NRC report shows materials opportunities at the forefront of corrosion science

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Several converging forces have created opportunities for revolutionary advances in understanding and mitigating corrosion, according to a report recently released by the National Research Council. From aging infrastructure to emerging technologies, understanding the underlying causes of corrosion could have a major impact on the quality of materials in different applications, the environment, and even the economy. However, the report said, realizing these advances will require a joint effort among government agencies and departments in coordination with the research science and engineering communities.

This is an exciting time for corrosion research, according to the study, because of the convergence of three major developments: the ability to tailor the composition and structure of materials on the nano- and mesoscales, the ability to experimentally probe materials and chemical reactions in greater depth, and the ability to model more computationally intense problems than before.

Traditionally, corrosion issues have been addressed after-the-fact, when a problem has already emerged. This is largely due to gaps in knowledge about the underlying causes of corrosion, which makes it hard to predict and prevent. However, advances in tools and techniques for materials characterization (such as electro-chemical probes and microscopy) and modeling (such as molecular dynamics and multiscale modeling) have created new research opportunities that could enable scientists and engineers to proactively design materials for specific service environments.

The report identifies four grand challenges related to corrosion research, which could each have direct and immediate applications in engineering:

1. the development of cost-effective, environment-friendly, corrosion-resistant materials and coatings;
2. high-fidelity modeling for the prediction of corrosion degradation in service environments;
3. accelerated corrosion testing under controlled laboratory conditions that quantitatively correlate with the behavior observed in service environments; and
4. accurate forecasting of the remaining service time until a major repair, replacement, or overhaul becomes necessary.

According to the study, meeting these grand challenges requires a concerted effort among scientists and engineers, but the payoff could be paradigm-changing. Cost-effective methods for avoiding, mitigating, predicting, and sensing corrosion could be determined in advance for various materials in various service environments, with positive impacts on safety, maintenance and replacement costs, environmental impact, and stability.

In this age of advanced technologies that expose materials to ever-harsher environments, understanding the fundamental processes of corrosion will become even more important, according to David Duquette, the John Tod Horton Professor of Materials and Science Engineering at Rensselaer Polytechnic Institute and co-chair of the study. "Corrosion will be a major issue for advance reactors, for exploration studies for natural resources, and for things like wind turbines sitting in saline environments," he said. "Understanding and preventing corrosion will be very important, probably in ways that we can't even think of right now."

The report calls for federal agencies to lead the corrosion research effort, and lays out a framework for doing so that includes opportunities for incremental advances with high return on investment and high-risk but potentially transformative projects. The framework is outlined in four recommendations:

1. Federal agencies and departments should identify the areas of corrosion research that are important to their mission. Each one should draw up a roadmap for its responsibilities, taking a cross-organizational approach and including input from industry.
2. Funding agencies should initiate programs designed to stimulate both single-investigator and collaborative team efforts, and should underwrite the costs of test laboratories open to the corrosion community and their collaborators, including industry.
3. Agencies and departments should assume responsibility for disseminating the results of their research.
4. The Office of Science and Technology Policy (OSTP) should launch a multi-agency effort to encourage corrosion

To combat the effects of materials degradation, this mooring ring, shackle, and thimble with rope uses three different techniques. The ring and eye bolt was originally painted, the shackle and thimble has been galvanized (zinc coated), and the mooring line was made of nylon. Courtesy of Erik Svedberg.

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research. OSTP should form a multiagency committee on corrosion, with initial charges of documenting federal expenditures in this area and encouraging multiagency efforts augmented by collaboration with state government and private entities such as professional societies, industry consortia, and standards making bodies.

"Our infrastructure is falling apart," said Duquette. Corrosion damage is affecting aging aircraft, aging transportation systems, aging military equipment, and much more. "We have to understand what those problems are and how to solve them."

The report, *Research Opportunities in Corrosion Research and Engineering*, was authored by the National Materials Advisory Board from the National Academies Division on Engineering and Physical Sciences. It is available through the National Academies Press, www.nap.edu.

Kendra Redmond

UNESCO releases report on the current status of science worldwide
www.unesco.org

While the United States, Europe, and Japan (known as the Triad) may still be leading the global research and development (R&D) effort, they are increasingly being challenged by emerging countries. This is one of the findings of the United Nations Educational, Scientific and Cultural Organization's (UNESCO's) *2010 Science Report*, launched at the Organization's headquarters on November 10, 2010, World Science Day.

The UNESCO *Science Report* depicts a rapidly changing landscape. While investment in R&D is growing globally (in volume), emerging countries are clearly gaining strength in science and technology. This can be seen especially in terms of Asia's share of gross domestic expenditure on research and development (GERD).

Led mainly by China, India, and South Korea, Asia's share increased from 27% to 32% between 2002 and 2007. Over the same period, the Triad has registered a decrease. In 2002, almost 83% of R&D was carried out in developed countries; by 2007 this share had dropped to 76%. This trend is even clearer when industry's contribution to GERD is considered. Between 2000 and 2007, the private sector share of R&D spending, as a proportion of gross domestic product (GDP), saw a sharp increase in Japan, China, Singapore, and especially South Korea, while it remained stable in Germany, France, and the United Kingdom and even saw a slight decrease in the Russian Federation and the United States.

"The distribution of research and development (R&D) efforts between North and South has changed with the emergence of new players in the global economy," said UNESCO Director General Irina Bokova in her foreword to the report.

The proportion of researchers in developing countries increased from 30% in 2002 to 38% in 2007. Two-thirds of this increase is due to China alone. Today, Europe, the United States, and China each contribute 20% of the world's researchers, followed by Japan (10%) and the Russian Federation (7%).

The developed countries have also seen their share of scientific publications drop from 84% in 2002, to 75% in 2008. During this period, China's share more than doubled, increasing from 5.2% to 10.6%, even if the citation rate of its articles lags behind those in the Triad. The number of articles published by researchers in Latin America has also increased, mostly from Brazil.

This transformation is being helped by the extremely rapid development of the Internet, which has become a powerful vector for disseminating knowledge, particularly evident in emerging countries. "The rapid diffusion of Internet in the South is one of the most promising new trends of the Millennium," said the report.

While the emerging economies have been content, until now, to carry out R&D activities outsourced from the developing countries, they have now moved on to a process of autonomous technological development and applied research. China, Brazil, and India have thus initiated simultaneous catching-up processes in industry, science, and technology. This has also meant the arrival on the world scene of multinational firms from emerging countries in sectors such as automobile manufacturing, consumer goods, and high-tech industries like aircraft manufacturing.

However, while more researchers and scientists are being trained in developing countries, they are not necessarily finding jobs in their country of origin. India, Turkey, some countries in sub-Saharan Africa, and Southern Asia are particularly faced with this problem. At least one-third of African researchers were estimated to be working abroad in 2009.

Finally the report stresses the need to intensify scientific cooperation, particularly between countries in the South.

"I am convinced that, more than ever, regional and international scientific co-operation is crucial to addressing the interrelated, complex and growing global challenges with which we are confronted," said Bokova in the foreword to the report. Increasingly, international diplomacy will take the form of science diplomacy in the years to come. "In this respect, UNESCO must and will pursue its efforts to strengthen international partnerships and co-operation, in particular South–South co-operation. This science dimension of diplomacy was one of the original reasons for including science in UNESCO's mandate. It has fundamental significance for UNESCO nowadays, at a time when science has tremendous power to shape the future of humanity and when it no longer makes much sense to design science policy in purely national terms."

Copies of the report can be obtained from the UNESCO Web site at www.unesco.org. □

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