

A Landscape Study on the Development of Smart Material in China

Introduction

Smart materials are defined as a class of materials that have the capacity to sense environment and respond to external stimuli via an active control mechanism. These materials are incorporated into a growing range of products with increasing levels of functionality, and have made a great impact on health and the use of energy and information and communications technology.

The global smart materials market was estimated at US\$27.74 billion in 2013 and is expected to approach US\$63.28 billion by 2020, according to Transparency Market Research. Geographically, North America currently leads the smart materials market, with a share of 38% in 2013, followed by Europe. Asia Pacific is predicted to grow expeditiously in the coming years, and China presents a potentially lucrative market in this area.

The UK is leading the innovation of smart materials technologies and is interested in establishing partnerships with China. The UK-China Smart Material Technology Partnering mission aims to integrate the complementary expertise of the innovation bases of the two countries to collectively produce smart materials solutions in transport, aerospace, healthcare, building and energy.

This short report outlines the current development of smart material technology in China, and will cover the following four areas:

- Chinese government's investment and tax incentives
- Scientific literature publications
- Centres of excellence in smart material research
- Smart material industry in China

Chinese government's investment and tax incentives

The robust growth of China's smart material market has been actively supported by the government's significant investment and tax incentives on high technology sectors over the past two decades. Smart materials was firstly listed in China's 863 Technology Programme (or State High-Tech Development Plan) in 1991. Major national funding organisations such as the National Science Foundation of China and the China Aerospace Fund have since gradually increased their budgets over the year to support smart material R&D activities in China. In 2012, China's 12th Five-Year Development Plan for national strategic emerging industries listed new materials as one of the seven priority industries. Smart materials such as shape memory alloys, rare-earth magneto-strictive materials and piezoelectric materials are considered to be the key development directions in the Plan. In addition, new material technology is listed as one of the eight high-technology areas that receive R&D tax incentives from the government under the R&D Super Deduction and High New Technology Enterprise R&D programmes. Therefore, since the early 1990s, China's smart material market has been rapidly gaining competitiveness compared with developed countries such as the US and Japan.

Scientific literature publications

With the government's strong support in smart materials research, the number of scientific publications in this area has increased significantly since 1990. A recent literature landscape study conducted by ICUK reveals China produced the second highest number of scientific papers in the area of smart materials since 1990. As shown in Figure 1, between 1990 and 2015 there were nearly 60,000

papers published in China. This number is considerably more than that of other countries excluding the US in the top 10 countries' list.

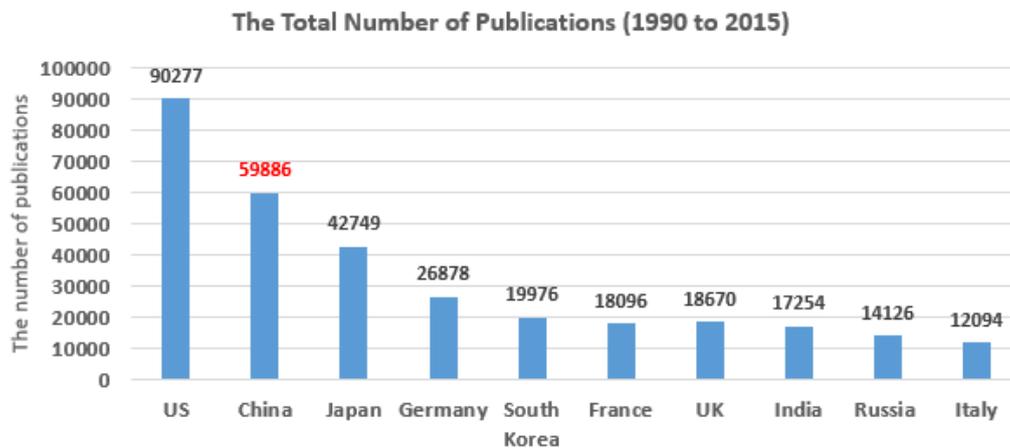


Figure 1: The number of scientific publications by top 10 countries between 1990 and 2015

Note: This literature landscape study was conducted by ICK using Scopus® database, the largest abstract and citation database of peer-reviewed literature. Scientific publications were selected from the period between 01-Jan 1990 and 09-July 2015, and the search was limited to English language publications only. Key words selected cover the scope of the following smart materials: photoconductors, piezoelectric, eletrostrictive, magnetostrictive, electrochromic, electroluminescent, electro-optic, magneto-optic, photochromic, thermochromic, thermoluminescent, mechanochromic, thermoelectric, shape memory, chemochromic, photovoltaic, piezochromic, hydrochromic, electro-rheological-fluid, magnetorheological-fluid, smart fabrics, smart textiles, hydrogel, biomimetic, ferroelectric, self-healing, self-cleaning and smart packaging.

