when compared to other countries. Glance through almost any newspaper or business magazine and there is likely to be an article lamenting this fact and presenting very startling numbers to support this conclusion [4,5]. While some of the numbers may be up for debate there are data gathered by the National Science Foundation (NSF) that reveal that the United State's engineering community may be in for even rougher times in the near future [6].

The NSF's Science and Engineering Indicators 2006 presents several disturbing findings regarding current trends in elementary and secondary students' performance in the areas of math and science. Based on assessment testing conducted over the last decade, less than 20% of graduating high school seniors performed at a "proficient" level in science and math in 2000 and 2003, respectively. As defined, the proficient level would be the absolute minimum skill level needed to transition directly into an engineering school without needing remedial classes in some area. Leading to the conclusion that greater than 80% of potential students lack the very basics needed to become engineers [6].

Given these data, the NSF and other organizations are making a push to reenergize student interest in science and engineering with the hopes that this excitement will lead to improvements in student performance. It is with these goals in mind that the UofL Micro/Nanotechnology Center (MNC) held its first annual Nanotechnology Fellows Symposium (NTFS). The initial NTFS was open to secondary science and math educators in the Jefferson County Kentucky school systems, both public and private. The MNC chose to focus on the educators, versus students, in hopes of reaching a much broader range of students over a longer period of time. By providing teachers with the knowledge and tools needed to excite their students about an emerging technology area, more students will be reached than could be by focusing on the students themselves.

## SYMPOSIUM

### "But when will I ever use this?"

This question is the eternal enemy of teachers, especially those in math or science. The answer is not always easily conveyed to impatient students and has not been made easier by the increasing number of distractions that compete for students' time. The general goal of the NTFS is to provide the teachers that participate in the event with an arsenal of examples and classroom laboratories specifically designed for the high school student level and that can be used to answer this question with real world applications. The 2006 Nanotechnology Fellows Symposium consisted of a one-day event hosted on the University of Louisville campus, attended by eleven local high school educators (see tables 1 and 2).

Subjects	Total Attending
Math	3
Physics	3
Biology	2
Chemistry	3
Table 1: Subjects represented	

### Morning sessions

The largest portion of the event was dedicated to presentations by UofL researchers detailing the focus areas of their labs (See table 3). These presentations were specifically geared for a general audience. The focus of the presentations was not on specific details or quantitative results of the projects, but had the goal of introducing the research areas as broad topics and to stimulate interest and discussion between the attendees and presenters.

The first presentation, *A Micro History of Time*, was a general overview and history of the micro/ nanotechnology and MEMS

fields. Beginning with the development of the transistor and progressing through the evolution of semiconductor technology to MEMS applications, this presentation provided a stable foundation on which the following presenters could build. This presentation was designed to not only provide the starting point for the symposium, but also to provide the educators with concrete, non-research examples of the technologies which were to follow. Being the most mature of the technologies presented, the MEMS field is filled with numerous easy to understand sensors and

Schools Represented	
Waggener	Public
Trinity	Private
Manual	Public
St Xavier	Private
Seneca	Public
Farnsley	Public
Ballard	Public
Central	Public
Table 2: Schools represented	

systems which can be easily understood by high school students without the need for advanced, college level math or physics. Many examples were provided which could be presented as case studies for class projects; i.e. airbag sensors, fall sensors for consumer electronics and deformable mirror devices for projection televisions.

Following this introduction, the next two presentations focused on the nano end of the spectrum. *Nanoscale Electronic Devices*, focused on this emerging topic of research at UofL. The main subject of the presentation revolved around carbon nanotubes (CNTs) and their uses and applications. The teachers present were particularly interested in this topic due to the buzzword nature of the field currently. It was generally felt that the pop culture presence of CNTs presented a good opportunity to engage students and draw them into the topic. The arrangement of carbon molecules and some of the basic mathematical calculations for current flow in the carbon nanotubes were used to illustrate that even at the most advanced level of physics, simple calculation can often be used to approximate difficult phenomenon. *Everything You Wanted to Know About Nanotechnology, But Were Afraid to Ask* provided a bird's eye view of nanotechnology including a discussion of the debate that revolves around the definition of nanotechnology itself. The differences between the bottom-up method of self-assembly and the top-down techniques of traditional fabrication technologies were discussed and some everyday examples of nanotechnology were provided for the educators.

*Research for High School Students* highlighted one of several projects currently underway within the MNC that directly involves one or more local high schools students in cutting edge research. Beginning as a student shadow and progressing to directed, independent laboratory work these students get a unique taste of what will be required to receive an advanced degree in engineering. Results obtained by the student were shown for illustration purposes. Discussions revolved around the requirements and traits necessary for a high school student to be successful in a research environment and the level of commitment required from both the student and the researcher.

