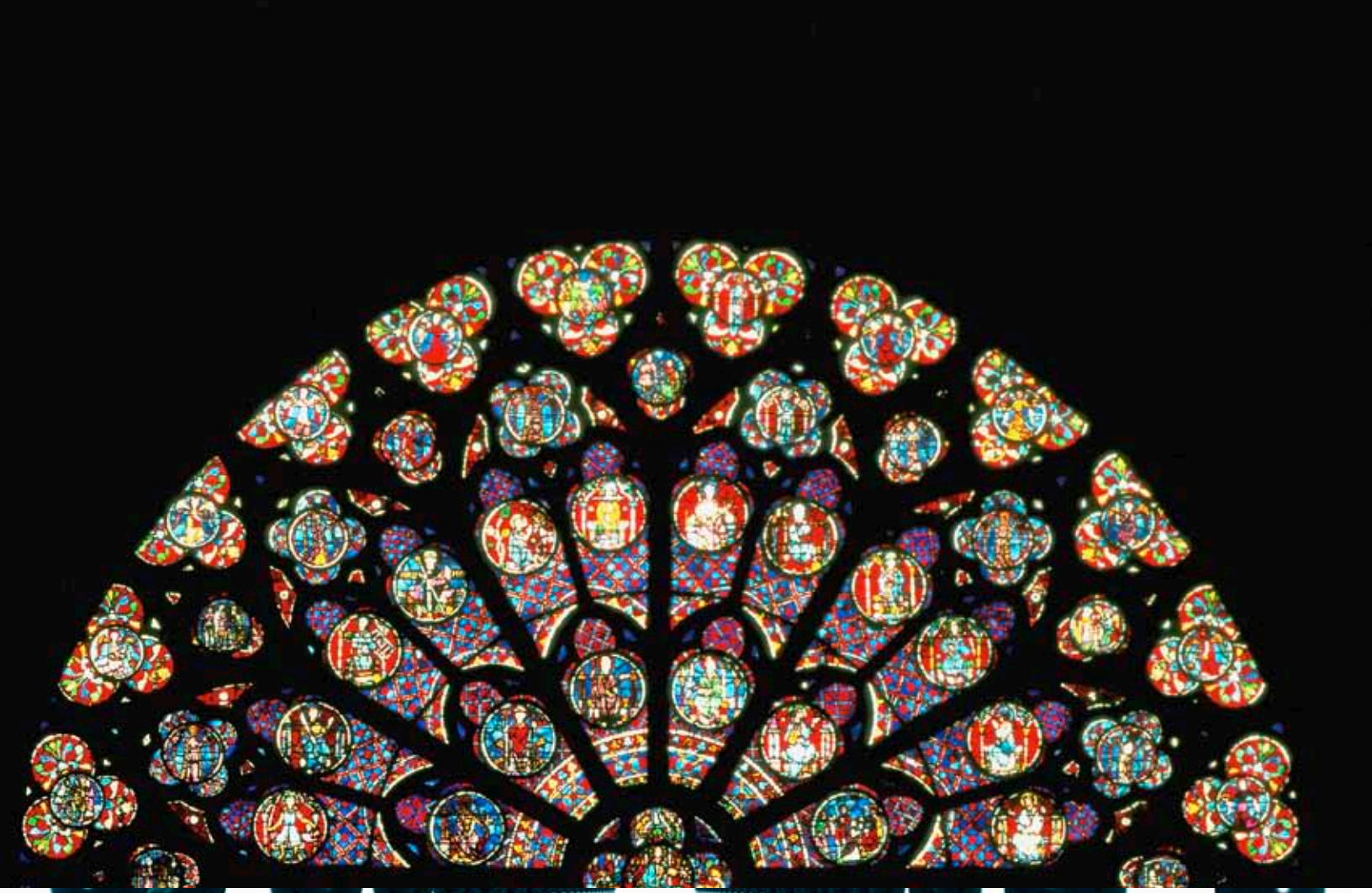

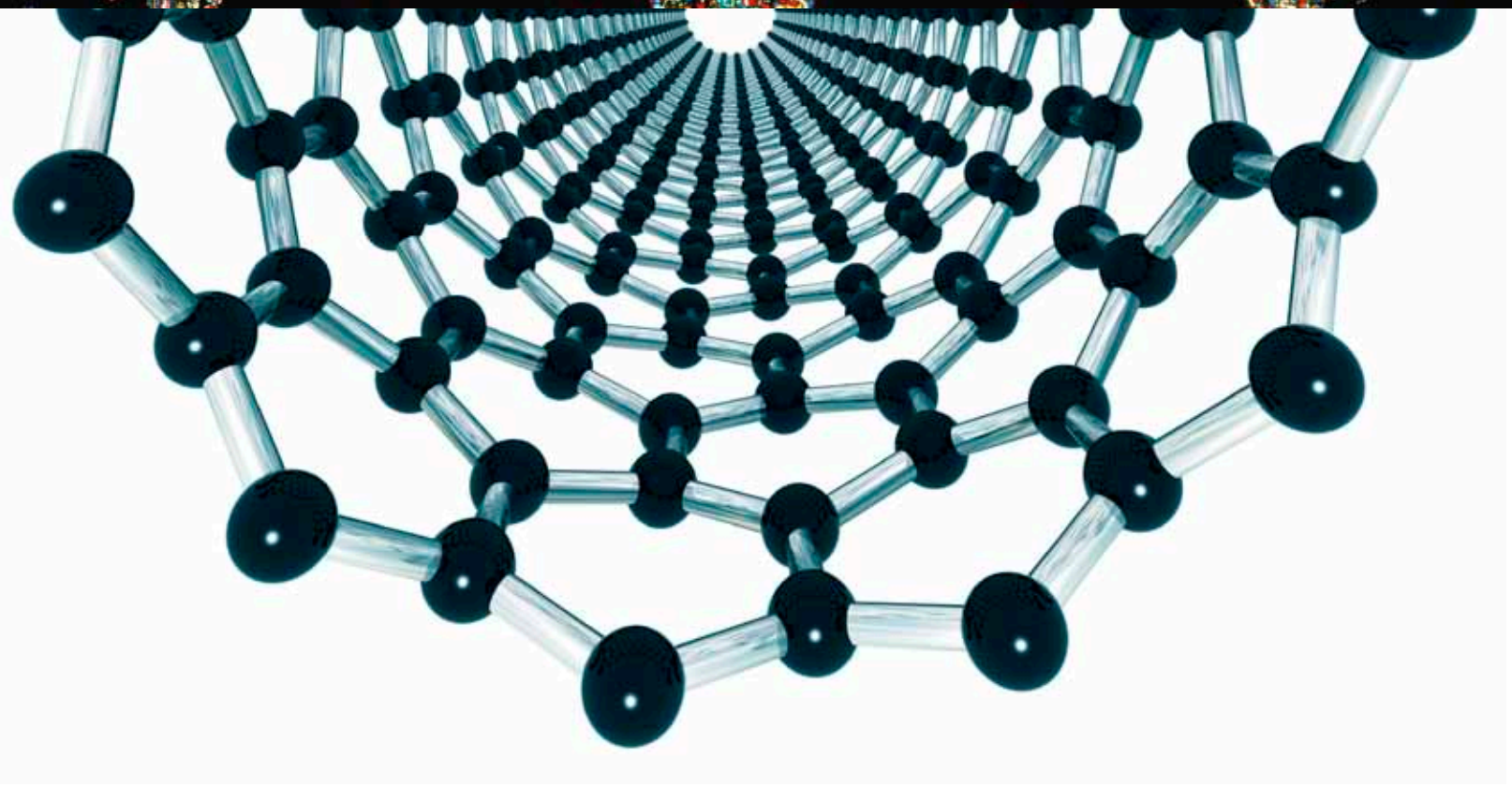

STAINED GLASS, BATTERIES AND THE BRAIN

WHAT DO BRILLIANTLY COLORED glass, advanced batteries, and innovative technology to regulate brain functions have in common? The answer according to Professor Haim Grebel: they all involve nanoscale structures far smaller than the wavelengths of energy coursing through them in different regions of the electromagnetic spectrum. [CONTINUED]

