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Prospects for Research and Development in New Materials

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Abstract:

Market trends, be they tangible or not, have been left to the invisible hands of economy. Now that "sustainable development" on a global scale has become a thesis that knows no national boundaries, commodities as well as their production processes have come to be assessed from the viewpoint of social compatibility, that is, conformity to the social causes of energy and resource conservation, environmental protection, and respect for humanity. Against this background, how new materials will change in a continuing pursuit of delicate balance between functionality and price and what will have to be done in response to such changes are described with emphasis placed on their research and development.

1. Market Changes for New Materials

"Technology" is an assemblage of means and methods for translating various ideas into forms helpful to society and involves such cultural factors as education, custom, institution and history in the society where it has been nurtured. When we enter a new business field, for instance, we often introduce new technology. The important point is whether our corporate climate is suitable for nurturing and maturing the technology. What factors have been taken into account in selecting the new business domain? How human, technical, and marketing resources are prepared to campaign in the domain? How is the technology introduction positioned in the overall corporate strategy? Is the technology introduction timely? What changes are predicted to occur in the relevant market? These are important matters to be considered. Research and development (R & D) strategy cannot effectively work in concert with the management policy unless it links and shares concrete measures with the corporate business strategy.

"Market" continues to change with political and economical environments. The ability of a company to grow can be measured from adaptability to such market changes. In its core business, the company already has an accumulation of technologies and channels to the market. A system is already set in place accurately grasp what is signified by a "change" and to work out appropriate short-term and long-term strategies. In a new business, however, there are few success records to consult, and experience in the core business does not provide the company with courage and patience to cope with market transitions In a recession, in particular, the company tends to aim at safety and develop a negative force. This article reviews main factors underlying the recent market changes and ponders about how to bring out positive forces toward the future of the company from an R & D point of view.

1.2 Market slump and its background

The stagnant business environment surrounding new materials these days is definitely different from past recessions, and is attributable to changes in the framework of the economy.

First, the market is permeated with a sense of product saturation. The assembly industries, especially automobiles and home appliances, have vigorously pursued the "economy of quantity", as represented by mass production, price reduction and competitiveness at which Japanese companies excel, and as a consequence have shortened the product life cycle. As a result, supply has surpassed demand, and there have been marketed few products that excite consumers, interest. From a different point of view, social needs have shifted from material abundance through time availability obtainable from enhanced product functionality to human spiritual satisfaction.

Second, conservation of the global environment, coexistence with the ecosystem, and effective utilization of finite earth resources have become theses transcending national boundaries and are bringing about changes in the social value of products. For example, today's production line operations abound with such slogans as "energy saving in the material flow" and "product recyclability". These changes are often taken as new constraints upon the new material business, but riding this current of the times is no doubt the only way of winning the confidence of society and keep growing in symbiosis with it.

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Third and last, economic linkage and technology exchange with not only advanced nations but also developing countries have gained importance, and factors responsible for market fluctuations have become multi-layered. This means to enterprises that the technologies necessary for them to quickly respond to changes in the global market economy have changed in both the level and direction of sophistication, and have come to straddle different fields. From the standpoint of risk aversion, companies are called upon to share strategies in a strong cooperative relationship with other companies. It is suggested that companies in different industries and in some cases even in the same industry should cooperate to minimize the R & D investment and diversify the R & D risk in boundary areas where market growth is expected, such as environmental control technologies.

Generally speaking, the commodity flow system seems to be in a transition period from free competition based on the market to value creation involving linkage with society (including the administration). For, this is the way to "sustainable development".

2. Research and Development Responding to Changing Market

2.1 Technology development problems with new materials

Nippon Steel's new materials ("new components" may be a more apt term) are taken for example, and technology development issues with them are discussed. Our new materials are classified into four categories according to their market characteristics.

(1) Materials for electronics: Once new materials are developed in response to technological innovation toward higher efficiency in terms of frequency and compactness, for instance, they are functionally innovated one after another, and create new market values. Silicon wafers for IC and bonding wires for surface mounting can be cited as examples.

(2) Materials for industrial applications: Some of the conventional materials are optimized as to chemical composition, shape, surface flatness and purity, and are opening up new markets. Among them are ceramics for semiconductors, and metal foil carriers for automotive exhaust gas converters.

(3) Structural materials: There are structural materials with which new technologies and systems meet the social needs for energy and material conservation, and time and labour saving. Carbon fiber-reinforced concrete for sky scrapers, and plastic composites for automotive applications fall in this category.

