

Studies on China graphene research based on the analysis of National Science and Technology Reports^①

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Abstract

The study tries to reveal the situation and development trends of China's graphene research utilizing National Science and Technology Reports (NSTR) as the new data resource. Findings show a continual increase of graphene projects sponsored by the government. Most of them are from the National Basic Research Program of China and the National High-tech R&D Program, which reflects mainly aiming for breakthroughs of China's graphene research in major frontier fields and promoting industrial competitiveness. As a new material in nanometer area, the graphene research mainly focuses on nanometer research area. Besides, it has also involved more in the promising applications, such as advanced energy technology, biological and medical technology, testing and analytical instrument technology, etc. Major players are universities and research institutes, and they have collaborated a lot. Few enterprises have played an important role in the collaboration network, so China's graphene research is still mainly in the basic research step. Key scholars with their research interests have been revealed.

Key words: National Science and Technology Reports (NSTR), graphene, China, project

0 Introduction

Graphene is composed of a single layer of carbon atoms, which are densely packed into a benzene-ring structure. With unique combination of bonded carbon atom structures and its myriad and complex physical properties, graphene is poised to have a big impact on the future of material sciences, electronics and nanotechnology. Owing to their specialized structures and minute diameter, they can be utilized as semiconductor, components of integrated circuits and sensor devices. The reported properties and applications of this two-dimensional form of carbon structure have opened up new opportunities for the future devices and systems^[1-3]. As a result, this single-layer two-dimensional material with tremendous industry prospect has attracted wide research interests all over the world. Discovery of graphene research frontiers and investigation of graphene technology and industry evolution are important for policymakers around the world. In recent years, scientometrics has been used as a quantitative analysis method for scientific and technological research, which is mostly from the perspective of paper and patent analysis^[4-15].

Ma, et al. studied and evaluated global scientific production and developing trend of graphene research with bibliometric analysis and knowledge visualization

technology. The results proved that graphene research increased rapidly over past 20 years and boosted in recent 5 years. This distinctions in knowledge map show that clusters distributed regularly in keywords of applied patents in recent 5 years due to the potential applications of graphene research found gradually^[4]. Pan, et al. analyzed research frontier of graphene and its developing trends in China from the perspective of bibliometric method. By the statistics and analysis of country, institute and subject, they found that the graphene related research had got rapid development ever since the year of 2005, which was mainly in the subject of polymer physics, material science and applied physics^[5]. The Intellectual Property Office of UK government issued patent analysis report on global graphene research in the year of 2013, which provided comparative analysis of countries' research and development potential in graphene field from the perspective of technology theme, time zone and relative specialty index^[6]. Gridlogics technologies company conducted deep research into graphene key research institutes based on patent layout, cooperation and key technologies^[7].

From the research mentioned above, papers and patents have been widely used as data source for evaluation of graphene research. However, few researches have paid attention to the Science and Technology Reports (STR) which is also a very good data resource for evaluation and

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metric analysis of science and technology research^[16]. The study herein is trying to reveal China's research situation and development trends in graphene field from a perspective of NSTR metric analysis.

1 Methodology

National Science and Technology Report refers to the special literature prepared by the scientific and technical personnel in order to describe the process, progress and results of activities such as scientific research, design, engineering, testing and identification in accordance with the prescribed standard format. As one of the summary forms and achievements of national science and technology investment, science and technology report provides effective means for government performance evaluation and publicity effect of science and technology investment, and increases the transparency of scientific research work.

National Science and Technology Report Service system (NSTRS) was officially opened on March 1, 2014, which is a comprehensive service platform for the sharing and exchange of science and technology reports produced by financial aid projects. It can provide basic scientific research information for scientific research personnel, provide decision-making support for scientific and technological manager and help the public to understand and use national scientific research products.

In this study, Science and Technology Reports (STR) related to graphene were retrieved and downloaded on May 8th, 2017 from National Science and Technology Report Service system (NSTRS). The metadata elements include the title, author, author unit, report type, secret level, scientific report number, summary, keyword, classification number, plan name, project name and number, commitment unit, date of completion, etc.

