MATERIALS SCIENCE AND ENGINEERING DEPARTMENT

IOWA STATE UNIVERSITY

MSE ELEMENTS

Vol. 13, No. 1

Magnetic refrigeration gets global nod

With its imminent promise to cut global energy demand and reduce carbon dioxide emission, magnetic refrigeration (MR) technology was in the spotlight at the G-8 Energy Ministers Conference, held May 1-3, 2002, in Detroit, Michigan. It was one of eight Department of Energy-sponsored projects chosen by the Office of Science to represent DOE in an exhibit on emerging energy technologies.

Energy ministers from eight countries—the United States, Canada, France, Germany, Italy, Japan, Russia, the United Kingdom—and representatives from the European Union got a first-hand glimpse of a wide range of cutting-edge, energy-related U.S. research—from hydrogen fuel cells and hybrid solar lighting to biobased products, fusion, and renewable energy sources.

MSE Distinguished Professor ***Karl Gschneidner, Jr.,*** and colleague, MSE Professor ***Vitalij Pecharsky*** lead the nation in research on the "magnetocaloric effect"—the ability of certain magnetic materials such as gadolinium to heat when placed in a magnetic field and cool when removed from the field. When used in cooling devices, MR technology eliminates the use of harmful gases or hazardous chemicals and is more energy efficient than conventional refrigerators that use vapor compression.

The temperature on the panel read a cool 44 degrees Fahrenheit as U.S. Secretary of Energy Spencer Abraham listened to Gschneidner explain the workings of the world's first operational room temperature permanent magnet-based magnetic refrigerator.

Although the magnetocaloric phenomenon was observed at room temperature as early as 1881, and the first magnetic refrigerator for cooling near absolute zero was developed by Nobel Prize laureate William Giauque in 1933, large-scale commercial use of near room-temperature units has long awaited improvements in the technology. In the early 1990s Milwaukee-based Astronautics Corporation of America (ACA), a manufacturer of electronic systems and developer of cryogenic coolers using magnetic refrigeration, asked Gschneidner to design less expensive magnetic refrigerants for the liquefaction of hydrogen. Gschneidner was able to develop materials 10 to 30 percent more efficient than ACA was using in its tests and at one-tenth the cost.

With funding from DOE's Advanced Energy Projects Program, ACA collaborated with Gschneidner and Pecharsky (also senior scientists at the Ames Laboratory) to design, build, and test a proof-of-principle, room-temperature magnetic refrigerator. Unveiled in 1997, this unit achieved a record

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Greetings from the MSE department!

Summer has gone in a hurry, and we are back energized for what we expect to be a year of superlatives! Despite budget concerns at the university level, our depart-ment has reached "all-time records" in several areas: our undergraduate enrollment reached 140, the highest ever; the average starting salary for MatE B.S. graduates is the highest in the engineering college for the second year in a row; and MSE department research expenditures reached an all-time high of $14.2 million in FY'01.

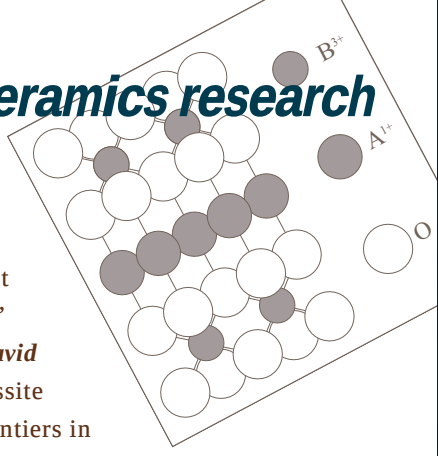
In this issue, we bring you examples of exciting research going on in the department. Professors **Gschneidner** and **Pecharsky's** breakthrough work on magnetic refrigeration materials may lead to a totally revolutionary new refrigeration technology. Their work was one of only eight projects showcased in the G8 Energy Ministers' Summit in Detroit recently. You will also read about an exciting research initiative CNDE received for smart materials from NASA. The initiative is coordinated by MSE Professor and CNDE Director **Bruce Thompson**. Seven projects involving MSE professors have already begun. You will also find an article on transparent conducting oxides, an interesting research project carried out by Professor **David Cann** and his students.

