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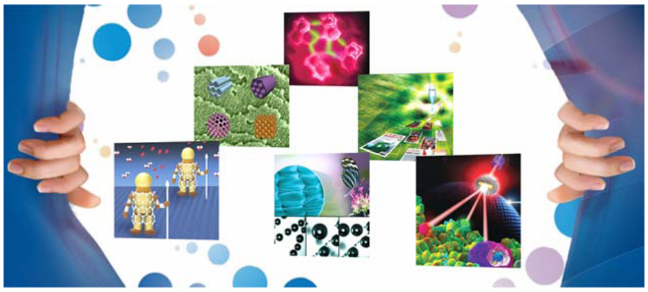
EDITORIAL

China: A Big Player in a Small World

Nanoscience and nanotechnology measure and manipulate matter on the nanometer scale, 10^{-9} meters. To put that in scale, the diameter of a human hair and the thickness of one sheet of newspaper are each about 100,000 nm. It is very, very, very small! Although nano as a concept is still unknown to most nonscientists around the world, the Chinese public is already enraptured with the nano concept. Nanomaterials show new, unusual, and sometimes totally different properties compared to their bulk ones. Nanosized gold displays tunable colors, a lower melting point, and surprising catalytic activity. In fact, nano is already embedded throughout our day-to-day lives. Sunscreens with high sun protection factor (SPF) generally contain TiO_2 or ZnO nanoparticles to absorb ultraviolet (UV) light. In nature, the strength of our teeth, lotus leaves' ability to self-clean, and the superadhesion of gecko feet are all attributed to unique micro/nanostructures.

My first exposure to nanoscience came during the 1980s when I was a graduate student in Jilin University. At that time, I did not understand the term nano; nanomaterials were not yet popular and were not even called nano at the time, referenced instead as "ultrafine" particles. While in graduate school, beautiful ultrasmall electron microscopy images quickly drew my attention. I started to work on the synthesis of pillared clays and related catalysts. Their unique structures, high surface areas, large interlayer spacing (>2 nm), and good catalytic activities immediately drew me into the fantastic "nanoworld", from whence I have never stopped being fascinated.

My home country of China is one of the pioneering countries that initiated nanoscience and nanotechnology research. Over the past decades, Chinese nanoscientists have made a number of important breakthroughs in various fields of emerging fundamental research and technology applications of nano. The Jianguo Hou group at the University of Science and Technology of China demonstrated plasmon-enhanced Raman imaging with spatial resolution below one nanometer (0.5 nm), resolving the inner structure and surface configuration of a single molecule. Chinese scientists from Dalian Institute of Chemical Physics of the Chinese Academy of Sciences (CAS) developed highly efficient nanocatalysts, which can make a direct, nonoxidative high



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conversion of methane, exclusively to ethylene and other organic molecules. Yanlin Song and co-workers from the Institute of Chemistry, CAS, developed a pollution-free green plate technology using controllable features of functional hydrophilic/lipophilic nanomaterials with digital technology for the next generation of green nanoprinting. This advanced technology has eradicated contamination, lowered costs, and gained a better printing effect compared with the traditional techniques, leading the print industry into a new age of greenization and digitalization. The Shoushan Fan group from Tsinghua University developed superaligned carbon nanotube arrays, which can easily be converted into continuous, transparent, and highly conductive films for various applications, including carbon nanotube touch screens on mobile phones commercialized in 2012, bringing high impact results in the industrial field. Today, with these types of research outcomes in nano, more and more Chinese researchers are breaking into the list of the world's top scientists.