2 Results and discussion

2.1 History and development trends of graphene projects

The number of government-supported graphene projects, which have been collected by the NSTRS from 2006 to 2015 is 184. Among them, 141 projects were sponsored by the National Basic Research Program of China (973 Program), which were the main supporting way for China's graphene research, as seen in Fig. 1. Apart from that, 32 projects have been supported by the National High-tech R&D Program (863 Program). From the mentioned above, it can be concluded that China's graphene

research supported by government have been mainly from 973 Program and 863 Program.

Based on the existing basic research programs conducted by the National Natural Science Foundation and early-stage basic research key projects, 973 Program organizes and implements key projects to meet the national strategic needs. The strategic objective of the Program is to mobilize China's scientific talents in conducting innovative research on major scientific issues in agriculture, energy, information, resources and environment, population and health, materials, and other related areas.

Objectives of 863 Program are to boost innovation capacity in the high-tech sectors, particularly in strategic high-tech fields, in order to gain a foothold in the world arena to strive to achieve breakthroughs in key technical fields that concern the national economic lifeline and national security; and to achieve "leap-frog" development in key high-tech fields in which China enjoys relative advantages or should take strategic positions in order to provide high-tech support to fulfill strategic objectives in the implementation of the third step of our modernization process.

Therefore, China's graphene research has been conducted mainly aiming at mastering key new materials and advanced manufacturing technologies to boost industrial competitiveness, promoting research and innovation in order to seek breakthroughs in major frontier fields of far-reaching and strategic importance, and also consolidating a highly qualified contingent for basic research and cultivating a number of personnel with innovative capabilities.

Fig. 2 displays the change of graphene-related projects supported by government. It can be seen that the number of graphene projects have exhibited continual growth from the year of 2006 to the year of 2011, with the highest level of 50 projects in 2011. In the year of 2012 and 2013, the number of projects maintained a very high level, with the number of projects of 44 and 39, respectively. From the discussed above, China's government has strongly supported graphene research for a long time. As for the year of 2014 and 2015, the number of graphene related projects was merely 1. It is because most national science and technology reports were submitted into the system at the end of project. Probably, those projects that were set up in 2014 or 2015 did not get the final stage, so there were few projects of 2014 and 2015 in the system. From Fig. 3, it can be seen that 973 Program and 863 Program have always been main supporting channels for China's graphene research since 2006, in accordance with Fig. 1.