The vertically integrated design course sequence introduced three years ago is receiving excellent support from industry. We have several industrial projects jointly supervised by sponsoring engineers from industry and our faculty. Managing large numbers of projects becomes a challenge when combined with our increasing enrollment. We can always use more industrial projects as well as faculty mentors for those projects, so please let us know if you can provide a project and are willing to work with the students.

We are also very pleased to welcome two outstanding young assistant professors to our faculty. Drs. **Xiaoli Tan** and **Eugene Zubarev** joined our department last month. You will read about their background and interests on page 7.

Once again, we will be in Columbus, Ohio, for the Annual Meeting of TMS this fall. The ISU reception will be held on Tuesday, October 8, at the Hyatt Regency Columbus at the Greater Columbus Convention Center in the Franklin D Room. If you attend the meeting or are in the vicinity, come join us and meet our bright students and excellent faculty.

Pushing the envelope on ceramics research



"Most people wouldn't think of ceramics as good conductors, but that's what makes it interesting," says MSE Assistant Professor ***David Cann***, whose research on delafossite structures is uncovering new frontiers in the field of conducting ceramics.

Most ceramics are insulating, but with careful control in the chemistry and the environment in which they are processed, they can attain high conductivities. Even so, according to Cann, the conductivity of ceramics is often unstable. However, this inherent instability can be exploited, as ceramics can be used as temperature sensors, oxygen sensors, and chemical sensors, and in many other applications.

Delafossite structures were discovered in the 20th century, but only in 1997 were they thrust into the limelight by Japanese researchers at the Tokyo Institute of Technology. The material is unique because of its high conductivity and transparency, making it useful in a wide range of optoelectronic devices. What is even more unusual, according to Cann, is the nature of the conductivity. In solids there are essentially two means of conduction—electrons (n-type) and holes (p-type)—and delafossite materials can be made to conduct both.

The delafossite crystal structure is an assemblage of layers and has closely related electrical and optical properties in the composition of these layers and the way they are stacked. "When a metallic layer, such as Cu, is sandwiched between two ceramic layers, such as Ga_2O_3, it comprises the $CuGaO_2$ structure," Cann explains. "We're looking to modify the structure of the ceramic layer by incorporating different atoms. This will affect the way the ceramic and metal layers in the structure interact and ultimately how the material conducts."

"While most ceramics are good insulators, one needs to push them to the limit by changing the chemistry and/or the atmosphere to make them into conductors," says Cann. Understanding the properties of delafossite structures is one way to make this happen.

Cann's research is supported by a National Science Foundation Career Award and involves undergraduate and graduate student participation.

MSE faculty part of cutting edge
NASA research

The concept of "ageless" aerospace vehicles or those that can sense degradation in their condition and take action on what they have sensed is a new research area that NASA is developing. In a recent $2 million NASA grant awarded to ISU's Center for Nondestructive Evaluation (CNDE), several MSE faculty will contribute their expertise in the areas of fiber optics, nano- and ceramics-based sensors, and materials design to improve the reliability of space vehicles.

"As more aerospace vehicles are built with composite and multi-layered engineering materials, questions about their aging become greater," explains MSE Distinguished Professor and CNDE Director ***Bruce Thompson***, who will head the project.

MSE faculty involved in the grant are ***David Cann, David Jiles, Karl Gschneidner, Jr., Vladimir Tsukruk, Vitalij Pecharsky, Mufit Akinc,*** and ***Steve Martin,*** in addition to faculty from the departments of aerospace, mechanical, and electrical and computer engineering.

The program, "Advanced NDE for future aerospace systems," will also focus on issues associated with NASA's immediate priority: maintaining the safety of human crews in manned space activity. Research topics will include the ability to locate leaks and conduct thorough inspections on vehicles and equipment in outer space, an improved understanding of degradation of composites used in structures, and other nondestructive evaluation needs of space structures.

Continued from page 1

Magnetic refrigeration

cooling power of 600 watts—100 times greater than any previous room temperature magnetic refrigerator.

In June 1997, Gschneidner and Pecharsky announced the discovery of the giant magneto-caloric effect of a new alloy, gadolinium-silicon-germanium (Gd-Si-Ge) that was two to ten times larger than what was being used in the existing proof-of-principle apparatus. Hence, the researchers believed that Gd-Si-Ge would be able to operate at room temperature in a magnetic field produced by a permanent magnet. This discovery opened the door for potential commercial applications in the smaller units used in refrigerators and home and automotive air-conditioning units.

