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Review

Focus on the Chinese revolution of catalysis based on catalytic solutions for the vital demands of society and economy

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ABSTRACT

Catalysis is one of the most cross-cutting technologies in the chemical industry, intensely influencing our daily society. Its practical application is closely related to the engineering disciplines. At present, the academic and industrial research on catalysis in our country has made great breakthroughs in fields like hydrocarbon production, oil-quality upgrading processes, green chemical engineering, and other energy and chemical users of catalysis. In this paper, we attempt to summarize the industrial catalysis achievements and present a discussion on the direction and the development strategy for catalysis, based on economic and social demands.

1. Introduction

Catalysis, a core technology with great influence on socio-economic development, is a interdisciplinary science that integrates chemistry, materials science, engineering and other disciplines. The key aspect of catalysis is its actual practical application. It is therefore closely related to the chemical engineering discipline. The application performance of the catalyst is the fundamental strength of catalysis, and its developmental trajectory not only promotes social and economic progress, but also changes the historical process of human beings. In the early 20th century, Mittasch's contribution to the efficient Fe-based catalyst for ammonia synthesis laid the foundations for the development of modern agriculture and solved the problem of human food consumption with the large-scale promotion of nitrogenous fertilizers [1]. By the 1960s, the invention of molecular-sieve catalysts for oil cracking led to a substantial increase in gasoline yield and octane number and provided the energy foundation for the vigorous development of the transportation industry and led to its fascinating revolution [2]. The invention of the Ziegler-Natta catalytic system allowed the high-pressure efficient polymerization of ethylene, propylene and butene to high molecular structures and promoted the large-scale production of synthetic materials. The development of the three-way Pt-Rh-Pd catalyst for the decomposition of hydrocarbons, CO, and NO_x in automobile exhaust, harmful to the environment, into the harmless N_2 and O_2, greatly improved the environment [3,4]. These important progresses in catalysis have accelerated industrial and social changes. It can be said that the ubiquitous catalyst has played a major supporting role

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in the development of human society.

After a several-generations' effort by Chinese scientists and engineers, China has made a number of important breakthroughs in the development of science and technology that, in recent years, involve catalysis. The 16th International Congress on Catalysis has been successfully organized by Cai Li et al. Several scientists, like Can Li, Xinhe Bao [5,6], among others, have been awarded honorary titles by international academic organizations. Zhang's [7,8] series results were evaluated as important progresses. At the same time, we have achieved vital industrialization in the fields of hydrocarbon production, oil-quality upgrading processes, green chemical engineering, and other fields of energy and chemical catalysis [9,10]. These results of world-class major catalytic industrialization have, to some degree, driven China's economic and social development.

However, many complex issues need to be addressed for further development in the complex field of catalysis. On the one hand, it is necessary to clearly understand the complex surface science and physicochemical phenomena related to catalytic reactions, and to integrate materials science and new methods of inorganic chemistry to design and prepare complex nano-structures of efficient catalyst materials. On the other hand, the catalyst should be mixed with a binder and then shaped, and the reaction kinetics and modulation of the catalytic processes are still not very clear for industrial applications. Both these aspects involve complex problems such as materials diversity, variability of catalytic materials, chemical process suitability, macroscopic preparation, magnification effects, and correlations between intrinsic and apparent properties. These complex issues and the requirements for catalytic development should be mutually supportive and reinforcing. However, from the perspective of industrial catalysis, the most attention should be paid to the capacity of the catalysis to solve or not important economic and social problems; that remains the mission of catalysis [11,12].

This paper attempts to summarize the achievements of the industrial catalysis, and tries to present a discussion on the direction and the strategy for catalysis, based on economic and social demands.

2. The advancement driven by catalysis

With the rapid economic development of our country, the challenges caused by the lack of energy resources and by environmental degradation have become increasingly significant. Catalytic workers have carried out much fundamental research as well as industrial practices in the areas of hydrocarbon production from coal and methanol (MTO and MTX processes), oil-quality upgrading, green chemical industry, and many more [13,14]. Important progresses have been made. Fig. 1 presents the milestones of major industrial catalysis.

2.1. The production of hydrocarbons from coal

In our energy consumption structure, 90% corresponds to fossil fuels, 68.7%, 18% and 3.8% being from coal, oil, and natural gas, respectively. Given the abundant coal resources in China [15], the development of hydrocarbons production from coal is of special significance. As the 485th Xiangshan science conference pointed out, in our society the key focus has been changed from hydrocarbons processing to hydrocarbon synthesizing. The economy is the basic and the most critical necessity for a technology. The value of the methanol-to-olefin (MTO) technology lies not only in its economy, but also in the exploration of a new non-oil olefin production path. By diversifying the raw materials for olefin production, such route would affect the global energy map. It is estimated that, in the next five to ten years, olefin production from coal will reach about a quarter of the total olefin production, making a significant impact on the olefin industry [16–18].

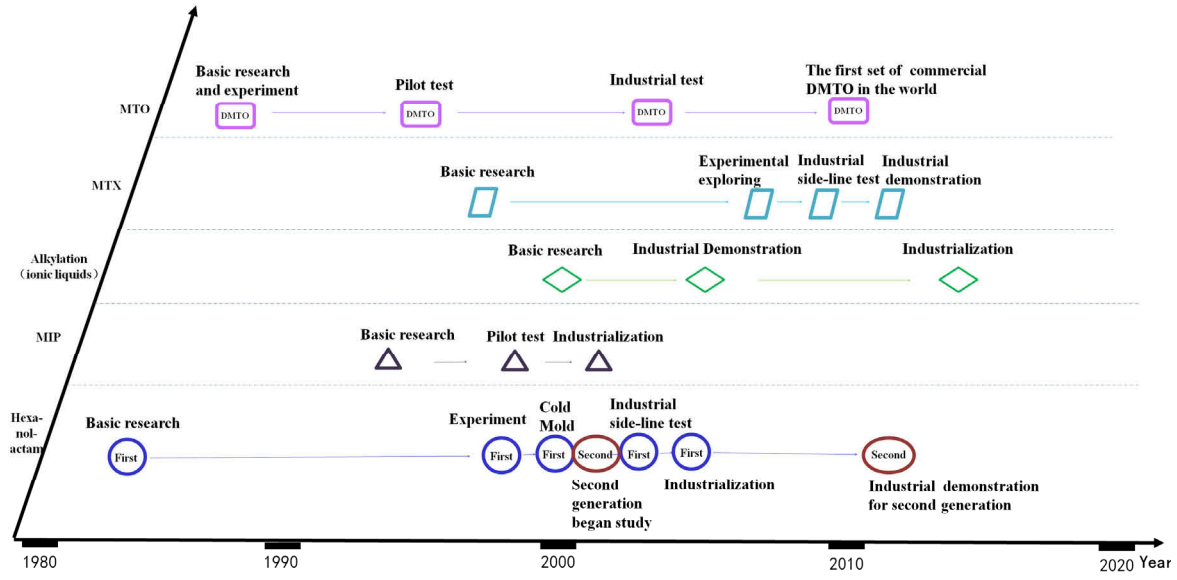

Fig. 1. The milestones of major industrial catalysis in China.