Investigating how light interacts with a wide range of materials in the world of the amazingly small has occupied Grebel for much of his career. He often works with structures measured in nanometers. At a billionth of a meter, or the equivalent of ten hydrogen atoms in a row, a nanometer is indeed very small. Yet even though the scale of optical wavelengths is far larger than a few nanometers, the effect of nanostructures on wave propagation can be profound, and Grebel's efforts have important real-world implications in fields ranging from communications and computing to electric power production and medicine.

PHOTO: DOUG PLUMMER

Professor Haim Grebel

ANCIENT ARTISANS KNEW

"They didn't understand the theory, of course, but Roman and medieval craftsmen discovered that adding metallic elements like gold and silver to glass created brilliant colors which have lasted for thousands of years," Grebel says by way of introducing the basics of his research. "It's the manner in which nanoparticles of these elements interact with certain frequencies of visible light that produces such colors. We now have a better understanding of the basic scientific principles and can extend our investigation to man-made materials and structures."

Although very distant in time and very different in purpose, there is a connection between the interplay of light and metallic nanostructures in the research conducted by Grebel today. The link involves what are known as surface plasmons – coherent charge waves on metallic surfaces. Understanding this phenomenon has led to the development of unique infrared filters for the National Aeronautics and Space Administration, and to new biomedical platforms for studying viruses.

A related avenue of investigation has entailed visible plasmon laser technology. These lasers, confined to the surface of metal electrodes, could lead to the creation of practical nanoscale optical sources for medical diagnostics and ultra-fast communications in computer chips that continue to decrease in size.

The significance of Grebel's research is underscored by the funding he has received from sources that include the U.S. Army and Navy as well as the National Science Foundation. His work as a member of the Department of Electrical and Computer Engineering was also recognized in 2009 with the NJIT Excellence in Research Award. In 2011, Grebel joins the distinguished group of faculty honored with the NJIT Overseers Excellence in Research Prize and Medal.

In recent years, graphene and carbon nanotubes have been a major focus of Grebel's investigations. Graphene, a two-dimensional carbon crystal that is a single atom thick, can be rolled into nanotubes which are one nanometer in diameter. These are the materials that could be fundamental to dramatic breakthroughs in battery technology, the creation of implantable nanoscale devices that counteract malfunctions in the brain, and other beneficial applications yet to be imagined.

Graphene and carbon nanotubes take researchers into the realm of structures that do not exist naturally and which have originated in the laboratory. Grebel says that the theoretical possibilities of such structures have been discussed for decades, especially with respect to creating the ever smaller transistors long viewed as essential for ever faster computing. "But if we are truly creative in our thinking, if we ask the right questions, the unique properties of these materials will yield unexpected insights and uses. The key is to let yourself dream."

"WE'RE STILL WORKING TO UNDERSTAND THE FUNDAMENTAL PROPERTIES OF GRAPHENE AND CARBON NANOTUBES, AND THAT'S WHERE THE REAL EXCITEMENT IS. WE HOPE THIS WILL LEAD TO FURTHER DISCOVERIES." *– Professor Haim Grebel*

INSPIRED BY EINSTEIN

Grebel says that he was inspired to explore the unexpected in science, and specifically to study physics, by a book that Albert Einstein wrote to explain his theories of relativity to the general public. "Einstein asked himself questions about beams of light that no one had thought of before. Reading his book convinced me that if you think hard enough about something you may make discoveries that seem crazy at first, but which could be proven true and add to our knowledge of the world."

After earning his PhD at the internationally renowned Weizmann Institute of Science in Israel, Grebel came to the U.S. and worked at Stevens Institute of Technology. He has been at NJIT since the mid-1980s, where he's also director of the university's Electronic Imaging Center and a member of the Materials Science and Engineering Program.

