THE EXPLORATORY ADVANCED RESEARCH PROGRAM

NANOSCALE APPROACHES

for Highway Research

EXPLORATORY ADVANCED **RESEARCH**

Breakthrough Ideas for Highway Research

THE FEDERAL government spent approximately $1.5 billion on nanoscale research in FY 2008. Work directly related to highway research represented less than one-tenth of 1 percent of that figure. The Federal Highway Administration (FHWA) is working closely with government, industry, academic, and international partners to push forward a strategic investment in nanoscale research. FHWA's Exploratory Advanced Research (EAR) Program has been investigating nanoscale research conducted in relation to highways, and this process led to a March 2009 workshop involving almost two dozen experts from academia and other Federal programs. These experts met to share their understanding of nanoscale research and to learn about key highway research issues in infrastructure, safety, operations, and environment.

Michael Trentacoste, FHWA Associate Administrator for Research, Development, and Technology and Turner-Fairbank Highway Research Center (TFHRC) Director, said at the opening of the workshop that, "FHWA needs new research methods and new partnerships to face broad challenges and to work toward crash-free, longer lasting, and lower impact highways."

Opportunities and Challenges for Nanoscale Research

Nanoscale science, or nanotechnology, is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers. One nanometer is 100,000 times smaller than the width of a human hair.

An opening question at the workshop for both program managers and researchers was, Why spotlight nanoscale opportunities in highway research? Highway transportation research engages in addressing broad, long-term societal goals, such as public health and safety, sustainability, and environmental stewardship. As scientific research moves to smaller scales, new and innovative research methods and partnerships are needed to solve complex questions. As with other areas of science and engineering, highway research also is moving toward investigating phenomena at smaller scales. Assessing relevant opportunities from work being developed for other industries can accelerate breakthroughs in highway research. Spotlighting nanoscale research can accelerate the ability of researchers to measure, model, and manipulate matter at the nanoscale in pursuit of solving highway research needs.

As part of FHWA's ongoing strategy, the workshop was a critical step in scoping areas of opportunity for investment and assessing funding levels for nanoscale research that support highway research needs. The workshop provided the opportunity to:

- Inform the highway research community about nanoscale studies relevant to highway research.
- Inform nanoscale researchers about highway research needs.
- Identify potential opportunities for investing EAR Program funds within the nanoscale focus areas.

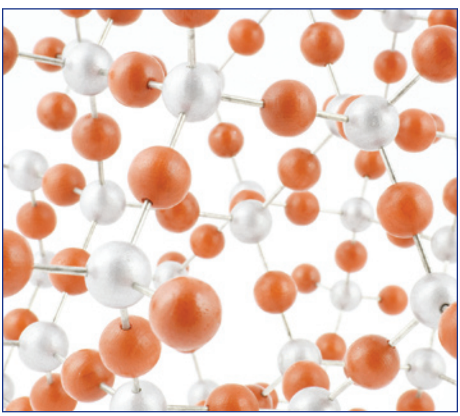
The workshop already has promoted an open interchange of ideas among key leaders in nanoscale research relevant to FHWA programs. Nanotechnology promises breakthroughs in multiple areas, offering a potential for synergy and benefits across many traditional research focus areas.

What Nanoscale Research Could Do for Highways

There are multiple potential nanoscale applications in highways. For example, concrete is a material containing pores on a nanoscale, a result of the chemical reaction between cement and water. Repeated exposure to deicing chemicals causes oxidation, cracks, and long-term deterioration to occur in the structure. Utilizing nanotechnology to create smart self-healing materials and structures could lead to less frequent and faster construction, as well as to increased durability and improved performance, all helping to prevent catastrophic failure.

The ability to constantly monitor materials also could offer improved predictive performance models. During construction, nanotechnology can allow for embedding increasingly smaller sensors throughout a structure or pavement. These sensors could be used for long-term monitoring of corrosion and could offer an invaluable tool in monitoring bridges. By using a car-mounted data reader, information from the embedded sensors could then easily and safely be collected as the vehicle passes.

Nanoscale Research for Safety and System Operations



How might application of nanoscale technologies change the current approach to intelligent vehicle systems and IntelliDrive℠? As an example, it is believed that nanoscale technology will provide a low-cost means to create an infrastructure that vehicle-based systems can use to maintain lane position and advise drivers of approaching intersections and interchanges. TFHRC Chief Scientist Jonathan Porter noted that, "The world beyond highway research has a much greater interest and investment in sensors and electronic devices. By engaging partners, we can identify ways to exploit this investment to solve transportation problems." There is great potential for taking advantage of promising research from other industries.