In comparison, China was only at the 4th place ten years ago. The number of scientific publications produced by China was less than a third of that the US published between 1990 and 2005, far behind Japan and Germany (Figure 2).

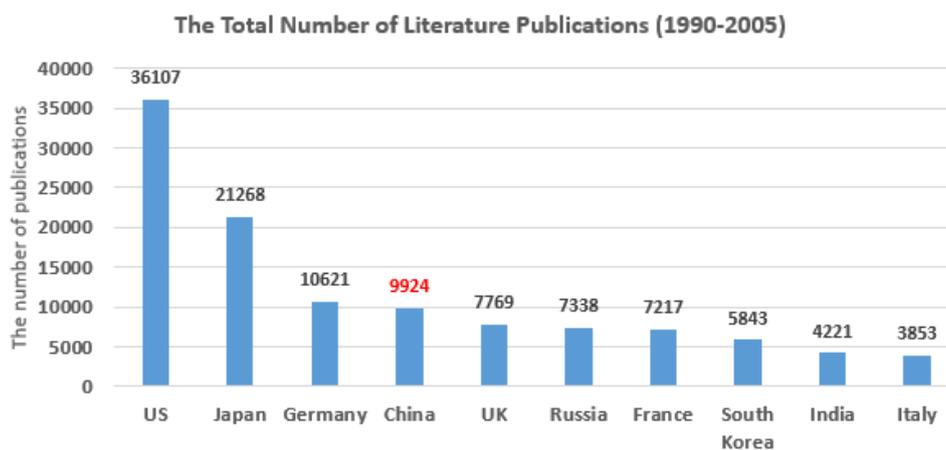


Figure 2: The number of scientific publications by top 10 countries between 1990 and 2005

Notably, there was a dramatic increase in the proportion of Chinese scientific publications to the world between 1990 and 2014, the percentage increased exponentially from only 2% in 1990 to 23% in 2014 (Figure 3). The analysis shows nearly a quarter of the world scientific literature on smart materials were published by China in 2014. With China's dominate role as a global manufacturing centre, this accelerated development in smart material technologies will arguably revolutionise many traditional industry sectors in China ranging from transport, energy, building environment to healthcare, security

and packaging, which represents potential threats and real opportunities to many developed countries.

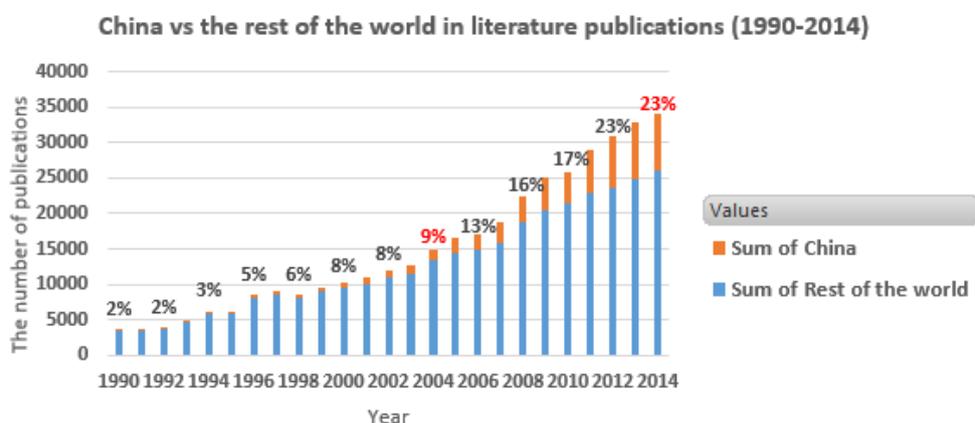


Figure 3: China vs the rest of the world in publications between 1990 and 2014

Centres of excellence

According to the literature analysis, the top ten Chinese universities/institutes by the number of scientific publications are shown in Table 1. Tsinghua University (1st) and Harbin Institute of Technology (2nd) are clearly leading the smart material research in China. Two Shanghai based institute/university-Shanghai Jiaotong University (6th) and Shanghai Institute of Ceramics Chinese Academy of Sciences (8th) gave a total of 3016 publications, indicating **Shanghai** as a centre of excellence in this field.