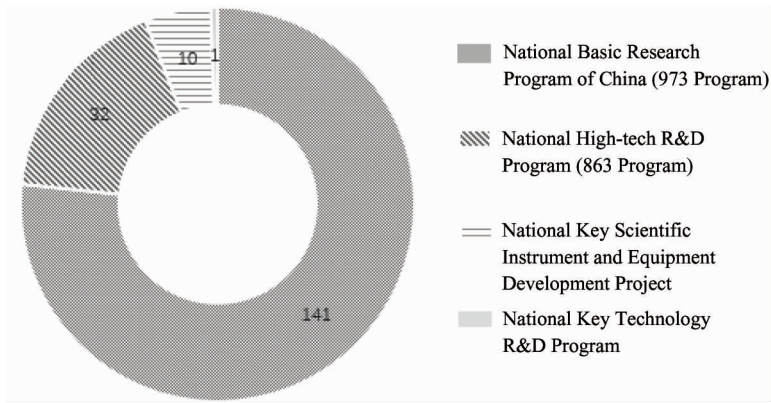


Fig. 1 Number of graphene projects supported by different programs in China

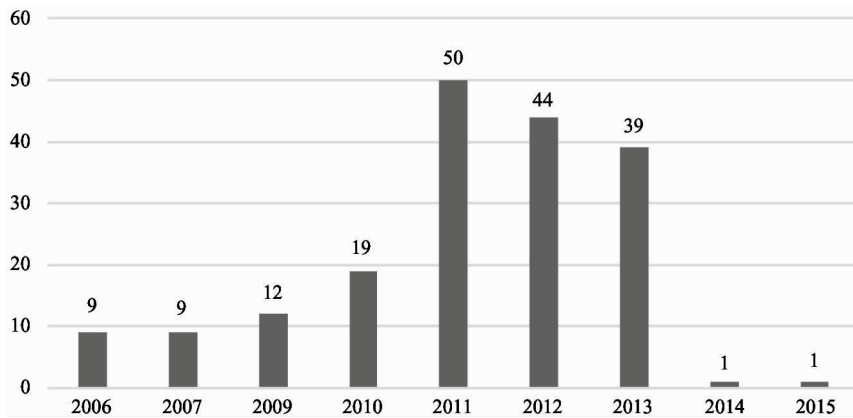


Fig. 2 Number of graphene projects in China by year

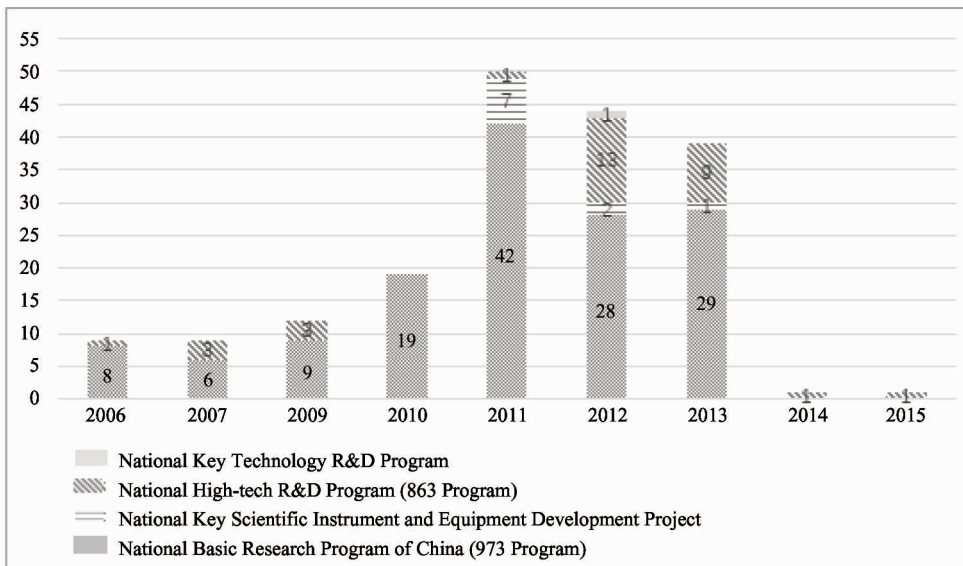


Fig. 3 Number of graphene projects supported by different programs in China by year

2.2 Technology layout among graphene research

The graphene research supported by Chinese government has been mainly conducted in nanometer research area, with the number of 78 projects, which accounted for more than 1/3 of the total graphene projects, as seen in Fig. 4. The second research focused

new materials technology, with the number of 21 projects. As a new material in nanometer area, it is not very hard to understand why the research of graphene focused on nanometer research and new materials technology. The other areas which the graphene research has also more involved in are advanced energy technol-

ogy, biological and medical technology, testing and analytical instrument technology. Those are main ap-

plications that graphene research has been mainly aiming for.

