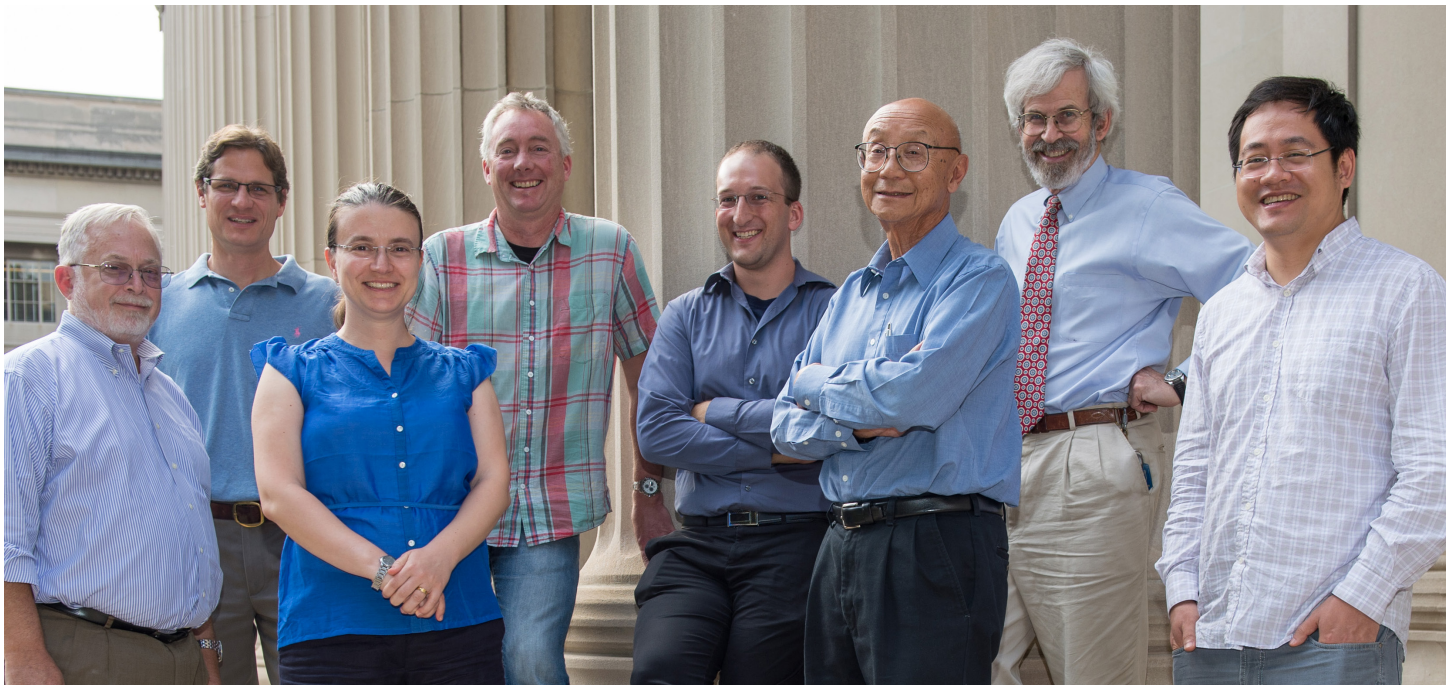
Department of Nuclear Science and Engineering
Massachusetts Institute of Technology

SPOTLIGHT ON **NSE EDUCATION**

Understanding and predicting materials behavior: NSE takes an interdisciplinary approach



L to R: Ronald Ballinger, Thomas McKrell, Bilge Yildiz, Dennis Whyte, Michael Short, Sidney Yip, Linn Hobbs, Ju Li.

One of the great challenges in the world of nuclear engineering is the behavior of materials under extraordinarily harsh conditions. Over time, the intense radiation, high temperatures and stresses, and corrosive environments in fission and fusion reactors alter material properties and behavior; understanding these changes is central to effective reactor design and operation.

"Strategic planning in the Nuclear Science and Engineering department is leading us to a greater emphasis on materials in extreme environments, in both education and research," explains NSE associate professor Bilge Yildiz, who has taught the department's class on nuclear materials since 2008. "Experimentally and computationally, understanding and predicting how materials evolve as they age in nuclear environments is essential."

To learn more about NSE please contact
Professor Richard K. Lester, Head
Department of Nuclear Science & Engineering
rklester@mit.edu

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Close coupling of computer simulations with experiments is an important approach for developing new knowledge of nuclear materials. For this reason, undergraduates and graduate students who take the nuclear materials class must complete an end-of-term computation or experimental project on a subject of their choice, with input from guest lecturers.

"It's a great opportunity for our students," says Yildiz. "Not just for nuclear materials, but for the whole range of nuclear work, where computational modeling and simulation is increasingly important." This importance is exemplified by Professor Ju Li's subject in Computational Nuclear Science and Engineering, which teaches programming, algorithms, and modeling.

On the experimental side, a number of MIT NSE faculty are working to develop in-situ techniques for probing material behavior under functional conditions similar to those found in reactor chambers, both to validate simulations and gain new insights. "You can do a post-mortem, but it's important to be able to see what's going on in real time, the dynamic evolution of the materials, because mechanisms of structural evolution cannot be captured post-mortem," notes Yildiz.

NSE Professor Dennis Whyte is using this approach to explore plasma-surface interactions, a central issue in fusion reactor design, while Li is developing better understanding of charge/discharge mechanisms in battery materials. Yildiz is probing structure-reactivity-stability relations on surfaces in fuel cells, and corrosion at elevated temperatures.

Materials work at NSE is also increasingly engaged with the Institute's Materials Science and Engineering and Mechanical Engineering departments, developing interdisciplinary knowledge through several broad initiatives. These include the Department of Energy-sponsored Consortium for Advanced Modeling of Light-Water Reactors, which is focused primarily on nuclear fuel-related challenges, including fuel rod cladding – the slender tubes that hold fuel pellets while they are in use in fission reactors.

Cladding is a critical element in reactor safety, and its operational lifetime is an important factor in the entire nuclear fuel cycle. Notes Yildiz, "The rods are in the reactor for a few years, and they're subject to irradiation, corrosion, and the deposition of 'crud.' If we know more about how these mechanisms degrade the material properties, we can make better lifetime predictions, do more effective design, and also reduce uncertainty, which allows us to get better performance without reducing safety margins."

Another interdisciplinary project is the DoE's COFFEI effort (Chemo-mechanics of Far-From-Equilibrium Interfaces), which is centered at MIT's Materials Processing Center and Materials Science and Engineering Department. "We're looking at how lattice strain affects oxygen transport and reactions on high-temperature oxides, which come into play in fuel cells and reactor materials," says Yildiz.

Going forward, NSE is looking to expand the educational side of its materials work. Consideration is being given to making the materials class a requirement rather than an elective, and the establishment of additional class offerings is also a possible step.

"There are two basic things we want to give to our students," says Yildiz. "First, the general principles of nuclear science and engineering, the core they need to understand our discipline. And second, knowledge that will be helpful to them in their area of specialization or research. Materials knowledge currently falls into the latter category. We need to provide them with a good amount of insight into how materials age in a nuclear environment, which they can utilize as they go deeper in their research."

Written by Peter Dunn
Photo by Justin Knight