China is also one of the world's top investors in nanoscience. Prior to the turn of the twenty-first century, the investment was small, and focused mainly on nanomaterials, supported by the Ministry of Science and Technology (MOST). The growth in Chinese investment came when the government issued the "National Medium and Long-Term Science and Technology Development Plan" in 2006, where nanoscience was highlighted as one of the key development areas in China.[1] The MOST supported more than 150 projects on nanotechnology between 2006 and 2015, involving tens of millions of US dollars each on diverse research areas such as nanomaterials, nanodevices, nanoenergy,

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nanocatalysis, and nanomedicine. The National Natural Science Foundation of China (NSFC) supports many additional research projects in all these nanorelated areas, and recently launched two major programs in nanotechnology and nanomanufacture. In 2012, China also launched a Strategic Pioneering Program on nanotechnology led by the CAS, which has a budget of one billion yuan ($152 million) over five years.[2] Moreover, a number of national nanotechnology bases and advanced infrastructures have been built—the National Center for Nanoscience and Technology in Beijing, the National Engineering Research Center for Nanotechnology in Shanghai, the China International Nanotechnology Innovation Cluster in Suzhou, the Shanghai Synchrotron Radiation Facility, and the China Spallation Neutron Source, for example.

While China is now the leader in terms of the number of papers in the Science Citation Index (SCI), citations, and patents, only a minority of those are considered originally innovative. The new government sees innovation as central to China's long-term development. Yet most researchers in China are keen to follow hot and trendy research areas. Few have the spirit of *Shi Nian Mo Yi Jian* (meaning "taking a decade to sharpen a sword") or are willing to pursue solutions of big challenge questions and new areas. At this stage, nanoscience truly needs to focus on innovative, high-impact, breakthrough, and seminal research rather than the quantity of output. China's scientists should unleash the creativity to innovate, take a leadership role in nanosciences, and promote technology transfer to ultimately generate socioeconomic benefits.

Although the research and development expenditure in China has greatly increased in the past decade, and now the percent of total GDP put toward research and development is very similar between China and the United States, the proportion of that investment on basic research is relatively low (5%) compared with that of the United States (18%).[3] In addition, the levels of development in the different areas of nanoscience are disproportionate. Given their inherent uncertainty, the most innovative ideas often do not initially get much recognition or support. Moreover, the Chinese research assessment system, as in many other countries, relies heavily on simple metrics like the number of SCI papers. Factors such as fundamental, economic, and social impacts of the research are given less weight as compared to quantity of papers. Moreover, the lack of a strategic framework for nurturing and progressing nascent research from lab to industry impedes the realization of such impacts. Currently, Chinese research, as with its economy, is at a significant juncture.

China is actively creating a more conducive environment to sustain its scientific development and drive the economy. Thousands of talented and ambitious scientists and engineers come back to China from abroad via the well-known "Thousand Talents Plan", and young researchers in China are greatly encouraged to start their own laboratories through funds earmarked for young scientists by the MOST and NSFC. The government has also done much to stimulate scientific output into productivity. As a typical example, in 2013, the MOST launched the establishment of the China Innovation Alliance of the Graphene Industry (CGIA) via the China Industry−University−Research Institute Collaboration Association, which aims to support the commercialization of graphene in China.[4] Promising graphene-based commercial products are emerging and driving the economy, for example, smartphones with graphene-based touch panels, a graphene-based lubricant used as an engine oil additive, increasing oil lifetime from 1000 to 5000 miles, and a graphene-based capacitor for city buses.

Although nanoscience and nanotechnology have been developing rapidly in the past decades, there are still big challenges in precise synthesis, structure manipulation, controllable assembly, interfacial engineering on the atomic scale, single-atom and *in situ* characterization, theoretical understanding, nanodevices, scaling-up synthesis and applications in nanocatalysis, nanoanalysis, nanoenergy, nanomedicine, and nanoelectronics. These offer great opportunities for the world's nanoscientists, including of course Chinese nanoscientists.

We look forward to seeing many more breakthroughs coming from China. *ACS Central Science* is one of the important venues for exciting fundamental discoveries and developments regarding nanoscience. We welcome and encourage Chinese scientists to submit high impact and innovative articles.

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Notes

Views expressed in this editorial are those of the author and not necessarily the views of the ACS.

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ACS Cent. Sci. 2016, 2, 577−578