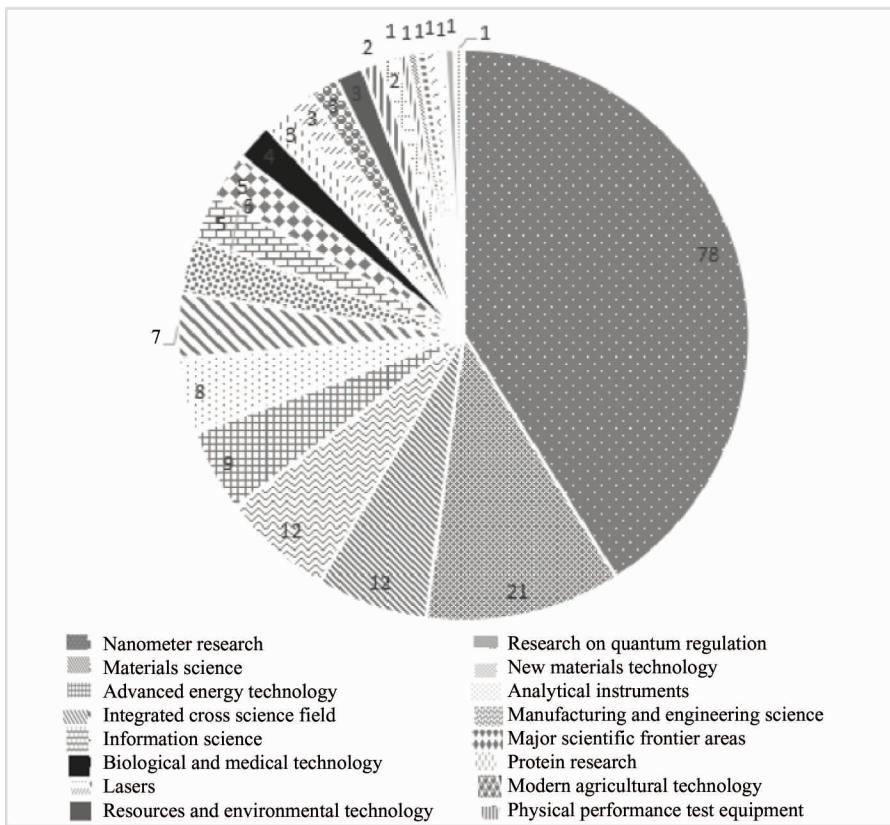


Fig. 4 The number of graphene projects in different technology areas in China

Fig. 5 displays the change of graphene-related projects in different technology areas by year. The number of graphene research in nanometer research has exhibited a continual growth, with the number of 3 in 2007 to the number of 22 in 2013. Nanometer research was not only the main research area for graphene research, but also the continual and rapid growing area for graphene research. Quantum regulation was another continual and important technology area for graphene research, with the number of 3, 8, 5 and 1 projects in the year of 2010, 2011, 2012 and 2013, separately. Similar to Fig. 3, there were few projects in the year of 2014 and 2015. Probably, it is also because those projects that were set up in 2014 or 2015 did not get the final stage, so there were few reports submitted to the NSTR system.

2.3 Institutes distribution among graphene research

Fig. 6 lists the top 20 institutes in China's graphene research project. They are Tsinghua University (THU), Institute of Physics, Chinese Academy of Sci-

ences (IOP CAS), Fudan University (FDU), Peking University (PKU), Xiamen University (XMU), Nankai University (NKU), Dalian Institute of Chemical Physics, Chinese Academy of Sciences (DICP CAS), Institute of Chemistry, Chinese Academy of Sciences (IC CAS), Nanjing University (NJU), National Center for Nanoscience (NCNST), Jilin University (JLU), University of Science and Technology Beijing (USTB), Shanghai Jiaotong University (SJTU), China University of Science and Technology (USTC), Shanghai Institute of Applied Physics, Chinese Academy of Sciences (SIAP CAS), Beijing University of Aeronautics and Astronautics (BUAA), Beijing Institute of Technology (BIT), Suzhou University (SUDA), Wuhan University of Technology (WUT) and Central South University (CSU), respectively. Among the top 20 institutes, 14 are universities, and the other 6 are research institutes from Chinese Academy of Sciences. From this point, most of China's graphene research still focuses on basic research, which has been mainly conducted by universities and research institutes. It is still a bit away from industry applications.