Building on this success and drawing on the results of basic ISU research, ACA developed a new rotary design. Their efforts resulted in a compact unit that runs virtually silently and vibration free, with high efficiency and no harmful emissions. This was the new design that G-8 attendees viewed in May.

So when will a compact, pollutant-free magnetic refrigerator that has received favorable reviews from national energy officials see commercial application?

"It's difficult to predict where the first application will be," speculates Pecharsky. Gschneidner and Pecharsky believe the potential is huge, especially at a time when industry partner ACA is taking the lead in launching the technology. But important issues in private sector funding and federal support still remain to be sorted out. "The next step to commercial reality is to cross the threshold of what is known in industry as the 'valley of death' or the chasm that lies between funding sources and consumer availability," says Pecharsky.

Meanwhile, efforts to add to the technology continue at a steady clip. Gschneidner and Pecharsky along with MSE Professor ***David Jiles*** and Ames Lab researcher ***Seong-Jae Lee*** are currently researching ways to design a permanent magnet configuration capable of producing a magnetic field twice as high, considerably improving the efficiency of the cooling process. The understanding is that the stronger the magnetic field, the greater the cooling power.

"Progress (in this field) is measured in small steps, and this is just another one of those steps," reflects Gschneidner. "However, we've come a long way since first announcing the breakthroughs in the technology and magnetocaloric alloys just five years ago."

Undergrads as industry problem solvers

Heath Reimers

"Everyone had some area of specialization that could be used to advance the effort," Reimers said.

"Industry problem solving is an integral part of the classroom experience for students."

Gone are the days when students' first encounters with industry came through senior-year plant tours. Today, industry problem solving is an integral part of the classroom experience for students, sometimes as early as their sophomore year.

Take, for instance, a project that MatE senior **Heath Reimers** completed this spring at Caterpillar's manufacturing facility in Peoria, Illinois. The goal was to evaluate the quality of used components that the company regularly discarded and to determine if it would be safe to put them back into service for another life cycle. The move held the potential to reduce waste and save money for the company.

Under the supervision of MSE Professor **David Jiles**, Reimers and team members, MatE seniors **Emily Kinser** and **Matt Cambronne**, junior **Casey Harvey**, and sophomore **Craig Bossard,** performed a series of nondestructive evaluation tests on the parts. They learned how to use ultrasonic inspection instrumentation through ISU's Center for Nondestructive Evaluation to conduct a performance analysis to detect flaws. During visits to the Peoria plant and Caterpillar's large engine facility in West Lafayette, Indiana, the students conducted further tests and interacted with industry experts. Their findings were then charted and compiled in a final report to the company.

According to Reimers, teamwork pushed the project along at a steady pace. "Everyone had some area of specialization that could be used to advance the effort," he said, "so we didn't have to rely on any *one* individual to get the project done."

Kinser felt she benefited from being able to contribute to the project starting her sophomore year and continuing it as a senior. "I sensed an evolution in my role as a team member from a young sophomore who had minimal knowledge of industry or materials science to a veteran of the project in a managerial role," she recalled. Both Reimers and Kinser acknowledge critical help provided by industry contact Doug Rebinsky.

"These projects provide real-world experiences," said MSE Professor **Steve Martin**, who helped coordinate the team assignments. "Students meet challenges along the way, but it has a way of teaching them that the process is just as important as the final product." Other companies that have helped students learn through design projects include Pratt & Whitney, Deere, Sperry, Kohler, Rockwell Collins, Sauer-Danfoss, Inc., and research units at Ames Lab and Iowa State.

As for the final outcome, Reimers is happy to report that Caterpillar was very pleased with the results, enough to pique the interest of higher-ups in the company by way of questions and comments.

Additional projects from industry are always welcome. As MSE undergraduate enrollments grow, the number of student design projects that can be done also increases.

Please contact David Jiles (515-294-9685, magnetics@ameslab.gov) or Steve Martin (515-294-0745, swmartin@iastate.edu) if your company has a potential design project.