Rank	University/Research Institute	Number of Publications
1	Tsinghua University	3103
2	Harbin Institute of Technology	2344
3	Zhejiang University	1728
4	Nanjing University	1696
5	Jilin University	1563
6	Shanghai Jiaotong University	1532
7	Xi'an Jiaotong University	1516
8	Shanghai Institute of Ceramics Chinese Academy of Sciences	1484
9	Huazhong University of Science and Technology	1189
10	Sichuan University	1119

Table 1: Top 10 Chinese universities/ institutes by the number of publications (between 1990 and 2015)

Furthermore, another search for smart material related Chinese key laboratories and centres were carried out. Table 2 listed selected examples of key labs/centres and their affiliated universities/institutes as well as top academics and their research focuses. Note, this is not an exclusive list and the results are only based on initial search.

It is worth mentioning that State Key laboratories are national-level laboratories receiving funding and administrative support directly from the central government. Ministry of Education (MOE) laboratories are one level lower than State Key labs, governed by Ministry of Educations of China. Provincial and regional laboratories supported by local governments, normally receive less funding than MOE labs and State Key labs.

Ref	Key Labs or Centres	University/Institute	Top Academics
1	1) Key Lab. of Advanced Material, MOE 2) Key Lab. of Organic Optoelectronic and Molecular Engineering, MOE 3) State Key Lab. of New Ceramics and Fine Processing	Tsinghua University	Prof. Longtu Li Prof. Jingfeng Li Prof. Cewen Nan
	Main areas of focus: Multi-ferroic, magneto-electric, ferroelectric, piezoelectric, thermoelectric materials; Functional polymer-based composites; Organic optoelectronic materials etc.		
2	Centre for Smart Materials and Structures	Harbin Institute of Technology	Prof. Jinsong Leng Prof Wenjing Tian Prof Wenwu Cao
	Main areas of focus: Shape memory polymers, electro/ magneto rheological fluid and devices, megnetostrictive materials, ferroelectric and piezoelectric material; Fiber optic sensors and Interrogation Systems; Multifunctional nano-composites		
3	1) Lab. of Solid State Microstructures and Innovation Center of Advanced Microstructures 2) National Lab. of Solid State Microstructure	Nanjing University	Prof Junming Liu Prof Zhiguo Liu
	Main areas of focus: Thermoelectric materials and ferroelectric, Photonic and Electronic Materials, Ferroelectric		
4	1) State Key Lab. of Mechanics and Control of Mechanical Structures 2) Key Lab. of Intelligent Nano Materials and Devices, MOE 3) Key Lab. of Smart Material and Structure Institute	Nanjing University of Aeronautics and Astronautics	Prof Kongjun Zhu Prof Jinhao Qiu Prof WanLin Guo
	Main areas of focus: Piezoelectric materials; smart structural material and health monitoring; Shape memory material and functional composites; Electro-optical fibres; Controllable fabrication and surface properties of grapheme; Functional boron nitride nanomaterials and their unusual properties; Novel molybdenum disulfide devices and structures; Fabrication and Physical Properties of Nanoscale Energy Materials		
5	State Key Lab. of High Performance ceramics and superfine microstructures	Shanghai Institute of Ceramics	Prof Haosu Luo
	Main areas of focus: ferroelectric single crystals. piezoelectric materials and devices Functional ceramics and superfine microstructures; Inorganic functional materials		
6	Functional Materials Research Lab.	Tongji University	Prof Jiwei Zhai Prof Xi Yao

	Main areas of focus: Ferroelectric, piezoelectric, pyroelectric, thermoelectric materials and devices; integrated ferroelectrics and ferroelectric micro electro-mechanical system		
7	Electronic Materials Research Lab., MOE	Xi'an Jiaotong University	Prof Xi Yao Prof Zhuo Xu Prof Yunzhi Wang
	Main areas of focus: Piezoelectric,thermoelectric, electo-optic, ferroelectric materials and devices; Shape memory material and strain glasses		
8	State Key Lab.of Luminescent Materials and Devices	South China University of Technology	Prof Yong Cao
	Main areas of focus: Conducting polymers, optoelectronic conjugated polymers and devices including electroluminescent and photovoltaic devices		
9	State Key Lab. of Metal Matrix Composites	Shanghai Jiao Tong University	Professor Zuyao Xu
	Main areas of focus: Metal Matrix Composites, polymer matrix composites and new functional composite materials.		
10	State Key Lab. of Supramolecular Structure and Materials	Jilin University	Prof Wenjing Tian
	Main areas of focus: Organic Optoelectronic Materials		

Table 2: Ten leading Chinese universities/research institutes in smart material research

The locations of the above selected universities/institutes are shown in Figure 4. Shanghai, Nanjing and Northeast region near Harbin are seemly the hot spots. This result is also consistent with findings of the primary interviews conducted by ICUK with a few stakeholders. It is therefore these three cities are selected to be the destinations for this mission.

