論説 Commentary

# Chemistry-oriented transformation of Japanese industry

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## Electronics-oriented transformation of industry started in the 1980s

In the present article, I would like to discuss a tendency seen throughout Japan's industrial structure, which may be called chemistry-oriented transformation of industry.

Let's review the positioning of the chemical industry. Figure 1 shows the amounts of added value yielded by major industries in Japan (Data taken from Industrial Statistics Tables, and price-level adjustment is not taken into consideration). Added value means the amount of sales by all enterprises belonging to a certain industry after deduction of paid expenses (excluding personnel cost). In other words, added value is an index to show how much value the industry has added to the input (e.g. raw materials, energy, etc.) purchased from outside, by technologically transforming the input to gain a greater amount of sales.

Some 30-odd years ago, the scale of the electronics industry (the electrical machinery industry) was nearly the same as that of the chemical industry. As shown in the chart, these industries were almost the same in terms of added value, at about 4 trillion yen. In the beginning of the 1980s, however, the electronics industry began to expand drastically, and in the second half of that decade it became by far the top industry, with an about 17% share of the total amount of value added by all the manufacturing industries in Japan.

In contrast, for the more than 15 years since 1990, the amount of added value of the chemical industry has been consistently stable, fluctuating within a range of 11 to 12 trillion yen, although showing a slight decrease. Before 2000, it mostly continued to be bigger than the automobile industry. Furthermore, while the amounts of added value of the other industries have varied depending on business fluctuation, only the chemical industry has steadily shown a slight increase in added value over an extremely long period of time. Since the total amount of added value of all the manufacturing industries has been slightly decreasing (e.g., the added value of the electronics industry and that of the general machinery industry have been decreasing since the 1990s), the relative importance of the chemical industry has been gradually increasing within the overall manufacturing industry.

Although the dominance of the electronics industry will certainly continue for the time being, the data shown above may reveal a tendency that the chemical industry is gradually taking the lead in Japanese industry.

The rapid expansion of the electronics industry in 1980s was really amazing. It happened not only because of expansion of global markets for electronic consumer goods (e.g. TV sets, personal computers), but also because electronic products begun to be widely used in a variety of ways in various sectors of Japanese industry. This transformation was called the microelectronic revolution or the IT revolution, and was characterized

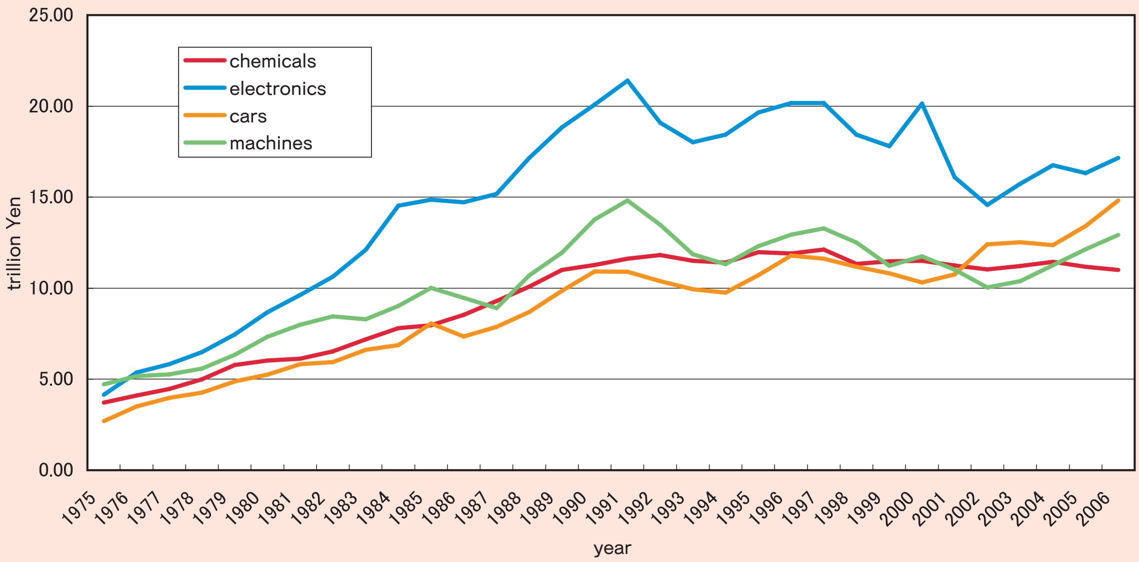


**Fig.1 Amounts (Nominal) of Added Value of Major Industries in Japan**

by a rapid increase in the demand for electronic instruments and electronic parts having the functions of automatic control or communications.