MSE is cool and growing

The numbers are impressive—from 80 students five years ago to 140 this semester. Undergraduate enrollment in the department has surged, and MSE Assistant Department Chair and Professor **Larry Genalo**, in charge of recruitment and curriculum, confidently points to several reasons for these heartening statistics.

For starters, materials engineering has gained visibility on par with other traditional branches of engineering in the eyes of Iowa high-school seniors. The department's sustained participation in College of Engineering recruiting programs, such as the Program for Women in Science and Engineering and Scholar's Day, has helped significantly.

Another part is the many trips Genalo along with materials engineering undergraduates take to various K-12 schools throughout Iowa and the neighboring states. Their demonstrations have gotten kids interested, not only in math and science, but in materials engineering as well. "Our demonstrations relate well to what students are learning in high-school science, including basic applications in physics and chemistry," said Genalo—enough to get them to look at the exciting things going on in the department, whether it's research in magnetic refrigeration, fiber optics, or bone implants.

Along with a jump in enrollment, Genalo also stresses that the department continues to attract highly qualified students. About 10% are National Merit Scholars and half are honor students with high scholastic achievement aptitude scores. Moreover, female students account for 30% of total enrollment, one of the highest in the engineering college. This year the department awarded a number of academic scholarships, again attesting to the pool of talented freshmen entering MSE. "When you attract good students, they're going to qualify for more scholarships, which becomes a valid recruiting mechanism in itself."

So what does a rising tide mean for department resources? More lab sections and much more faculty time spent in teaching these additional sections, according to MSE Chair and Professor **Mufit Akinc**. MSE does not employ teaching assistants, which means faculty will be teaching both the lectures and labs. "We hope some of these problems will be alleviated at least in part when we move to Hoover Hall in a year or so," Akinc added. Hoover Hall means more lab space and better facilities. It will also help provide a quality teaching environment and will be an additional recruitment tool.

MSE grads move on to jobs and degrees

The MSE department graduated 23 students over the past year, with four earning both undergraduate and graduate degrees. All graduates are currently employed in their field, attending graduate school, or pursuing other interests.

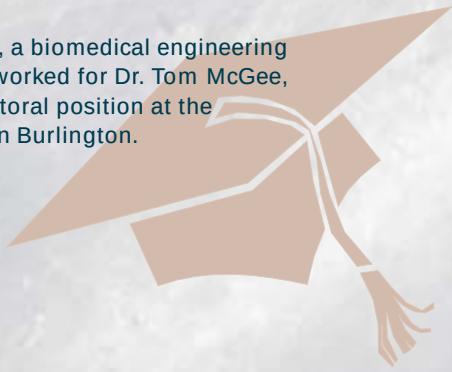
It was a good year for MSE grads and potentially an even better year for their employers!

Texas claimed two students—**Adam Buckalew** (MatE) is at Boeing, and **Ernest Hofer** (MatE) is employed by Bell Helicopter. Some elected to stay in Iowa—**Kimberly Brueske** (MatE) is employed by Maytag in Newton, **Michael Foubert** (MatE) is at Ames Lab, and **Eric Straw** (MatE) is working for Fansteel/Wellman Dynamics in Creston. The remaining grads chose graduate school. **Luke England** (MatE), **Henry Kang** (CerE), **Justin Peters** (MatE), and **Jason Saienga** (CerE), are all currently graduate students in the MSE department at ISU. **Jon Ihlefeld** (MatE) is in MSE at North Carolina State University, **Michael Krashin** (MatE) is in law school at Loyola University in Chicago, and **Nicole Stephenson** (MatE) is studying biomedical engineering at the University of Iowa.

Tiffany Byrne (MatE/MSE), **Justin Riney** (MatE/MSE), and **Kurt Ulmer** (CerE/MSE) received both bachelor's and master's degrees as part of the MSE B.S./M.S. program as did **Kevin Sutherland**, featured in the MSE newsletter last fall.

Intel was the employer of choice for three master's students—**Tiffany Byrne** (MSE) and **John Meyers** (MSE) are in Phoenix, Arizona, while **Kurt Ulmer** (MSE) is in Oregon. Three other grads are continuing work they had while returning to graduate school—**Matthew Besser** (MSE) is a scientist at Ames Lab, **David Hillman** (MSE) is in a permanent position at Rockwell Collins in Cedar Rapids, Iowa, and **Eric Johnson** (MSE) continues to work for John Deere in Moline, Illinois. **Justin Riney** (MSE) will be doing missionary work in Norway. Plans are not known for **Vitaliy Ivchenko** (MSE) and **Xiaowen Zhai** (MSE).