<i>A Micro History of Time</i>	Kevin Walsh
<i>Nanoscale Electronic Devices</i>	Bruce Alphenaar
<i>Everything You Wanted to Know About Nanotechnology, But Were Afraid to Ask</i>	Robert Cohn
<i>Research for High School Students</i>	Michael Martin
<i>BioMEMS and BioNanotechnology</i>	Robert Kenyton
Table 3: Presentation topics and presenters	

The final talk of the day, *BioMEMS and BioNanotechnology*, detailed the bioengineering department and the research that is being conducted there. The numerous examples presented during this presentation included Lab-on-a-Chip devices, catheter-based blood pressure sensors and artificial valves and heart devices. This area of research drew the interest of all the science teachers present due to the very cross-disciplinary nature of the field.

### Mad Scientist Cooking

The University's cleanroom and metrology laboratories hosted the second session of the MNFS with a cooking show style presentation (See figures 1 and 2). Using the pressure sensor that is fabricated during the undergraduate lab class as a sample, the attendees were shown a complete fabrication sequence starting with bare silicon wafer and ending with a packaged product. To make this possible pre-processing was performed on a number of samples with each left at a different point in the fabrication sequence. The bare silicon wafer was shown to the Fellows and the details explained. This wafer was then coated with photoresist, exposed and developed with the accompanying explanations. A second wafer was waiting in a pre-pumped down sputtering machine where an example of metal deposition was demonstrated and the lift-off process explained. Several intermediate steps were then explained including impurity implantation, silicon etching, dicing and packaging. The group then tested a working packaged sensor. To conclude the tours, the group was shown the same device along with many other nano-scale samples using scanning electron microscopy and atomic force microscopy.

### Microfabrication on a Budget

In order to make any laboratory examples relevant for the Symposium attendee it is necessary to redesign the procedure. The equipment and chemicals that are considered essential for any micro/nano fabrication lab would be well beyond the budget of the average high school science department. It is possible to illustrate the basic fabrication concepts using low-cost, low-risk supplies available at most craft supply stores or websites. An example of this type of experiment, the construction of a microfluidic channel was demonstrated.



Figure 1: Nanotechnology Fellows in Lutz Microfabrication Cleanroom



Figure 2: Nanotechnology Fellows viewing SEM demonstration in ERINC lab facilities

The materials required for this experiment were:

- Overhead transparencies
- A UV source
- A computer with Microsoft Paint (or equivalent) and a laser printer
- A hole punch
- Glass microscope slide
- Isopropyl alcohol
- Craft Grade Glass Adhesive

Figure 3 illustrates a sample mask for the fluidic channel that can be printed onto one of the transparencies using the laser printer. Laser printer toner will absorb low dose UV light and can therefore be used as a mask for exposing the UV sensitive glass adhesive. The adhesive is applied to the glass slide and the mask is pressed onto the substrate, spreading the adhesive. The adhesive is then exposed using the light source for a period of several minutes. After curing, the adhesive will adhere to the glass allowing the mask to be carefully peeled away. The slide was then placed in the IPA for development. Punching out the round portion of the mask using the hole punch forms the reservoirs for the channel. The mask can be replaced on the slide forming the top of the channel. The channel may then be filled with fluid using capillary action.



Figure 3: Sample mask for fluidic channel, printed using standard laser printer.

The construction of this simple channel can be used to illustrate several key fabrication techniques to students. The drawing, printing and use of the mask represent photolithography. Application, patterning and etching of the adhesive are a small-scale version of thin film formation and manipulation. Beyond the basic construction laboratory, a creative instructor will be able to leverage the channel to perform other experiments; i.e. effects of viscosity on flow, effect of differing geometries on flow, formation of electrical switch, etc.

### Open Discussion Forum

The events of the day were concluded with open discussions between all participants, hosts and attendees. The response of the Fellows was very enthusiastic and discussion revolved around the next steps that should be taken and how to improve events in the future. All of the attendees were interested in further development of a series of low-cost fabrication experiments such as the one presented. The educators felt that these laboratories would be highly effective in engaging students and helping motivate their interest in engineering.

Lengthy discussions also revolved around how the technical information presented could be integrated into current curriculum. While the attendees were excited by the presentation, there was concern that given the constraints that are already placed on classroom time, it would be difficult to incorporate the material independent of tie-ins to

current lessons. Even with this concern, all present requested that an effort be made to develop classroom materials, including pre-made PowerPoint slides, videos and class work.

## CONCLUSIONS

Based on the success of the 2006 Nanotechnology Fellows Symposium, plans are under way for the follow on event to take place during the summer of 2007. A larger emphasis will be placed on hands on laboratory time and study plan development, at the request of the 2006 Fellows. Using the input from the open discussion, the presenters will be better able to tailor their talks to the needs of secondary educators. Work is under way to develop a complete package of low-cost, high school appropriate experiments. As a direct result of the MNFS, eight additional high school students have joined the research team in the Bioengineering department and plan to make engineering a career choice. In addition to the MNFS 2007 plans, two of the Fellows have joined the MNC staff in a grant NSF submission for addition funding to further develop the outreach this outreach program at UofL.