"Toni Morrison, who spoke at my daughter's recent Rutgers commencement, challenged all in her audience to find a direction in life that is fulfilling and genuinely meaningful," Grebel relates in reflecting on his career choices. "Science does this for me; it's my niche."

Wryly, he goes on to comment, "I also hope that what I do has some meaning for other people. My PhD advisor said that our work should matter to at least one other person. So that's what I like to believe, that my research is of interest to at least one other person."

With a nod to Richard Feynman, the Nobel Prize-winning American physicist, Grebel adds, "You can't do good work in a vacuum. Otherwise, at the end of the day, you just wind up talking to yourself. You need to be surrounded by intellectual curiosity at all levels, the curiosity of students and colleagues, and to benefit from both positive and negative feedback."

The recognition that Grebel has garnered as a researcher and educator indicates that what he does is significant to a substantial number of people, including the many PhD candidates he has mentored as they pursued their degrees. For Grebel, the academic environment offers special opportunities for stimulating and meaningful interaction.

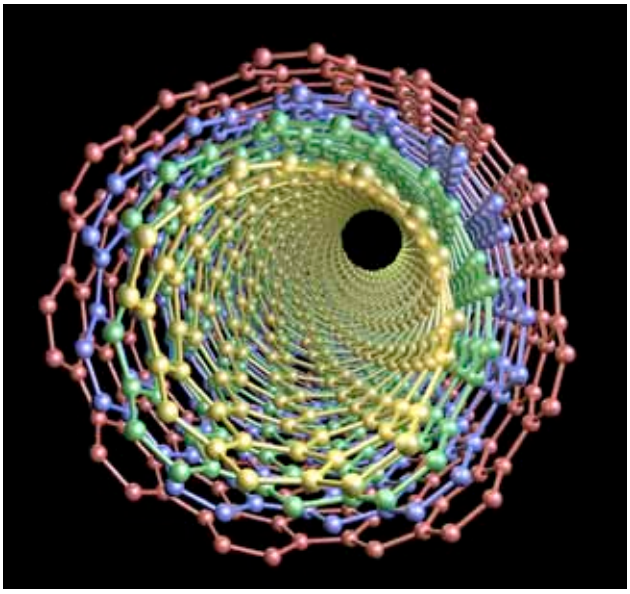

Illustration of a multi-walled carbon nanotube – a material that could lead to breakthroughs in communications, computing and medicine, and to applications yet to be imagined.

Alumnus Nan Ni says that Grebel helped him channel his own curiosity toward successful completion of his PhD in 2007. "I was really encouraged to 'learn how to learn' while following my interest in antenna design." Today, Ni is applying the knowledge he gained at NJIT and the analytical skills sharpened with Grebel's guidance to his work at Amalfi Semiconductor in California. Amalfi was founded in 2003 to develop solutions for one of the most challenging technical issues in wireless communications – the power consumption of cellular handsets.

John Tobias, a 2002 PhD alumnus, offers a comparable perspective. He says that he was guided in his dissertation research by Grebel as if he were a colleague. His work focused on the propagation of electromagnetic energy in ordered structures also known as photonic crystals. A significant aspect of this research was its scalability to microwave frequencies. In addition, Tobias commends Grebel and NJIT for supporting his pursuit of a doctorate while simultaneously working for the U.S. Army and building his own company, ElectroQuest, whose services include assuring the integrity of systems and structures against electromagnetic disruptions such as lightning strikes.

"PROFESSOR GREBEL IS ALWAYS THERE TO HELP YOU AS A VERY CONCERNED TEACHER AND COLLEAGUE. HE EVEN DOES HIS BEST TO REPAIR OUR EQUIPMENT HIMSELF WHEN THERE IS A PROBLEM." *– Amrita Banerjee*

HANDS-ON ADVANCES

Grebel is not only inspired by the intellectual stimulation afforded by students and colleagues at NJIT. He also values the ability to fabricate functioning devices incorporating carbon nanotubes and graphene. "There are very few schools where the entire process can be completed at the same location and NJIT is certainly one of them. Our students are involved every step of the way, which is very important and satisfying for me." Such "table-top" prototypes push creative thinking still further, which is critical in this very competitive field.

