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Review (Special Column on Progress in Catalysis in China during 1982-2012)

# Progress in catalysis in China during 1982–2012: Theory and technological innovations

XIN Qin *, LIN Liwu

*State Key Laboratory of Catalysis, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian 116023, Liaoning, China*

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ABSTRACT

The development of catalytic science and technology in China dates from the early 20th century. In the beginning, the efforts of our predecessors gave an initial period of steady development. Then in the 1960s, there were serious obstacles by human factors during which the development of catalysis was stagnant and we lost more than ten years of development opportunity. In the 1980s, catalysis in China entered a period of rapid expansion. During this period, three main research sectors, namely, Chinese Academy of Sciences (CAS), universities, and industries, were rapidly established and development recovered. Researchers carried out research using reaction kinetics as the main method and means. In basic research, the discovery of novel catalytic materials, characterization methods, and novel catalytic reactions were the main research directions. The introduction of surface science and nanoscience has greatly promoted and deepened the basic exploration of catalysis. Catalysis is now changing from an art to a science. In different historical periods, researches in applied catalysis were determined by national needs and these have made notable contributions to many fields, such as the optimal utilization of coal, petroleum and natural gas, advanced materials, and protection of environment as well as human health. Currently, China has begun contributing to important progress in catalysis and is moving towards becoming a regular contributor.



## 1. Introduction

Since the People's Republic of China was founded, its catalytic research teams have been positioned in three main sectors, namely, Chinese Academy of Sciences (CAS), universities, and the research institutes of the industry. The older generation of scientists, such as Zhang Dayu, Cai Liusheng, Cai Qirui, Yu Zuxi, and Min Enze et al., are the representative figures of these sectors. During the Cultural Revolution, research teams suffered from severe damage to facilities, incomplete and obsolete instruments, temporary shortage of young scientists, and lack of research funding [1–3]. Since the reform and opening-up policy was introduced in the 1980s, CAS, Commission of Education, and Science & Technology Commission have organized and established many high level catalytic research teams, such as State Key Laboratory of Catalysis led by Guo Xiexian, Xin Qin, Xu Yide, Xiong Guoxing et al. and Dalian Institute of Chemical Physics (DICP), CAS led by Lin Liwu, Li Wenzhao, Wang Hongli, Zheng Lubing et al., State Key Laboratory of Physical Chemistry of Solid Surfaces, Xiamen University led by Cai Qirui, Wan Huilin, Zhang Hongbing et al., State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, CAS led by Peng Shaoyi, Zhong Bing, Chen Songying et al., State Key Laboratory for Oxo Synthesis and Selective Oxidation, Lanzhou Institute of Chemical Physics, CAS led by Li Shuben, Yin Yuanqi, Wang Hongli, Chen Yingwu, Shen Shikong, Kou Yuan et al., Changchun Institute of Applied Chemistry, CAS led by Wu Yue, Xie Xiaofan, Zhang Manzheng et al., teams at Fudan University

* Corresponding author. Tel: +86-411-84379071; E-mail: xinqin@dicp.ac.cn
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led by Deng Jingfa, Gao Zi, Zheng Sheng'an, Li Quanzhi et al., teams at Perking University led by Pang Li, Li Xuanwen, Xie Youchang, Lin Bingxiong et al., teams at Nanjing University led by Chen Yi, Xu Qinhua, Yan Qijie et al., teams at Jilin University led by Cai Liusheng, Zheng Zuoguang, Ding Yingru, Zhen Kaiji, Wu Tonghao et al., teams at Zhejiang University led by Jin Songshou, Zheng Xiaoming, Shen Zhiquan et al., teams at Tsinghua University led by Zhu Qiming et al., teams at Tianjing University led by Zhang Liu, Zhao Jiusheng, Qin Yongning, Zhong Shunhe et al., teams at Nankai University led by Li Hexuan, Xiang Shouhe, Tao Keyi et al., teams at Dalian University of Technology led by Wang Xiangsheng, Cai Tianxi, He Ren, Jin Zilin et al., teams at Zhejiang University of Technology led by Liu Huazhang et al., teams at South China University of Technology and Sun Yat-Sen University led by Huang Zhongtao, Zeng Shaokui et al., teams at East China of Science and Technology led by Wang Ren, Li Chenglie et al., teams at Fuzhou University led by Wei Kemei, Fu Xianzhi et al., SINOPEC Corp Research Institute of Petroleum Processing led by Min Enze, Li Dadong, He Mingyuan, Wang Xiqing, Shu Xingtian et al., Shanghai Research Institute of Petrochemical Technology led by Zhang Shi, Guan Xingya, Chen Qingling et al., SINOPEC Fushun Institute of Petroleum and Petrochemicals led by Hu Yongkang, Han Chongren et al., SINOPEC Beijing Research Institute of Chemical Industry led by Mao Bingquan, Liu Xinxiang, Yang Yuanyi et al.