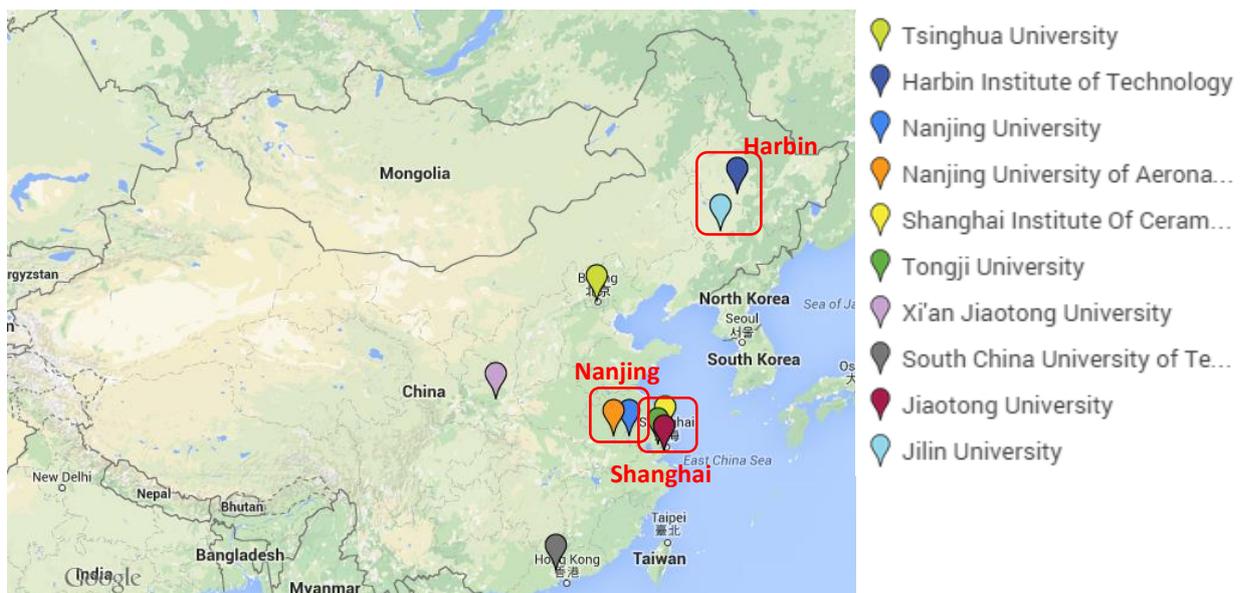


Figure 4: The locations of ten leading universities/institutes in the area of smart material research

Smart Material Industry in China

Chinese smart material industry is considered to be relatively immature compared with developed markets in Japan and the US. Also, the development of the overall industry appears to be not well balanced.

The analysis from a patent landscape study shows Japan filed the most patent applications between 1973 and 2013, nearly half of a total of 7236 patents were from Japan, followed by the US. China was ranked at the 3rd place, with over 1000 filed patents. Interestingly, the analysis reveals the top three Chinese assignees are from universities-Shanghai Jiaotong University, Shanghai Institute of Ceramics and Tsinghua University, which reflects the immaturity of the Chinese smart material industry-innovation is primarily led by universities and research institutes rather than large companies as in Japan.

The patent analysis also indicates the unbalanced growth of the smart market in China. It is found that main areas of Chinese patents are shape memory alloys, biomimetic composite materials, self-cleaning materials and piezoelectric materials. This finding is consistent with the results from another published study which concluded that shape memory alloy, piezoelectric and magneto-strictive material sectors have been developed more rapidly than other areas due to the market demand and abundantly available rare earth materials in China. It is estimated that piezoelectric material takes up to nearly 50% share of China's smart material market.

Table 3 summarises general information of seven publicly listed large companies in the smart materials business (Table 3), aiming to provide a brief overview of leading players in China. As smart material is not a traditional sector in China, more relevant companies could be found in the overlapping technology space among other areas such as sensors and functional materials. ICUK is currently working closely with local science and technology authorities and their technology transfer agencies from the three visiting cities to ensure relevant local companies to be presented at the partnering events.