Nanoscale Research for Environment Stewardship

There are several environmental applications for nanotechnology in highways. One example is the ability to monitor mobile source pollutants dur-

Nanotechnology and Pavements

Although much progress has been made in reducing concrete's propensity to crack, this goal remains elusive. In 2008, FHWA launched "High-Performance Stress-Relaxing Cementitious Composites (SRCC) for Crack-Free Pavements and Transportation Structures," an EAR Program project conducted at Texas A&M University's Texas Transportation Institute. The project aims to make a concrete that is 50 percent less likely to crack in a typical concrete transportation infrastructure under typical service conditions. The study is investigating SRCCs on two scales, nano to micrometer and micrometer to millimeter. On the nanoscale, the stress-relaxation effect of various materials occurs as nano cracks form at the interface of the cement-paste matrix molecules and the embedded SRCC molecules, releasing energy. After crack formation, further relaxation results from sliding friction at the interface. The project is expected to conclude in 2010 and aims to stimulate research and further the implantation of new crack-resistant concrete designs.

ing construction and operations by using nanoscale devices to bind with road-based pollutants. Low-cost environmental sensors could monitor the air, water, and soil quality, and the technology could allow large-scale monitoring of the operation to continually map pollution levels. Nanoscale research could lead to an increased use of recycled materials in pavements through a better understanding of bonding at the boundaries of different materials and the design of very thin coatings to improve the workability and durability of recycled materials, which would also help to reduce costs. Nanoscale research also could result in the development of smaller, lower cost sensors, which would use substantially less energy. Self-powered sensors also would contribute to the efficiency and reduced environmental impact of the highway network.

Long-Term Applications

As part of the Nanoscale Workshop, participants looked to the long-term potential for nanoscale research. Workshop participants envisioned research leading to:

- New structural materials that could absorb increased force without catastrophic failure for appli-

cation on critical structural elements, or with adaptable properties that could respond to environmental conditions (e.g., wind or water force) or increased temperatures associated with climate change.
- Pavements with multifunctional properties, such as the ability to generate or transmit energy and increased durability.
- Vehicles that could obtain advanced information from an array of location-enhancing nanoscale sensors for collision avoidance and coordinated, self-correcting travel routing.
- Improved energy-efficient interfaces between nanoscale sensors and local data collection and communication networks.

The Future for Nanoscale Highway Research

"We expect the Nanoscale Workshop to lead to an overall increase in research targeted at highway program needs," says David Kuehn, EAR Program Team Director at FHWA. "The workshop was an ideal opportunity to collaborate and leverage nanoscale technology that is being developed for other industries and to accelerate our ability to solve long-term highway research questions."

Building on information shared at the workshop, the EAR Program sought research in four topics that have the potential to provide significant and immediate opportunities:

1. Theoretical understanding of nanoscale structural and mechanical modeling.
2. Experimental understanding of pavements through development of nanoscale-measuring devices.
3. Nanoscale sensors for assessing structural health.
4. Nanoscale approaches for inhibiting corrosion.

Although the short-term aim of the 2009 Nanoscale Workshop was to assist with identifying specific opportunities to invest EAR Program funds, the long-term aim is to build a focus on highway research needs within the nanoscale research community, particularly through outreach to experts and stakeholders. It is hoped that this focus will increase longstanding partnerships and ultimately use new research methods for solving highway research questions.

Following the success of the Nanoscale Workshop, the EAR Program continues to scan for relevant extramural nanoscale research in academia, the government, and on the international scale. Leveraging nanoscale technology that is being developed for other industries can accelerate solutions to long-term highway research questions. However, progress will require a long-term commitment to build interest and expertise among graduate students and early career researchers in emerging fields and to point them toward highway research issues. For nanoscale research to lead to technological breakthroughs, it is important for the EAR Program to build the bridge between scientific opportunities and highway program needs. Coordination

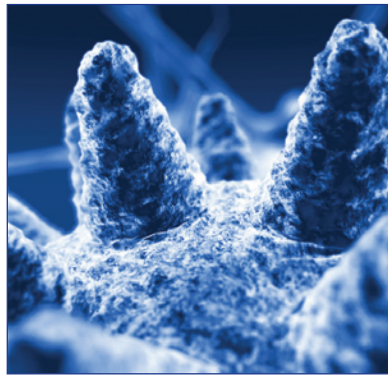
What is the Exploratory Advanced Research Program?

FHWA's Exploratory Advanced Research (EAR) Program focuses on long-term, high-risk research with a high payoff potential. The program addresses underlying gaps faced by applied highway research programs, anticipates emerging issues with national implications, and reflects broad transportation industry goals and objectives.

To learn more about the EAR Program, visit the Exploratory Advanced Research Web site at www.fhwa.dot.gov/advancedresearch. The site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events. For additional information, contact David Kuehn at FHWA, 202-493-3414 (email: david.kuehn@fhwa.dot.gov), or Terry Halkyard at FHWA, 202-493-3467 (email: terry.halkyard@fhwa.dot.gov).

and collaboration with other government, academic, and international laboratories with highway-relevant programs is ongoing, and as new developments emerge, the EAR Program continues to refine and focus its short- and long-term nanoscale opportunities.

On a final note, researchers need to be realistic about the difficulties of moving from a concept to application. It might take considerable effort to move from working at the nanoscale in the laboratory to delivering nanoscale materials at a commercial production scale that would function effectively and safely in harsh field conditions typical of highway infrastructure.



Learn More

For more information on FHWA's strategic direction for nanoscale research and future funding opportunities, contact David Kuehn at FHWA, 202-493-3414 (email: david.kuehn@dot.gov).

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