Maria Roemhildt, Ph.D., a biomedical engineering graduate student who worked for Dr. Tom McGee, has accepted a postdoctoral position at the University of Vermont in Burlington.



MSE Emeritus Distinguished Professor addresses scholarship recipients


John Verhoeven

More than $44,000 in scholarship money was given out at this year's MSE awards banquet—a 76% increase over last year! Forty-two students benefited from the generosity of alumni, industry, and friends of the department and college.

The banquet was held April 11, 2002, in the Scheman Building at the Iowa State Center. Thirty-two new scholarships were presented in addition to eleven continuing National Merit Award recipients. Two students, two faculty, and one staff member were also honored with special achievement awards.

The keynote speaker was *John Verhoeven*, an MSE Emeritus Distinguished Professor, who spoke on Damascus steel and modern-day efforts to replicate its forging process. Working with a blacksmith, Verhoeven has developed a method that produces sword blades matching the original museum blades in both surface pattern appearance and internal microstructures.

Verhoeven spent his professional career teaching metallurgy courses at ISU and doing research in physical metallurgy, funded mainly through Ames Lab. In 1985 Verhoeven became an Anson Marston Distinguished Professor in Engineering.

In addition to an exceptional increase in scholarship money received, approximately 120 people attended this year's ceremony—a record-breaker awards banquet!

Scholarship Recipients

L. C. "Doc" and Lina Allen Scholarship
Christopher Pruess

Dorothy Avery and Maurice Clark Scholarship
Bryan Baker

Samuel Walker Beyer Scholarship
Matt Cambronne

Oscar L. Bock Scholarship
Darrel Enyart

Otto and Martha Buck Materials Science and Engineering Scholarship
Eric Wagner

Clarence Ford Scholarship
Jonathon Goldie

Murray Gautsch Scholarship
Jon Bolluyt

Frank Kayser Memorial Scholarship
Heath Walker

David C. Lovell Scholarship
Tyson Pederson

Mary and Donald Martin Scholarship
Daniel Bakken

Frank S. McCutcheon III Scholarship
Kristin Johannsen

David T. Peterson Scholarship
Meagen Marquardt

Roderick Seward, Flossie Ratcliffe and Helen M. Galloway Scholarship
Michael Dau
Jeff Nissen

Gordon Stiles Scholarship
Christopher Hansen

David R. Wilder Scholarship
Ryan Haase

Deere and Company Scholarship
Shannon Dudley
Joshua Huffman
Rachel Neuendorf
Jessica Raim

S.A.M.E.-NY City Post/William J. Hunkin II Scholarship
David Leege

Square D Foundation Scholarship
Emily Kinser

Engineers Week Scholarship
Meredith Berger
Kent Heitman
Kristin Schipull

Materials Engineering Alumni Scholarships
Ryan Anderson
Nathan Ashmore
Jason Holzmueller
Andrew Manning
Nathaniel Phillips
Neal Porter
Amber Schneeweis

2002–2003 MSE National Merit Scholars
Andrew Becker
Drew Enlow
Christopher Hansen
Joshua Huffman
Jeffrey Leib
Colleen Prosser
Michael Schmidt
Amber Schneeweis
Paul Stanley
Scott Williams
Benjamin Zimmerman

Special Achievement Award Recipients

Departmental Research Award
MSE Associate Professor
Brian Gleeson

Departmental Service Award
MSE Staff Member
Krista Briley

Outstanding Senior Award
Jon Ihlefeld

Student Leadership and Service Award
Luke England

Teaching Effectiveness Award
MSE Associate Professor
Alan Russell

Welcome aboard!

Xiaoli Tan comes to ISU from the University of Illinois at Urbana-Champaign where he completed his Ph.D. this past August. Tan's B.E. and M.S. degrees are from Xi'an Jiaotong University in the People's Republic of China. At Illinois, Tan conducted studies on domain switching and piezoelectric single crystals and ceramics. His research plans at ISU include work in the area of ferroelectric thin films processing, characterization of single crystals for potential applications in ultrasonic nondestructive evaluation, and in-situ TEM study of deformation mechanisms in metal thin films. Tan's family includes his wife, a six-year-old daughter, and a four-year-old son.

