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Bringing Students to the Mountain: Developing Partnerships to Introduce Students to Cutting-edge Research

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ABSTRACT

Many materials science education and outreach activities are designed to be easy and cost-effective to implement in K-12 classrooms. While these activities are extremely effective at teaching broad materials science concepts such as size and scale, materials properties, and the use of tools in science, they do not connect very closely to the work being done in materials science research laboratories. In an effort to more closely connect our outreach efforts to the work being done by our researchers, the University of Wisconsin-Madison's Materials Research Science and Engineering Center (UW-MRSEC) has developed a partnership with Hitachi High Technologies America, Inc. This partnership allows us to introduce public audiences to a state-of-the-art tabletop scanning electron microscope (SEM) that is being used by UW researchers. In this paper, we describe the partnership including the use of the SEM in our Research Experience for Teachers (RET) program and in our community outreach programs.

Keywords: outreach, education, SEM, K-12, materials science

1. INTRODUCTION

The NSF-sponsored Materials Research Science and Engineering Center at the University of Wisconsin – Madison (UW MRSEC) investigates the structure and properties of materials interfaces at the molecular and atomic levels. The UW MRSEC is comprised of three interdisciplinary research groups (IRGs 1-3), which focus on a wide array of materials from inorganic semiconductors through liquid crystals¹. In addition to the research groups, UW MRSEC has an interdisciplinary education group (IEG) that creates and disseminates a broad range of educational materials that arise from the materials science research and expertise in the center².

1.1 IEG vision and philosophy

The vision of the UW MRSEC IEG is to increase the number and diversity of individuals knowledgeable about materials science and interested in pursuing careers in the field. As a center, the MRSEC approaches education and outreach with the same dedication and creativity as research and all members of the center participate in these efforts. To realize our vision, IEG uses an iterative “create, disseminate, and evaluate” approach. New materials science activities and curricula are developed in close collaboration with the researchers in the MRSEC, the new material is disseminated to age-appropriate audiences, the efficacy of the material is evaluated through a variety of methods, and the activity is refined based upon the results of the evaluation. We disseminate material through a wide range of venues including our highly regarded website² which reaches over 100,000 people each year, large science festivals that impact several thousand people, workshops for educators, and field trips on the UW campus. Through these varied dissemination methods we are able to reach a broad audience including K-12 students, college students, educators and the general public.

1.2 IEG approach

The IEG has been creating educational materials for well over a decade. Our philosophy has been to create simple, cost effective activities that teach basic materials science concepts such as materials properties, size and scale, and the applications of materials science and nanotechnology research. These materials are easily disseminated via our

education website², at large events such as science fairs, and during workshops for teachers. These educational activities are also easy and cost-effective for teachers to introduce into their classrooms. In Fig. 1, a UW MRSEC graduate student is teaching a third- grade boy about hydrophobic and hydrophilic materials using dried lotus leaves, hydrophobic sand (magic sand), instant snow polymer, and sodium polyacrylate (water lock diaper gel). All of the materials required for this activity are non-toxic, readily available, and easy to obtain.

Although these activities are very effective and engaging, UW MRSEC recently began to explore ways to expand the scope of our activities to give K-12 and public audiences a more authentic research experience. To do this, we developed a partnership with Hitachi High Technologies America that allowed us to introduce the public to the TM3000 tabletop scanning electron microscope (SEM).

Fig. 1 A UW MRSEC graduate student teaches a third grade boy about hydrophilic and hydrophobic materials using safe, simple, cost-effective materials.

2. METHODOLOGY

The TM3000 SEM has several features that make it ideal for educational environments. It is compact enough to be moved by automobile and simple enough for elementary-aged children to operate. The TM3000 SEM is able to magnify up to 30,000x and it plugs into a standard outlet so no special equipment or electrical alterations are needed for its use.

Hitachi loaned the SEM to the UW MRSEC IEG for three months during the summer of 2012 as part of their involvement in Change the Equation (CTEq), a non-profit organization comprised of members of the business community. The stated mission of CTEq is “Through our coalition of CEOs, Change the Equation pledges to foster widespread literacy in science, technology, engineering and mathematics (STEM) that sparks an innovative spirit in students and prepares them for postsecondary options.”³

3. RESULTS

Since Hitachi loaned the TM3000 SEM to IEG with no conditions on its use, we used the instrument for a broad range of education and outreach activities including our Research Experience for Teachers program, a College for Kids summer camp, and large community outreach events.

3.1 Research Experience for Teachers (RET)

Our NSF-funded RET program is a cross-site collaboration between the University of Wisconsin- Madison (UW) and the University of Puerto Rico- Mayagüez (UPRM) that gives the participants research experience, as well as new tools and resources for their classrooms. The program partners K-12 teachers with UW and UPRM faculty, postdocs, graduate students, and staff for a six-week, on-campus, professional development experience.

Figure 2: a) Teachers in the RET program used the TM3000 SEM throughout the six-week program to collect images for the classroom curriculum they developed. b) UW RETs trained the UPRM RETs to use the SEM during capstone week and the UPRM teachers were able to collect images for their projects.

During the program, the teachers conduct research and develop cutting-edge curriculum for their classroom based upon their research. The cross-cultural aspect of the program improves the participants' cultural literacy and leads to the development of bilingual, culturally relevant education resources. In the fifth week of the program, the teachers meet at one of sites to present their research and curriculum to each other and to exchange ideas and resources about the educational systems in their respective regions. Capstone week was held in Madison, WI during the 2012 program.

The UW RET participants were trained to use the TM3000 SEM during the first week of the program and were granted access to the microscope throughout the entire six-week program (Fig 2a). Many of the teachers used the instrument to collect images that enhanced the curriculum they developed for their classrooms. During the capstone week, the teachers from UW trained the UPRM teachers to use the SEM to collect images for their projects as well (Fig 2b).