PhD candidate Amrita Banerjee recently took this step with the guidance of both Grebel and Research Professor Karl Moeller. She combined graphene and perforated copper screens to improve the detection of swine and avian flu viruses using infrared (IR) spectroscopy. The project was related to the focus of her doctoral dissertation on "graphene-coated substrates for biochemical and opto-electronic applications."

The affinity between graphene and organic material was key to creating a biocompatible platform that enhanced the IR signals, thus differentiating between the two viruses. IR and other types of spectroscopic analysis enhanced by appropriate graphene-coated substrates offer the potential for faster and more precise characterization of diverse biological materials, including E. coli, Salmonella, and even Anthrax bacteria. This could also be a superior approach to researching targeted drug delivery and evaluating the efficacy of drugs.

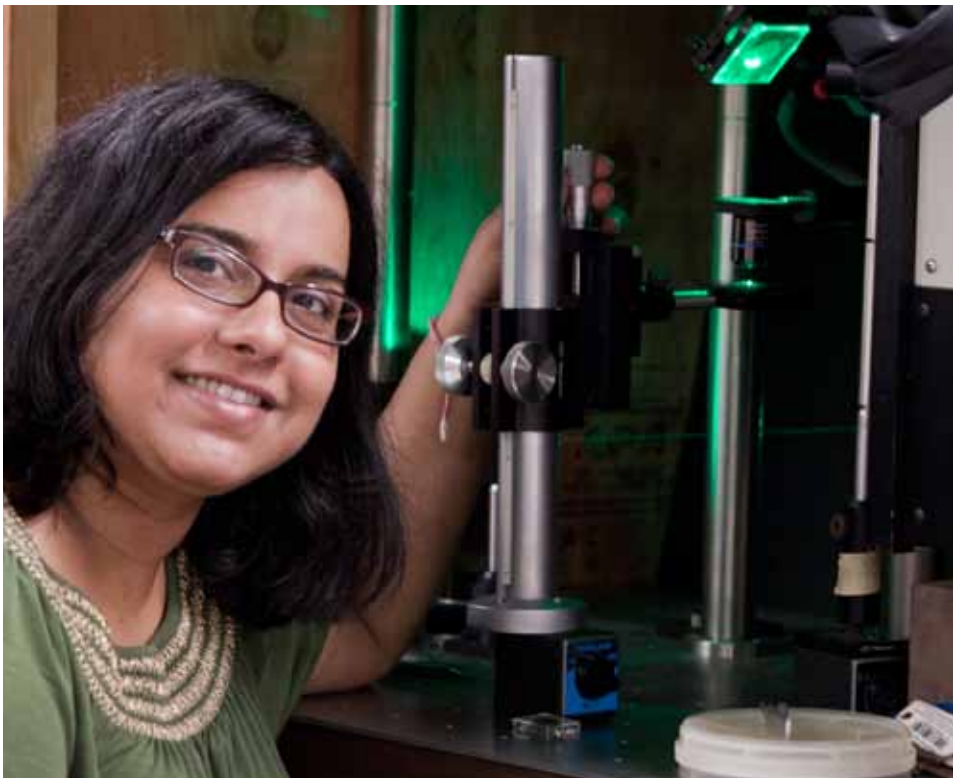

PHOTO: JED MEDINA

Doctoral student Amrita Banerjee has worked with Professor Haim Grebel, her dissertation advisor, on using graphene to develop better techniques for detecting and characterizing viruses and bacteria.

"Professor Grebel is always there to help you as a very concerned teacher and colleague," Banerjee says. "He even does his best to repair our equipment himself when there is a problem."

Grebel and Banerjee are in the process of applying for patents covering their work with the deposition of graphene on various substrates and its implications for spectroscopic analysis. These patents would join dozens of others on which Dr. Grebel is currently listed as co-inventor. Such wide recognition demonstrates the broad significance of Grebel's work in a variety of related areas.