Ref	Name	Location	Focus areas
1	Lanzhou Seemine Shape Memory Alloy Co. Ltd	Lanzhou, Beijing, Shanghai	Shape-memory alloys
<p>Intro: Founded in August 1997, Seemine is a subsidiary of Unisplendour Corporation Ltd. The company is a specialised high-tech enterprise engaging in the R&D of shape memory alloy medical instruments in China. It is also the first enterprise in China achieving large scale production of shape memory alloys. The company mainly provides products for the medical sector.</p> <p>Website: http://www.seemine.com.cn/</p>			
2	Ningbo Xianfeng New Material Co. Ltd	Ningbo, Zhejiang	Photochromic, anti-UV, anti-bacterial, flame retardant, recyclable shading materials
<p>Intro: The company operates under the brand APLUS in the international market, and was founded in 2003. As a leading manufacturer of sunscreen products, APLUS has developed various types of environmentally-friendly, energy-saving sunscreen fabrics, anti-UV, anti-bacterial, flame retardant, recyclable shading materials and photochromic materials for interior and exterior use. The company mainly provides products for the building and construction sectors.</p> <p>Website: http://www.aplus.cn/zh</p>			
3	Grinm Advanced Material Co. Ltd	Beijing, Jiangsu, Leshan	photo-electric material, semi-conductor silicon material, shape memory alloys, luminescent materials, LED fluorescent material, magnetostrictive material

Intro: GRITEK, a subsidiary of GRINM, is a leading high-tech company in the field of semiconductor silicon materials. The company owns more than 50 patents and its products can be widely used in integrated circuits, discrete devices, solar cell and other fields.

Website: <http://www.gritek.com/>

GRIKIN, a subsidiary of GRINM, is a pioneer in the world to develop and manufacture medical Stents by Nitinol shape memory alloy, focusing on the application of non-ferrous metals in the industry of semiconductor, electronics and medical applications.

Website: <http://www.grikin.com/index.htm>

GRIREM, a subsidiary of GRINM, focusing on the production, R&D of rare earth and related materials, possessing an integrated industry chain from rare earth mining to functional materials.

Website: <http://www.grirem.com/>

4	Advanced Technology & Materials Co. Ltd	Beijing, Tianjin, heye, Shanghai, Yichang, Shenzhen	Amorphous & nanocrystalline alloy, magnetic materials, refractory materials, energy storage and power generation materials etc
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Intro: Advanced Technology & Materials Co., Ltd (AT&M), a national high-tech enterprise, is a globally active precious metals and advanced material company. Their business covers the areas of precious metals, sensors, dental and medical products, quartz glass and specialty lighting sources. Their technology are focused in ten business fields including amorphous & nano-crystalline materials & products, magnetic materials, energy storage and power generation materials, refractory materials & products, powder metallurgy materials & products, welding consumables, bio-materials, engineering technology, high speed steel & Hss tools and diamond & diamond tools. AT&M provides products for the sectors including aeronautics, astronautics, telecommunication, electric power, electronics, metallurgical machinery, petrochemical industry, transportation and environmental protection, etc.

Website: <http://www.atmcn.com/cn/>

5	Lepu Medical Technology Co., Ltd	Shanghai, Beijing	Shape memory Alloy and medical devices
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Intro: The company is specialized in high-tech medical device R&D, production and sales. The company focuses in cardiac therapy, with products including interventional cardiology, occlusion devices, prosthetic heart valves, pacemaker, cardiac in vitro diagnosis products, angiographic equipment and anesthetic products. Lepu has seven wholly-owned and joint stock subsidiary companies, including Shanghai Shape Memory Alloy Co. Ltd which mainly manufactures shape memory alloys, specializing in the medical devices for congenital heart diseases.

Website: <http://www.shsma.com/>

6	Zhuzhou Times New Material Technology Co., Ltd	Hunan	Modified polymer composite and elastic sensitive material
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Intro: Founded in 1984, the company is engaged in the business of developing and manufacturing polymer composite materials for the railway, automotive, construction, shipping, environmental protection and wind power industries worldwide. Their products include polymer elastic components for shock absorption and noise reduction, insulation products and coatings, lightweight products special engineering plastics products, electromagnetic wires and composites.

Website: <http://en.trp.com.cn/>

7	Guanhao Biotech Co. Ltd	Guangzhou	Regenerative medical materials
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Intro: Grandhao Biotech Co., Ltd, a pioneer in the field of regenerative implantable medical devices. The company develops, manufactures and markets regenerative medical devices for the treatment of damaged tissue and organs.

Website: <http://www.guanhaobio.com/>

Table 3: Seven publicly listed Chinese companies in smart materials business.