The phenomenon described above could be called "electronics-oriented transformation of Japanese industry," in which electronic technology and electronic products become indispensable in the production processes and in the core parts of products in various industries.

Why did the electronics-oriented transformation of industry occur?

The simplest answer is that it occurred because many customers, both individuals and companies, wished "to reproduce electronic phenomena at close quarters. Therefore, they wanted electronic technology that enables reproduction of the phenomena."

Let's think of television sets as a typical example. People buy television sets because they perform a sequence of jobs well; i.e., receiving radio waves, converting the wave signals into image signals, and displaying them as pictures. In other words, it is important that various electronic phenomena could be reproduced by means of radio waves and electrons at close quarters, and customers buy the electronic technology that enables reproduction of the electronic phenomena. The same thing could be said for semiconductors and automatic control instruments.

However, customers rarely buy products of the chemical industry just because they reproduce chemical phenomena by means of chemical technology. For instance, bottle manufacturers buy PET resin, not because the resin reproduces PET-related phenomena, but because the function of the material is attractive. The customers buy products of the chemical industry, not because they expect to reproduce chemical phenomena at close quarters, but because they need the functions of materials produced by making the best use of chemical technology.

## Chemistry-oriented transformation of industry in two different manners

Is it feasible that chemistry-oriented transformation of industry will actually occur in the future?

Following the definition of electronics-oriented transformation of industry, we define chemistry-oriented transformation of industry as a phenomenon in which chemical technology and chemical products become indispensable in production processes and in the core parts of products in various industries.

Compared with electronics-oriented transformation of Japanese industry that occurred in the 1980s, it may be difficult to expect a rapid and prolonged increase of added value of the chemical industry in the near future; i.e., in and shortly after the 2010s. Since data in Fig.1 obviously show that rapid increase of added value of the chemical industry will be difficult, we have to conclude that chemistry-oriented shift of industry should hardly occur on a large scale in the sense that the chemical industry is to provide mass-manufactured commodities. It can be said, however, that chemistry-oriented transformation of industry may be realized on a considerable scale in two manners described below.

Firstly, customer needs for commodities which could reproduce chemical phenomena at close quarters may grow in the future. Secondly, demand for products of the chemical industry may increase because the functions of various new, advanced materials generated by the chemical industry could replace those of conventional products produced by other industries. In the past, demand for products of the chemical industry was aroused basically in this manner. A typical example can be seen in the recent use of carbon fiber instead of metal as a structural material of aircraft.

As for chemistry-oriented transformation of industry in the first manner, "Demand for chemical technology itself" to reproduce chemical phenomena at close quarters of users seems to have begun increasing throughout the world. A symbolic example is the fuel cell, which generates electricity by means of the chemical reaction between oxygen and hydrogen. Customers want to reproduce this chemical phenomenon at close quarters, which will be indispensable for operating their personal computers or automobiles. Since the fuel cell is a device to generate electricity, you may not notice that it is produced on the basis of chemical technology; however, this gives a good example of chemistry-oriented transformation of industry, because the key technology lies in reproduction of chemical reactions.

The chemistry-oriented transformation of industry in the second manner is that many chemical materials are becoming indispensable in producing various consumer and industrial goods. Typical examples of these materials are filters, light guide panels, polarizing films, lenses, etc., which are used as critical elements in digital electronic devices. Without these functional materials, commercial production of digital television sets and camera modules for portable telephones would be impossible. As chemical materials become advanced and multifunctional, the chemistry-oriented transformation of industry in the second manner becomes accelerated.

The chemistry-oriented transformation in the first manner implies that knowledge of chemistry will become more and more important in various industries. The chemistry-oriented transformation in the second manner leads to growth of the scale of the chemical industry itself. In other words, chemistry-oriented transformation of industry may bring about wide-spreading knowledge of chemistry and quantitative expansion of chemical products.