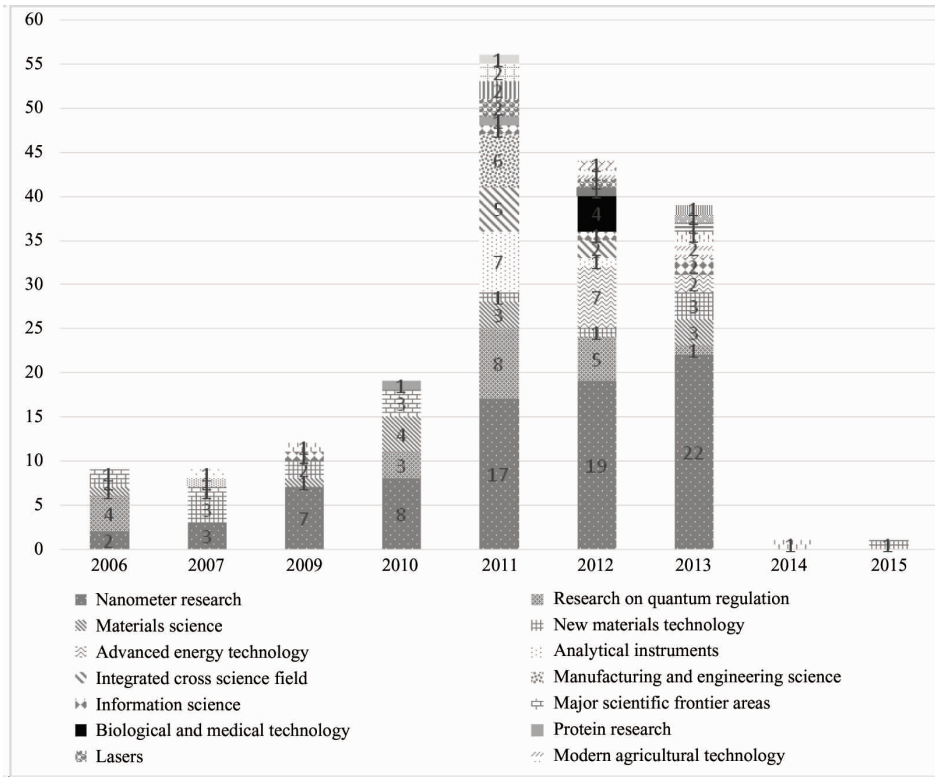


Fig. 5 The number of graphene projects in different technology areas in China by year

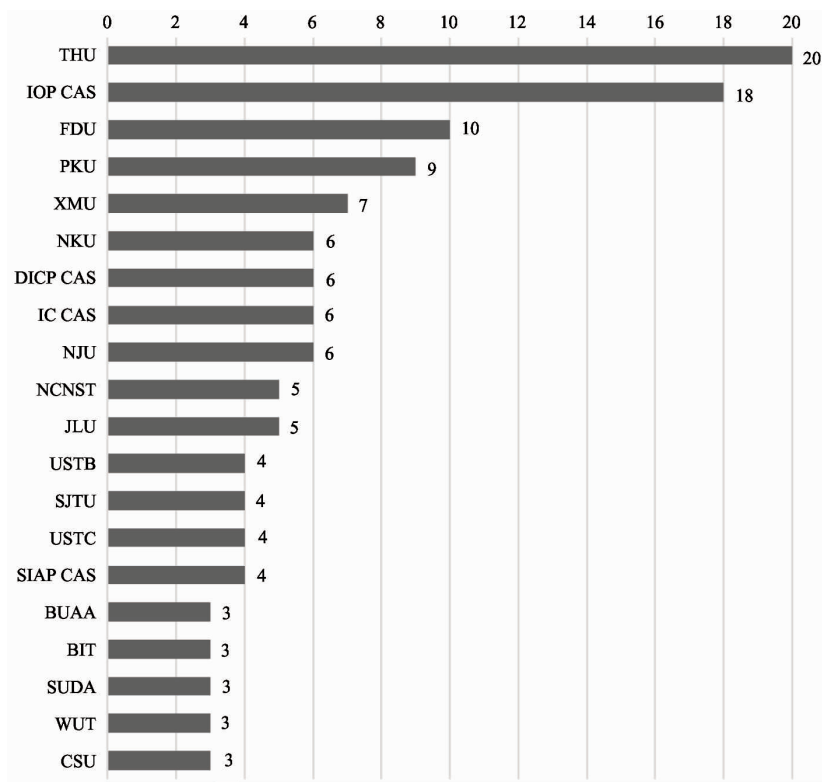


Fig. 6 Top 20 institutes in China's graphene research projects

Fig. 7 exhibits a collaboration network of major institutes in China's graphene research. It can be concluded that China's universities and research institutes do collaborate a lot in graphene research. Among them Tsinghua University has conducted most co-operations with other universities and research institutes, such as The National Center for Nanoscience and Technology, Shanghai Jiaotong University, Peking University, Fudan University, Zhejiang University, Harbin Institute of

Technology, Huazhong University of Science and Technology, Beijing Institute of Technology, Jilin University, Nankai University. Besides, The National Center for Nanoscience and Technology, Peking University, Shanghai Jiaotong University, Nankai University, and Fudan University also have conducted lots of collaborations with other universities and research institutes in graphene research.

