Materials science in China

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Far-sighted research policies, comprehensive research platforms, talent programmes and huge domestic markets are the impetuses for the fast progress of China's research in materials science.

In the past two decades, China — the world's most populous country with over 1.3 billion inhabitants — has continually experienced impressive economic development. China's annual gross domestic product (GDP) increased about 8 times from US$1,324.8 billion in 2001 to $10,385.7 billion in 2015, at an average growth rate of 9.64%. In 2015, China contributed over 25% — the largest percentage of all countries — of the world's economic growth. Similarly, the research output of China has increased remarkably in the same period. It is likely that scientific advances have had a major role in this phenomenal economic progress.

As materials form a central pillar of the country's economic growth, it is natural that the nation's wealth and desire for sustained economic advances have fuelled a strong determination from the Chinese government to pursue research in materials science. On the international stage, China is rapidly becoming the most active nation in which to conduct research into materials[1]. China has now published the second largest number of scientific publications and filed the largest number of patents of any country, on a yearly basis, between 2009 and 2013. Here, we discuss the reasons for China's fast development in materials science and the future challenges.

China's strengths

In recent years, China has produced a range of high-impact results in materials science; many of them are highlighted in the annual list of China's ten major scientific progresses or honoured by the National Science and Technology Awards. With the aim of optimizing investment return, China has devoted its efforts to many areas of materials research that are of national interest and that involve natural resources or research strengths. These areas include light-weight and high-strength metal alloys, rare-earth functional materials, catalysts, energy materials, renewable-energy technologies, electronic, optical and optoelectronic materials, and nanomaterials.

Far-sighted national strategy fuelling research. Recognizing the need for a strong research and development effort in science and technology for sustained economy growth, the Chinese government has implemented several policies for materials research. Notably, the 'National Nano Science & Technology Development (2001–2010)' outline and the 'National Medium and Long Term Science & Technology Development (2006–2020)' outline. These policies allocate earmarked financial support for science and technology, enabling leaps forward in research and development. As a result, many national programmes or funding agencies have received boosted budgets in the twenty-first century. The total budget spent on research and development in 2014 reached $205 billion (2.05% of the 2014 GDP), which is 14 times that spent in 2001 (~1.1% of the 2001 GDP) and the second largest after the United States.

Comprehensive research platforms. Increased financial support has enabled China to boost its infrastructure for materials research. In the past 15 years, several major national research facilities have been established, including the Shanghai Synchrotron Radiation Facility with the third-generation light source, the Soft X-Ray Free Electron Lasing Facility in Shanghai, the Chinese 100 kW Spallation Neutron Source in Dongguan (Guangdong Province), and high magnetic facilities in Hefei and Wuhan. Also, many national and regional research centres have been established. These centres are generally equipped with state-of-the-art facilities and employ high-calibre researchers; as a result, they provide powerful platforms for materials research and development in China.

Talented scientists returning to China. As human expertise is key to scientific and technological progress, in the 1980s the Chinese government began to encourage scientists to study abroad. From 1978 to 2014, more than 1.8 million out of approximately 3.5 million people who had embarked on this venture have returned to China; many of them have become influential leaders, such as ministers in government, university presidents, directors of research centres, and presidents and managers of major companies. Since 2008, China has further stepped up its efforts to encourage scientists and engineers to return from overseas by introducing attractive incentive programmes, such as the national 'Thousand Talents Plan' (for both senior scientists and

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young professionals). These programmes have attracted the return of more than 5,000 scientists and engineers from around the world (up to the end of 2015).

Huge domestic market. As China rapidly becomes the world's largest consumer market, advanced materials, such as for catalysts, paints, chemical sensors, biosensors, digital data storage, solid-state lasers, information displays and printing technology, are in demand. China's market for products of functional materials is bound to increase steeply as more scientific results are transformed into technology and applications. Naturally, the expanding Chinese market will attract more investment and ensure a talented and well-trained workforce in materials science.

Challenges

Despite its bright prospects, China faces challenges along the path to realizing highly competitive research on the world stage. First, China's GDP per capita remains small and the percentage invested in research is only about half of that invested by most Western countries. This translates to a smaller funding per capita available to Chinese scientists for research expenditure and facilities. Also, the availability of costly but powerful national facilities to the Chinese remains comparatively limited by international standards. This situation has substantially contributed to China's lagging achievements in materials science, particularly in fabrication techniques, scientific equipment and instrumentation, and device development, requiring expensive and sophisticated facilities.

Second, China's natural resources, such as minerals and energy materials, per capita are very limited. As a result, China needs to save raw materials, recycle used materials and reduce environment pollution to tackle the problems of diminishing resources and a polluted environment. In particular, air pollution is becoming a serious problem in most major Chinese cities, and residents are increasingly requesting better air quality and a cleaner environment. However, balancing these remedial efforts with fast economic growth is a challenge, which requires much wisdom and determination from the government. To address environmental issues, measures are being implemented nationwide, such as building more non-fossil fuel energy generators, curtailing industrial waste, and cleaning up waste gases and waters. Other initiatives include promoting electric cars, car pool lanes and free city bicycles.

Third, despite its prolific scientific publications, China has produced relatively few high-impact scientific and technological advances, and even less innovations regarding new frontiers in research. The weak foundation of science and technology from a historical perspective has been a major contributing factor, which China is trying hard to remedy. In addition, the tendency of Chinese scientists to follow 'in vogue' research tides or topics is an influential factor. Although the importance of basic science is widely recognized, most people shy away from the high risk of longer-term scientific research for fear of losing funding. China can benefit from more tolerant policies, which promote time-consuming research with the potential of higher impact but with a slower return. In addition, a stronger emphasis on the education of materials science at university-degree level is desired to cultivate students with a genuine interest in basic science. There are also poor connections between research and application, and hence, between academia and industry. To address these issues, both application-driven and fundamental research should be promoted.

Last, administrative wisdom is needed to improve the policy and governance for research and development management. As a result, this should motivate and encourage researchers and ensure enhanced innovation and higher productivity. To this end, a more effective evaluation and assessment system for funding decisions on the basis of scientific merits could significantly improve the quality of research and development.

Outlook

If the trend continues, China's annual expenditures on research and development will overtake that of the United States by 2022 and achieve first place on the global research arena. The Chinese government is positioned to continue its strong support for materials science. In the Five-Year Plan started this year, China continues to focus research on alloys, rare-earth materials, solid-state lasers, energy materials, catalysts, electronic displays, health care and ensuring a cleaner environment. The pursuit of high-impact and innovative research will be a high priority.

With a burgeoning pool of human talents, increased research funding and improved research infrastructure, China is undoubtedly destined to make significant advances in materials science and related technologies in the future. In particular, as the Chinese government is undergoing a comprehensive reform to improve the policy and management for research and development, the new measures are expected to majorly impact science and technology. By contrast, the huge Chinese population will consume more natural resources, demand more materials and exert increasing stress on the environment in the coming years. China will have to address these issues, devoting time and expertise to saving raw materials, on recycling and on management of environmental pollution. If these are ignored then the consequences may be serious. Nevertheless, we can be confident that by balancing remedial efforts and technological progresses, Chinese materials scientists and engineers are poised to have an important role in the forefront of global science and technology, which will benefit China and the world as a whole.

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Competing interests statement
The author declares no competing interests.

FURTHER INFORMATION
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