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NEWS AND OPINIONS

The nanotechnology race between China and the United States

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Summary It is generally agreed that the United States National Nanotechnology Initiative (NNI) has significantly influenced global nanotechnology development since its inception in 2000. The far-reaching impact of NNI and nanotechnology development, as evidenced by publications in high impact journals, has been rising rapidly over the last 10 years. Recently, the global nanotechnology community witnessed China's ascent in nanotechnology. With increased governmental funding and improved research infrastructure, China has made significant advances and currently has the fastest growing nanotechnology publications and related industrialization. On the one hand, the Chinese government, like the American government, continues to build and support a fertile nanotechnology community. On the other hand, efforts appear less organized in the European Union. Although the gap in nanotechnology impact between the USA and China has narrowed significantly over recent years, the two countries have evolved with their own research focuses. Yet, China is still left behind American nanotechnology in terms of average citations per papers and publications in high-impact journals. It is hopeful that competition and collaboration between the two countries in this field will positively advance the global nanotechnology development.

The art and politics of nanoscience and nanotechnology

Before the dawn of the new millennium, the then President of the USA Bill Clinton was invited by Science magazine to write an editorial. In the one-page piece entitled ''Science

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in the 21st century'', he wrote ''Imagine a new century, full of promise, molded by science, shaped by technology, powered by knowledge. We are now embarking on our most daring explorations, unraveling the mysteries of our inner world and charting new routes to the conquest of disease'' [1]. In 2000, the American government firmly kicked off its significant and influential National Nanotechnology Initiative (NNI) program after integrating all resources from Federal agencies, including National Science Foundation, Department of Defense, Department of Energy, Department of Health and Human Services (NIH), National Institute of Standard Technology (NIST), National Aeronautics and Space Administration (NASA), Environmental Protection Agency (EPA), Homeland Security, United States Department of Agriculture (USDA), and Department of Justice.

The NNI established four goals: (1) to advance a world-class nanotechnology research and development program; (2) to foster the transfer of new technologies into products for commercial and public benefit; (3) to develop and sustain educational resources, a skilled workforce, and supporting infrastructure and tools to advance nanotechnology; and (4) to support responsible development of nanotechnology. The NNI significantly pushes nanotechnology research forward. In 2006, the prominence of nanotechnology research began to exceed medical research in terms of publication rate. That trend appears to be continuing as a result of the growth of products in commerce using nanotechnology and, for example, five-fold growth in number of countries with nanomaterials research centers. The ''nanoscience and nanotechnology'' subject category of the Journal Citation Report (JCR) published by Thomson Reuters has increased rapidly. Correspondingly, both impact factors (published by Thomson Reuters) and SCImago Journal Rank values (SJR; published by Elsevier's Scopus and powered by Google's PageRank algorithms) of journals in the nanotechnology subject category have increased rapidly [2]. The aggregate impact factor of nanoscience and nanotechnology has been rising at a breathtaking rate, compared with other subject categories, reaching the top 10 after 2011. The hype and hope of nanotechnology challenging many previously unimaginable goals are especially high now, and many believe in forthcoming breakthroughs in the areas of nanomaterial-based diagnostic imaging, complementation of diagnostic tools combined with therapeutic modalities (i.e., theranostics), or nanoencapsulation and nano-carriers of biotechnology products.

Today, it is estimated that total NNI funding, including the fiscal year 2014, is about $170 billion. Currently, there are more than 60 countries that have launched national nanotechnology programs [3]. Governments and industry have invested millions of dollars in research funding in this rapidly growing field. By 2015, approximately one quarter trillion dollars will have been invested in nanotechnology by the American government and private sectors collectively. The continuous strategic investment in nanotechnology has made the United States a global leader in the field.

Ten years ago, when AAAS celebrated the 125th anniversary of the journal Science, the magazine invited the President of Chinese Academy of Science (CAS) Chunli Bai to write an essay for its special section ''Global Voice of Science''. The CAS President Chunli Bai's essay, entitled ''Ascent of Nanoscience in China'' [4] described, in general, the then development of nanotechnology and nanoscience in China, and openly announced the government's ambition to compete with other countries in the field. In 2006, the Chinese government announced its Medium and Long-term Plan for the Development of Science and Technology (2006—2020), which identified nanotechnology as ''a very promising area that could give China a chance of great-leap-forward development''. The plan introduced the new Chinese Science & Technology policy guidelines, which were later implemented by the Ministry of Science and Technology (MOST) that operates Nanoscience Research as a part of the State Key Science Research Plans. So far the Nanoscience Research program has invested about 1.0 billion RMB to support 28 nanotechnology projects. All of these endeavors led to the recent significantly rapid rise of nanotechnology in China as evidenced by its publications, industrial R&D and applications in the field.

The rapid development of nanotechnology-based science and technology in China attracted worldwide attention including from Demos, one of the UK's most influential think tanks. Led by Wilsdon and Keeley, Demos completed an 18-month study, interviewing many leading scientists and policy makers of 71 Asian organizations, including two well-known Chinese nanotechnology academics Dr. Chen Wang (the then Director of National Center for Nanoscience and Technology) and Academician Zihe Rao (Director of CAS Institute of Biophysics). After completion of the project, Wilsdon and Keeley published their findings in a book entitled ''China: The next science superpower?'' [5]. The authors wrote, ''China in 2007 is the world's largest technocracy: a country ruled by scientists and engineers who believe in the power of technology to deliver social and economic progress. Right now, the country is at an early stage in the most ambitious program of research investment since John F Kennedy embarked on the race to the moon. But statistics fail to capture the raw power of the changes that are under way, and the potential for Chinese science and innovation to head in new and surprising directions. Is China on track to become the world's next science superpower?'' Indeed, in recent years, China has emerged not only as a mass manufacturer, but also as one of the world's leading nanotechnology nations. Many nanomaterial-based semiconductor products come from China, and China dominates in the nanotechnology area of most-cited academic articles: the top eighteen out of the twenty scholars are of Chinese origin [6].

Changes in nanotechnology-related geopolitical landscape

With strong governmental and private sector supports, nanotechnology and nanoscience R&D has developed rapidly in both the USA and China. As shown in Fig. 1A, from 2003 to 2013, the USA led in the area of global nanotechnology publications in terms of the numbers of papers and their quality determined by the number of citations and H-index. China followed USA in the field. For instance, the total nanotechnology publications from USA were 160,870 with total citations of 4056,278, whereas, China published 154,946 papers with total citations of 2049,072. The quality of an article is usually judged by the number of citations