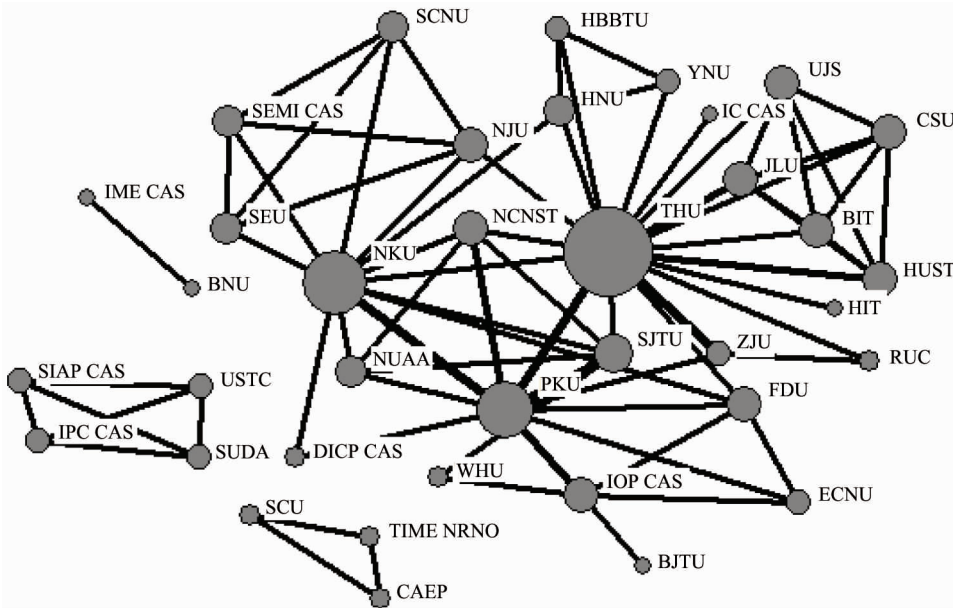


Fig. 7 Collaboration of China's institutes in graphene research projects

2.4 Key scholars in graphene research

Fig. 8 exhibits top scholars of National Science and Technology Reports in China's graphene. They are Chen Xiaolong from Institute of Physics, Chinese Academy of Sciences (IOP CAS), Shi Gaoquan from Tsinghua University (THU), Tian Zhongqun from Xiamen University (XMU), Jiang Lan from Beijing Institute of Technology (BIT), Liu Zhongfan from Peking University (PKU), and Pan Feng from Tsinghua University (THU), respectively. Chen Xiaolong from Institute of Physics, Chinese Academy of Sciences has submitted 7 national science and technology reports, which are mainly related to the controllable preparation, physical properties and device testing of graphene. Shi Gaoquan from Tsinghua University has also submitted 7 national science and technology reports, which are mainly focused on macro-controllable preparation of graphene material and its application, controllable assembly and compounding of graphene and graphene-based supercapacitor. Tian Zhongqun from Xiamen

University has submitted 5 national science and technology reports, which are mainly around development and application of graphene in Radiator Enhanced Raman Spectroscopy Instrument. Jiang Lan from Beijing Institute of Technology has submitted 3 national science and technology reports, which mainly focus on new method and scale limit of laser micro-nanosensor related to graphene. Liu Zhongfan from Peking University has also submitted 3 national science and technology reports, which mainly focus on low-dimensional functional materials-new diracmaterials, graphene and topological insulators nanostructures and derivatives. Pan Feng from Tsinghua University has submitted 3 national science and technology reports too, which mainly focus on non-catalytic synthesis and field emission properties of graphene/carbon nanotube composite structures and construction of nanometer gradient structure of ion beam bombardment and its application in memory.

