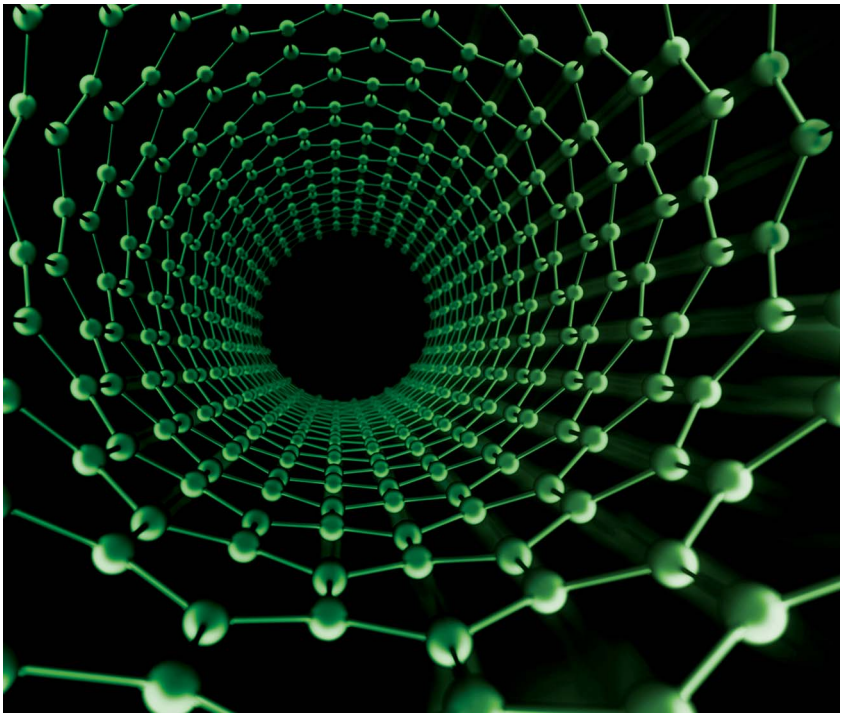
Nanoelectronics: An International Perspective

By MIHAIL C. ROCO
NSF and NNI

PAOLO GARGINI
ITRS Chairman
Intel



Discoveries and innovations in nanotechnology are flourishing worldwide. Centers of excellence and research networks with long term programs supporting nanoelectronics, nanomagnetics, and nanophotonics have been created in the United States (U.S.), Europe, Japan, and other parts of the world. The National Nanotechnology Initiative (NNI) has provided a long-term scientific focus, a partnership approach, and a means of environmentally responsible funding the field in the United States since 2000. The program also inspired and partially motivated nanotechnology R&D activities in about 60 other countries. Creative programs of similar investment scale are underway in Europe and Asia. In Europe, the FP7 program organizes all the EU research initiatives including in nanoelectronics into four categories: Cooperation, Ideas, People, and Capacities. For each objective, there is a specific program corresponding to the main areas of EU research policy. In addition, a European Commission program in Future Emerging Technologies (FET) addresses the disruptive approaches to nanoelectronics. In Japan, the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) promotes nanotechnology research and development and supports a network among researchers to provide cross-sectional, comprehensive support across research institutions and research fields. For example, MEXT also provides opportunities for outside researchers to use large and special facilities and equipment. Japan also has the New Energy and Industrial Technology Development Organization (NEDO), which contributes research and development activities in a variety of nanoelectronic programs, e.g., their Next-Generation Semiconductor Materials and Process Technology (MIRAI) Project.

In the first ten years, the research focus in the U.S. has been on uncovering nanoscale phenomena and on synthesizing nanostructured components to improve existing products. For illustration, researchers and manufacturers have placed functional

Digital Object Identifier: 10.1109/JPROC.2011.2113430

nanoscale layers in semiconductors since 2003, and this has already allowed the reduction of their size several times. The number of nanotechnology patent applications worldwide has increased annually by about 35 percent since 2000. Now, the research focus is shifting to science-based design of novel nanoscale systems, which could lead to novel products of high relevance for future semiconductors. By 2020, one may envision mass use of nanotechnology not only in the semiconductor industry but also in nanostructured catalysts, advanced structural and photonic materials, pharmaceuticals, energy conversion and storage, medicine, and technologies for environmental sustainability. Working in semiconductors at the confluence of information technology and nanotechnology is one of the most rewarding endeavors in science and engineering impacting modern society.

The successful cooperation between the NNI organization and the Semiconductor Industry Association (SIA) companies in the U.S. has led to the formation ofthe Nanoelectronics Research Initiative (NRI) jointly supported by SIA, NSF, NIST, twenty universities, and multiple states. Four centers of excellence have been formed to date. In addition, the yearly NNI conferences have evolved from U.S.-only meetings into an International Nanotechnology Conference on Communication and Cooperation (INC). Established in 2005, this conference rotates between Europe, Japan, and the U.S. Productive discussions held during INC conferences among leading researchers around the world have led to the formation of the International Planning Working Group on Nanoelectronics (IPWGN). This group has taken the responsibility for tracking all international nanoelectronics programs with the goal of encouraging international research collaborations to address under-resourced research vectors or topics.

During the IPWGN meetings it has become apparent that not only do the three regions share a series of common research vectors they support additional and different research vectors. In addition each region is contributing unique skills to the nanotechnology arena. For instance, Europe excels in More than Moore research, Japan is very strong in material research, and the U.S. has concentrated its "Beyond CMOS" efforts on demonstrating novel computing devicescapable of supplementing and eventually replacing the CMOS transistor as alogic switch in the 2020–2030 timeframe (i.e., "inventing the newswitch") with some emphasis on spintronics and graphene. There are multiple collaborations and people exchanges between the three regions that are enhanced by IPWGN.

The special IEEE issue published in December 2010 illustrates excellentselections of the research topics covered by the IPWGN.

Editor's Note: *Unfortunately this article was not included in the December 2010 issue as originally planned.* ■