## REFERENCES

- [1] University of Louisville, Speed Scientific School [homepage], [www.speed.louisville.edu](http://www.speed.louisville.edu), Nov 28, 2006,
- [2] Crain, M., "Development of a Microfabricated Piezoresistive Pressure Transducer for an Introductory Course in Microfabrication," Master Thesis, University of Louisville, Aug 1999
- [3] University of Louisville, Microfabrication Research Center, [homepage], [www.mems.louisville.edu](http://www.mems.louisville.edu), Nov 28, 2006
- [4] Wadhwa, V., "About That Engineering Gap...", BusinessWeek Online, [http://www.businessweek.com/smallbiz/content/dec2005/sb20051212\\_623922.htm](http://www.businessweek.com/smallbiz/content/dec2005/sb20051212_623922.htm), Dec. 13, 2005
- [5] Clayton, M., "Does the US Face an Engineering Gap?", The Christian Science Monitor, <http://www.csmonitor.com/2005/1220/p01s01-ussc.html>
- [6] Division of Science Resource Statistics, "Science and Engineering Indicators 2006", National Science Foundation, Feb. 2006

## ACKNOWLEDGEMENTS

Funding provided by NSF Cooperative Agreement EPS- 0447479

**Joseph Lake** received his B.S and M.S. in electrical and computer engineering from the University of Louisville (UofL), Louisville, KY, in 2003 and 2006, respectively. He is currently a full-time research engineer for the UofL Micro/NanoTechnology Center.

**Kevin Walsh** received the B.S. and M.Eng. degrees in electrical engineering from the University of Louisville (UofL), Louisville, KY, in 1978 and 1985, respectively, and the Ph.D. degree in electrical engineering (microelectronics) from the University of Cincinnati, Cincinnati, OH, in 1992. He is currently a Full Professor with the Department of Electrical and Computer Engineering, UofL, where he also serves as the Director of the UofL Micro/NanoTechnology Center. He has taught more than 20 different courses, advised more than 25 completed theses, and published more than 100 technical papers in the areas of micro/nanotechnology, microelectromechanical systems, microfabrication, packaging, sensors, actuators, cleanroom design/operation, and micro/nanotechnology course development. He is the holder of several patents and a cofounder of three technical start-up companies. He currently serves on the Editorial Board of Sensor Letters.

**Bruce Alphenaar** received his B.S. degree in physics from Trinity College, in Hartford CT in 1984, and his MS and PhD in Applied Physics from Yale University in 1991. Following his PhD, he worked as a post-doctoral research

scientist at Philips Research Laboratories in the Netherlands studying the electrical properties of nanoscale devices. His work on nanoelectronics continued at Hitachi Laboratories in Cambridge England, where he worked as a Senior Research Scientist. He joined the faculty of the University of Louisville in 2000 as an Associate Professor in Electrical Engineering with the distinction of University Fellow in Nanotechnology. His current interests include the electrical and optical properties of carbon nanotubes devices.

**Mark Crain** received his B.S. in mechanical engineering from Purdue University, West Lafayette, IN. in 1991 and his M.S. in electrical engineering from the University of Louisville, Louisville, KY in 1999. He is currently cleanroom manager for the UofL Micro/Nanotechnology Center.

**Robert Keynton** is currently the chair and a full professor of the Department of Bioengineering, a University Scholar, and the Associate Director of the Micro/NanoTechnology Facility at the University of Louisville. He received the B.S. degree in engineering science and mechanics from Virginia Tech in 1987, the M.S. and Ph.D. degrees in biomedical engineering from the University of Akron in 1990 and 1995, respectively. Dr. Keynton is an active member of ASME, IEEE-EMBS, and BMES, and has over 50 peer-reviewed publications, 70 conferences papers, and 6 patents pending in the areas of BioMEMS, microfluidics/Lab-on-a-Chip, micro/nanofabrication, MEMS modeling, and cardiovascular mechanics.

**Robert Cohn** received his Ph.D. in electric engineering from Southern Methodist University. He is currently a Full Professor in electrical and computer engineering at the University of Louisville. He is also Director of the ElectroOptics Research Institute and Nanotechnology Center (ERINC). His current research emphasis is the study of self-assembly in nanostructures using the Micro/NanoTechnology Center, which is a shared laboratory within ERINC.

**Michael Martin** received his B.S in physics from Austin Peay State University, Clarksville, TN, in 1994 and his M.S. in physics in 1999 from University of Louisville, Louisville, KY. He is currently a research engineer at UofL Micro/Nanotechnology Center with a research emphasis in microfabricated explosive preconcentration devices.