Eugene Zubarev was most recently a research associate at Northwestern University in Evanston, Illinois, working in the area of self-assembling dendron rodcoil molecules. Prior to that, he had a postdoctoral appointment at the University of Illinois at Urbana-Champaign. He received his Ph.D. in polymer chemistry from Moscow State University and his B.S. in chemistry from the same institution. Zubarev's research will center on the synthesis of well-defined polymers and shape-persistent organic nanostructures. Zubarev brings his wife and five-year-old daughter with him to Ames.

Courtesy appointments

Patricia A.Thiel, Distinguished Professor of Chemistry at Iowa State, and Michael G. Conzemius, Associate Professor at ISU's Veterinary Clinic Sciences department, join the MSE department on courtesy appointments this fall. In addition, Gundor Gunduz will serve as a visiting professor from the Middle East Technological University in Turkey.

Otaigbe leaves

Joshua Otaigbe left ISU in August of this year to move to Hattiesburg, Mississippi. He has accepted a tenured faculty position at the School of Polymer Science and Engineering at The University of Southern Mississippi. Although he will be missed in the department, we wish him luck with this future endeavor.

Keep us informed . . .

The MSE department also welcomes alumni donations. Your contributions help fund student facilities and projects, lab equipment, faculty teaching and research, and department activities.

Name_____E-mail _____

Graduation year, degree, student name *(if different from above)*

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Home address _____

City_____ State _____ Zip _____

Work address _____

Company, position _____

What's new _____

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Send your information to: MSE Department, Iowa State University
3053 Gilman Hall, Ames, Iowa 50011-3114
Or E-mail: mse@iastate.edu
Fax: (515) 294-5444
Web site: www.mse.iastate.edu/people/post_it.htm

Cybercontacts

Nathan Iverson
BSCerE'97
nateiverson@netzero.net
Lafayette, Colorado
He is doing an internship with a start-up company called Vicom Systems and is taking embedded system design classes at Colorado University this fall.

Doug Packard
MSPhysics'60
dc-pack@worldnet.att.net
Richland, Washington

Have you seen Hoover Hall lately?
The Web cam doesn't show it, but the skywalk is starting to happen!

Bissell Road was closed shortly after classes ended in May, and skywalk preparation began. The Howe Hall connection will occur on the front glass at the 2nd-floor hallway. The east end of the skywalk will flare where it joins Hoover (also at a 2nd-floor hallway) to provide a good view of the Marston Water Tower. The water tower will also be the focus of the atrium in Hoover. Plans call for floor-to-ceiling glass on the north side of the building where the walls curve between the classrooms and the auditorium.

The glass walls aren't the only architectural feature the two buildings have in common. In keeping with the Engineering Teaching and Research Complex identity, the same ribbon windows used in Howe will be exhibited in Hoover.

As for Bissell Road, costs prohibit "gating" initially but the idea will be left open as a future possibility. There will be a small incline in the road between Howe and Hoover and traffic will be cut from four lanes to two in that plaza area.

And above those two lanes of traffic, the skywalk, totally glass enclosed and with a concrete deck, should be ready for heat by this December.

Hoover Hall update www.eng.iastate.edu

Click on Hoover Hall Web Cam for additional photos.

Materials Science and Engineering Department
Iowa State University
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Ames, Iowa 50011-3114

JOIN US IN COLUMBUS, OHIO!

Alumni Reception at the TMS Fall Meeting

Tuesday, October 8, 2002

5:30 - 6:30 p.m.

Hyatt Regency Columbus Franklin D Room

Greater Columbus Convention Center

TMS
Minerals • Metals • Materials

MSE ELEMENTS

Vol.13, No. 1

Published twice each year by the Department of Materials Science and Engineering at Iowa State University.

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Prepared for the department by Engineering Communications and Marketing, College of Engineering, Iowa State University. ISU-ECM-03081

2002 FALL CONFERENCE

Iowa Science Teachers

Thursday, October 17, 2002

Polk County Convention Complex

ISU Family Weekend

September 20-22, 2002

Homecoming

October 11-13, 2002

IOWA STATE UNIVERSITY