3.2 Examples of RET projects utilizing the SEM

UW RET Kira Jacobson worked in the lab of Professor Nader Behdad where she researched the unique structure of the *Ormia ochracea* fly eardrum. The structure of this fly eardrum is being used as a model for new antennae arrays. As part of her activity, Jacobson took images of the *Ormia* fly's eardrum for a high school lesson on antennae and biomimicry (Fig. 3).

Figure 3. The left eardrum of the *Ormia* fly at 250 x (left) and 2,000x (right) magnification.

Figure 4. Printed Shrinky Dink film at 3,000x magnification.

UW RET Melissa Hemling developed an activity where high school students made their own microfluidic devices using Shrinky Dinks film to create the templates. The device patterns were printed on the Shrinky Dinks film using a laser printer. The Shrinky Dinks films were then shrunk in hot oil, which caused the ink to be raised to a height that could be used to form channels in the polydimethylsiloxane (PDMS) that was poured over the template to make the device. Hemling used the TM3000 SEM to collect images of the ink on the shrunken Shrinky Dinks film to show the students that the ink is not the smooth, straight line it appears to be at the macroscale (Fig. 4).

UPRM RET Brenda Estévez Moreno developed a classroom module to teach her students about the elastic properties of materials. She soaked an egg in vinegar for seven days and compared the elasticity of the treated egg to an untreated egg

Figure 5. Vinegar treated egg membrane at 2,500 x magnification (left). Untreated egg membrane at 3,000 x magnification.

using a device she had created to measure force on an object. Estévez Moreno used the SEM during capstone week to collect images of vinegar-treated and untreated egg membranes to show her students changes that were occurring with treatment (Fig. 5).

All three of these classroom curriculum modules were enhanced by the images the teachers were able to collect for their projects. In addition, the students were able to see how the tools scientists use enable them to gather information about the topics they study.

3.3 RET participants take the SEM into their communities

During the academic year, two teachers from the RET program borrowed the SEM for two weeks to use in their high school. Staff from IEG transported the TM3000 SEM to Beaver Dam, Wisconsin, a rural community of approximately 16,000 people, set up the microscope, and trained the teachers to use it. During the time the instrument was in Beaver Dam, 553 high-school students, 669 middle-school students and 55 community members interacted with the SEM; thus approximately 8% of the Beaver Dam population was impacted through this program. The local newspaper published two articles on the TM3000 SEM and its impact on the Beaver Dam community. (Fig. 6)

Figure 6. A screenshot of one of the two articles written about the TM3000 SEM in the local Beaver Dam newspaper.

3.4 Summer programs

As part of our vision to introduce K-12 and public audiences to materials science, IEG participates in various summer camp programs. In June 2012, fifteen middle school students came to campus for a weeklong materials science module as part of a three-week College For Kids experience that exposed the students to various disciplines on the UW campus. As part of the materials science module, the students synthesized ZnO nanoparticles and observed them by optical and scanning electron microscopy (Fig 7a). The students were able to see the difference in resolution between the two types of microscopes and gain a better understanding of the types of tools materials scientists use for research. Hitachi, Inc. used a description and photographs of this activity in an article about the TM3000 SEM that was published in a Japanese newspaper similar to the American Wall Street Journal (Fig. 7b).

Figure 7. a) A middle school student uses the SEM to observe ZnO nanoparticles he synthesized. b) An article Hitachi, Inc. published in a Japanese financial newspaper about the SEM and its use in the IEG summer program.

3.5 Community events

During the time the TM3000 was at the University of Wisconsin-Madison, it was used in two large community events.

Figure 8. Middle school students learn about the TM3000 SEM during Engineering Expo on the UW-Madison campus.

On the first Saturday of every month, UW hosts a Science Saturday with a particular theme. When the theme was size and scale, MRSEC faculty brought the SEM to Science Saturday and taught members of the public about the microscope and how to operate it. In addition, over 1000 members of the public had the opportunity to interact with the instrument during the biennial Engineering Expo event held on the UW Engineering campus (Fig 8).

Another type of community activity in which the SEM was utilized, was a Nerd Nite event. Nerd Nite is a monthly event held in more than 50 cities across the world including Madison, WI⁴. Members of the public are invited to attend and listen to local experts talk about their favorite scientific topic in local taverns. Ben Taylor, the assistant director of IEG, gave a talk on honeybee evolution using SEM images of bee anatomy that he had collected on the TM3000 SEM (Fig. 9). Due to the popularity of his talk, Taylor has been invited to present at the international Nerd Nite convention in August 2013.

Figure 9. SEM images used during a Nerd Nite talk on honeybee evolution; bifurcated bee leg hairs (left) and a bee tongue (right).

4. CONCLUSIONS

During the time IEG had the TM3000 SEM, over a thousand K-12 students and members of the general public had the opportunity to use an instrument that is often only available to scientists and engineers. Through these interactions participants learned about size and scale, the challenges of working at the nanoscale, and the tools materials scientists use to do this type of work. Due to the level of excitement generated by the SEM, these events were covered in three newspaper articles. Many members of the UW community and educators in Wisconsin have express interest in borrowing the SEM for use in education and outreach activities.

As a result of the interest and excitement generated by the TM3000 SEM, the UW College of Engineering and the UW Materials Research Science and Engineering Center collaborated to purchase the microscope in February 2013. The SEM is being used for research, instruction in an undergraduate engineering course, and for outreach events. IEG is beginning to develop new materials science curriculum that incorporates the SEM. Finally, the UW is developing a process that will allow local schools and communities to borrow the SEM for up to two weeks.

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