In surveying the real-world potential of graphene and carbon nanotubes, Grebel says that their unique properties could lead to extraordinarily small and fast transistors,

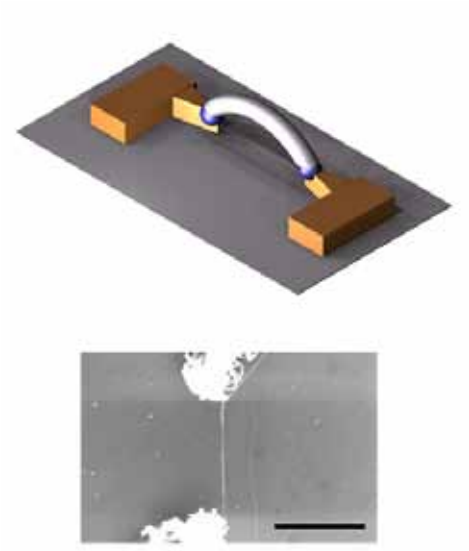

Diagram and actual photo of a carbon nanotube (CNT) bridge formed with a CNT bundle connecting electrodes as part of an electro-optics circuit. Growing carbon nanotubes at pre-designated positions is one of the challenges that Haim Grebel and NJIT colleagues have investigated in their efforts to advance the development of practical nanoscale electro-optic devices.

flexible flat-screen displays and solar panels, and batteries with the integral capacity to replenish their charge from solar energy. He even foresees using the capacity of these materials to regulate the flow of ions to create "pacemakers for the brain," implantable nanoscale devices to correct irregular patterns of brain activity caused by disease or injury.

But as important as these applications are, they constitute "traditional thinking" in Grebel's estimation. "We're still working to understand the fundamental properties of graphene and carbon nanotubes, and that's where the real excitement is," he says. "We hope this will lead to further discoveries – we need to dream out loud."

Grebel is clearly not one to compromise on the breadth of vision for his research. Comparably, it is said that when Benjamin Franklin watched the ascent of the hot air balloon invented by the Montgolfier brothers in the 18th century someone asked, "What good is this thing?" Franklin replied with characteristic wit, "What good is an infant?"

When it comes to his own investigation of phenomena in the realm of the incredibly small, Professor Haim Grebel definitely shares Franklin's point of view. ■

Author: Dean L. Maskevich is editor of NJIT Magazine.

AWARD WINNERS

EXCELLENCE IN EXTENDING KNOWLEDGE

The NJIT Board of Overseers Excellence in Research Prize and Medal, an award inaugurated in 2008, is bestowed on individuals who have been NJIT faculty members for at least five years in recognition of contributions that have singularly enhanced the reputation of the university.

In speaking of this honor, Emil C. Herkert, chairman emeritus of the Board of Overseers, has said, "Before I joined the Board, I knew that NJIT educated the highest-caliber professionals in engineering and many other scientific and technological disciplines. As an Overseer, however, I have learned much more about an institution that has enabled talented young men and women to achieve great personal success for well over a century. I have come to fully appreciate the scope and significance of NJIT's engagement in leading-edge research on the frontiers of knowledge."

Now chaired by Philip L. Rinaldi '68, MS '76, the Board of Overseers continues to support the pursuit of excellence in research, initiatives that look forward in time to a future where our fund of knowledge will be greater than it is today. The point in time when a particular investigation might be most fruitful could be a year from now, perhaps even a decade ahead. What matters is that talented investigators are encouraged to embark on voyages of discovery leading to knowledge which often proves to be useful as well as new. It is the excitement of the voyage itself that is the compelling spirit of excellence in research.

In 2011, Professor Haim Grebel joins the three other exceptional faculty who have been honored with the NJIT Overseers Excellence in Research Prize and Medal since its inception:

2010 – David B. Rothenberg
Professor of Humanities

2009 – Kamalesh K. Sirkar
Distinguished Professor of Chemical Engineering and Foundation Professor in Membrane Separations

2008 – Philip R. Goode
Distinguished Professor of Physics and Director of the Center for Solar-Terrestrial Research