Development of the fuel cell described as an example of the chemistry-oriented transformation in the first manner symbolically show increased significance of chemistry in Japanese industry, with chemistry-oriented transformation of industry following electronics-oriented transformation. This may suggest that, in place of physics, chemistry is going to play a key role in future industry.

We can see in the basic mechanism of electric power supply that the electronics industry relies heavily on physics. Almost all the power supply sources we now use rely on the principle of electromagnetic induction in which electric current is produced by rotation of coils. This principle of power generation is used in both nuclear power plants and thermal power plants, and the only difference lies in the mechanism of generating steam that supplies rotational energy. In other words, a principle of physics is quite essential in today's power generation. In the fuel cell, however, electricity is generated by the movement of electrons in the process of water production by the chemical reaction between oxygen and hydrogen. It can be said that a principle of chemistry is indispensable for power generation in the fuel cell.

It is quite certain that wide use of electronic phenomena will continue and that physics will continue to play an important role in industry as a fundamental field of science. We expect, however, that the day might come when chemistry and physics take roughly equal, important roles in industry. Chemistry-oriented transformation of industry may be described as actualization of such role sharing.

## History of the chemical industry from the aspect of value addition to unnecessary materials

A big possibility of chemistry-oriented transformation of industry may relate to the chemical industry coming to have an eco-friendly aspect. Chemical reactions begin to be widely demanded in various industries for the purpose of global environmental preservation, which may accelerate "chemistry-oriented transformation of industry." In other words, chemical technology could potentially play a central role in reducing environmental loads of materials emitted to the atmosphere, rivers, the soil, etc.

We could interpret the situation from a different aspect. Chemical technology could contribute to preservation of the global environment, if it were used for reducing carbon dioxide emissions and their accumulation in the air, which result from burning fossil fuels and other carbonaceous materials.

Now people begin to think that it might be becoming realistic to construct a plant to produce basic chemical products (e.g. ethylene) using carbon dioxide as the source of carbon. In this case, carbon dioxide and hydrogen are used as raw materials to produce chemical goods. In consideration of the burden of expenses for reducing greenhouse gas emissions, they begin to adopt an idea of constructing "a naphtha-free industrial complex" close to a thermal power plant or any other plant that emits a large quantity of carbon dioxide. From the viewpoint of the chemical industry, this concept may be interpreted as a change of raw material from naphtha to carbon dioxide. However, from the viewpoint of the electric power industry and the steel industry, which emit enormous quantities of carbon dioxide, it can be considered a process of converting their wastes into materials useful for the chemical industry by means of chemical reactions. In other words, it can be viewed as chemistry-oriented transformation of the electric power industry and the steel industry in a sense that chemical reactions are used in a basic production process to reduce carbon dioxide emissions.

In a naphtha-free industrial complex, wastes, or unnecessary materials, generated in use of fossil fuels in the electric power industry or the steel industry are converted into valuable materials. By nature, however, the history of the chemical industry consists of development of processes for adding value to unnecessary materials.

The word "chemistry" is derived from "alchemy," suggesting that the nature of chemical reactions lies in changing unnecessary substances or wastes into valuable materials. Ancient alchemists would have deceived others if they said that they could change junk metals into gold, while modern alchemists or chemists can use catalysts to realize advanced chemical reactions that enable unexpected material transformation.

Actually, the petrochemical industry started with the business of cracking naphtha, which was "unnecessary material" generated in the process of producing gasoline and other fuels from valuable petroleum. Manufacture of commodities from ethylene or any other basic raw material produced in naphtha cracking can certainly be considered "a process of value addition to unnecessary materials." When we go back in history, we find that the coal chemical industry started using tar as a raw material, which was also "unnecessary material" produced in the process of making coke fuel from coal. In addition, the significant technological revolution of ammonia production by fixation of atmospheric nitrogen in the modern chemical industry is chemical reaction between hydrogen and nitrogen, the latter being an "unnecessary material" which usually can be taken free from the air.

Value addition to useless materials and chemical reaction techniques that enable this value addition are key elements in preservation of the global environment and effective utilization of by-products or wastes generated in various industries. This is an essential reason why we consider that chemistry-oriented transformation of industry could occur in future.



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