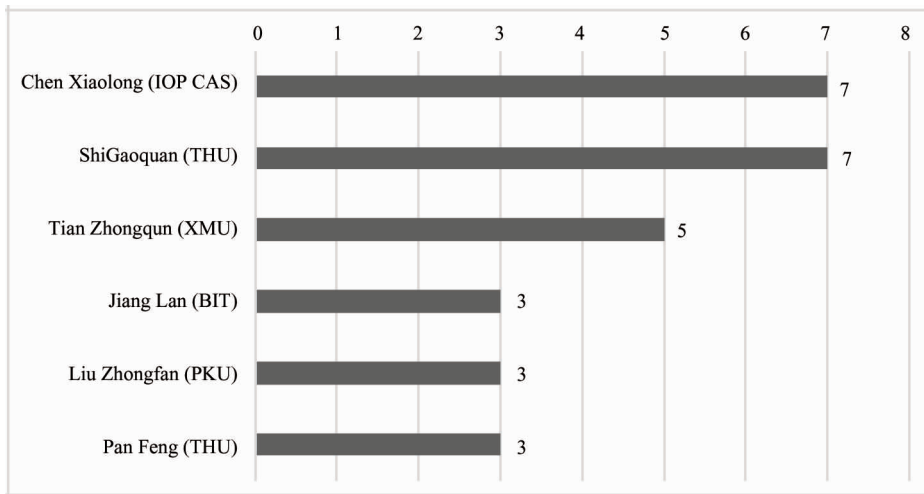


Fig. 8 Key scholars in China's graphene national science and technology reports

3 Conclusions

As a new nanometer material with unique properties and promising applications, graphene has drawn tremendous interests from the whole world. In previous studies, papers and patents have been widely used as data source for evaluation of graphene research. Few researches have utilized National Science and Technology Reports as the data resource for evaluation and metric analysis of graphene research. This study tries to use National Science and Technology Reports to study China's research situation and development trends in graphene field.

The number of government-supported Graphene projects from 2006 to 2015 is 184, and has exhibited continual growth. Among them, 141 projects were sponsored by 973 Program, 32 projects were supported by 863 Program. China's graphene research supported by government are mainly from 973 Program and 863 Program. Thus, China's graphene research mainly aims at seeding breakthroughs in major frontier fields and promoting industrial competitiveness.

The graphene research has mainly focused on nanometer research area, with the number of its projects accounting for more than 1/3 of the total graphene projects, which also exhibits a continual growth. The other areas which the graphene research have also more involved in are main applications that graphene research has been mainly aiming at, which are advanced energy technology, biological and medical technology, testing and analytical instrument technology, and so on.

All of the top 20 institutes in China's graphene research project are universities or research institutes. It can be concluded that most of China's graphene re-

search focuses on basic research, still a bit away from industry applications. As for the collaboration, China's universities and research institutes do co-operate a lot in graphene research. Among them Tsinghua University has conducted the most co-operations with other universities and research institutes. Besides, The National Center for Nanoscience and Technology, Peking University, Shanghai Jiaotong University, Nankai University, and Fudan University also have conducted lots of collaborations with other universities and research institutes in graphene research.

Key scholars that contribute a lot to the National Science and Technology Reports in China's graphene area are Chen Xiaolong from Institute of Physics, Chinese Academy of Sciences, Shi Gaoquan from Tsinghua University, Tian Zhongqun from Xiamen University, Jiang Lan from Beijing Institute of Technology, Liu Zhongfan from Peking University, and Pan Feng from Tsinghua University, respectively. Chen Xiaolong focuses on controllable preparation, physical properties and device testing of graphene. Shi Gaoquan mainly conducted macro-controllable preparation of graphene material and its application, controllable assembly and compounding of graphene and graphene-based supercapacitor. Tian Zhongqun's research is mainly around development and application of graphene in Radiator Enhanced Raman Spectroscopy Instrument. Jiang Lan devotes to new method and scale limit of laser micro-nanosensorrelated to graphene. Liu Zhongfan has done lots of research on low-dimensional functional materials-new diracmaterials, graphene and topological insulators nanostructures and derivatives. Pan Feng's research interests are mainly in non-catalytic synthesis and field emission properties of graphene/carbon nanotube composite structures and construction of nanometer gradient structure of ion beam bombardment and its

application in memory.

In a word, the study herein has provided a new area and prospect for science and technology evaluation by using a new data source, that is National Science and Technology Report which has been used to reveal the status and development trends for graphene field. Other technology fields can be studied in future research. And also more evaluation methods by using national Science and Technology Report can be discussed in future research.

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