The establishment of SINOPEC Corp and National Foundation of China further promoted the development of catalytic science and technology in China. The reestablished postgraduate education policy gave personnel training that cultivated many elite scientists in the catalytic field. With the meticulous planning and efforts of these academic leaders, Chinese catalytic research teams have collaborated widely with international research groups. Many researchers were sent abroad to study advanced technologies. Among them, a considerable number have become the elites in developed countries all over the world.

In order to participate in the international academic arena of catalysis, Chinese scientists in catalysis have actively participated in and host international meetings. China has hosted the China-Japan-America Congresses of Catalysis (that developed into the Asia Pacific Congress of Catalysis), International Conference of Spillover, and International Conference on Catalysis in Membrane Reactors. In addition, many bilateral and multilateral cooperation projects in science and technology have been signed with Japan, countries in Europe, USA, and Russia.

Since petroleum resources were becoming increasingly scarce, Li Wenzhao et al. proposed the project entitled "Conversion of Natural Gas", which was included in the 8th Five Year Plan. In order to get more research fundings, attract academic proposals and develop talents, Guo Xiexian, Cai Qirui, Peng Shaoyi, Min Enze, Chen Yi et al. proposed the national "summit climbing" project entitled "Optimal Conversion of Natural Gas and Refinery Gases", which was sponsored by the National Science Foundation of China and SINOPEC. At that time, this project was the biggest State key project in catalytic research. Its research topic was also the theme for a quite long period of time in China. After that, the development of catalytic science and technology was well supported in the 9th Five Year Plan, the National Key R&D Programs, 973 and 863 programs, etc. During this period, many mainstream journals of catalysis were launched (or resumed publishing), including *Chinese Journal of Catalysis*, *Journal of Molecular Catalysis (China)*, *Journal of Fuel Chemistry and Technology*, *Natural Gas Chemistry*, *Acta Petrolei Sinica*, *Petroleum Refining and Petrochemicals*, *Industrial Catalysis*, *Petrochemicals (China)*, and so on. The Catalysis Society of China and its Standing Secretariat were established. The National Catalysis Award and National Catalysis Prize for Young Scientists were set up. In 2010, an additional award for scientists below 35 years old, the National Catalysis Award for Excellent Young Scientists, was also established. In addition, the Chinese National Conferences on Catalysis were held biannually. Until now, there have been 14 conferences. The number of participants has increased from the previous hundreds to more than 1500 now. This conference promotes the exchanges of academic works and technology. At present, we have set up substantial international cooperation with the major catalytic powers and powerful countries. Chinese catalytic scientists serve as editorial members and international advisors in almost all the international mainstream journals of catalysis. The Secretariat of the Asia-Pacific Association of Catalysis Societies is located in China. As the representatives of Chinese Catalysis Society, Cai Qirui, Guo Xiexian, Chen Yi, He Mingyuan and Li Can have been members of the International Association of Catalysis Societies Council. In 2004, Li Can was appointed as the vice president of the International Association of Catalysis Societies, and as president in 2008. This was the first time that a Chinese catalytic scientist was appointed to be the president of the International Association of Catalysis Societies. It indicated that catalytic research in China is receiving more attention from international catalytic scientists. The above measures as well as the efforts in pursuing excellence and the dedication of the older generation of catalytic elites laid the foundation for the current state of Chinese catalysis.

## 2. Basic research in catalysis

### *2.1. Exploration of catalytic theory*

In the 1980s, a benefit from the reform and opening-up policy was that through the national and international exchanges and cooperation, Chinese scientists in the catalytic field were exposed to the novel ideas of catalytic theory in the world, and the attention paid to the development of new materials, reactions and characterization methods. Dr. Zhang Dayu [4,5] proposed the concept of surface bonding. Based on many years of industrial catalyst research experience, he proposed "Catalysts Library" and elaborated on the role of catalyst transplant in the R&D of industrial catalysts. Next, Chen Rong and Guo Xiexian et al. [6] published the relationship between the coverage in chemisorption and kinetics. They considered that empty active centers also played an important role in activating reactant molecules. Later on, Guo Xiexian et al. [7] investigated a concerted exchange mechanism of adsorption and desorption,