(4) Materials for challenging technologies: There are emerging technologies for which markets are still unclear as to future potential or there are no such markets as yet. Gas separation membranes and superconducting materials for magnetic levitation, magnetic shielding and electric power saving may be counted among them.

The product life cycle is generally divided into the embryo, growth, maturity, and decline stages as illustrated in **Fig. 1**. Some new materials have a long embryo stage, but the following growth stage for them is short, because, while the customers are pondering about the cost, long-term service performance and other aspects of the new products, the manufacturers tend to launch on a keen competition among them before the market ripens to create a sufficiently large demand for their offerings. From the technical standpoint, a lack in material standards and evaluation methods particularly for stock-type products and appreciation of cost over functionality for flow-type products are in the background of this trend.

(1) Electronic parts, the so-called passive components, are short in product life cycle, and are subject to severe market competition. On the other hand, however, the time from the price competition stage to the next product development stage is short, and there are many business opportunities. If process innovation is achieved to enhance the productivity of existing products and new products are launched in a timely manner as required by the market, the operating revenue scenario can be changed. The culture of the steel industry is slow to understand the characteristics of products that are short in life cycle and produced in small lots and diverse types (see **Fig. 2**). In this field, researchers themselves must visit customers or factories, attend to claims about products, solve production problems from the standpoint of material control, read market changes, and build fiduciary relations with customers. Through the development of such products as bonding wire for IC chips, we have achieved successes, although small in scale, and have learned many lessons. Research, development, and commercialization are always overlapped, and there is unique dynamism. If research is independent of other functions such as development, production and marketing, it will miss the opportunity of grasping market changes with the eye of a concerned party and translating the market change into new development in a timely manner. It should be noted that different stages of product life cycle require different strategies. Liquid crystal display (LCD) materials that have quickly earned high rating in the market recently are a good example of re-

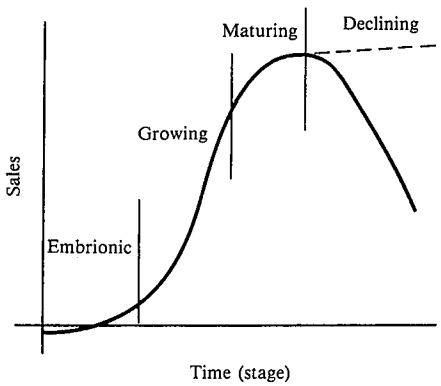

Fig. 1 Product life cycle

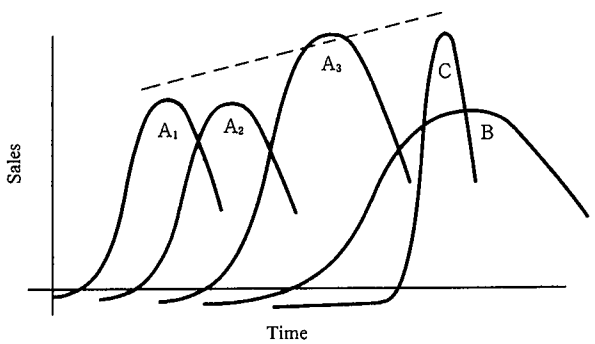

Fig. 2 Commodity chain (commodity portfolio)

search laboratories directly entering the market for product development. Once an appropriate business domain is selected after exhaustive research, it must be brought to a successful end with steadfastness. This should provide those engaged in the new business and R & D efforts with great confidence and strong sense of responsibility. The presence of leaders with field mindedness is an indispensable element for success at the research laboratory, and nurturing of such personnel is probably a key to success in the current new materials campaign.

(2) In this product category, products are often associated with specific products of customers. Once commercialized, such products take a long period of time before growing into mass production items for sale to customers in general. Direct linkage with the market provides direct and accurate information, which is conducive to further research and development. It is important that the understanding and cooperation of customers should be secured in regard to initial price setting, which as important bearings on the recovery of R & D investment. It is also essential to systematically develop necessary technologies, to establish generic technologies for efficient product development, and to minimize initial R & D investment through judicious coordination inside and outside the company. More specifically, ceramics for semiconductor production facilities accumulated technologies with rippling effects as related to such properties as rigidity, wear resistance, electrical conductivity, surface finish and interactions with laser rays with the progress of product development. Those technologies have produced synergetic effects on product development and have allowed expansion to cover LCD production facilities. As the semiconductor market is revitalized, the accumulated technologies will allow us to change our business profit structure.
Generally, new materials have much smaller markets than steel, nor are their business foundations so firmly established as for steel. Good buds will wither if business potential should be questioned for each individual product instead of assessing a product group stemming from the same trunk technology.

(3) Some component materials take a considerable length of R & D time. They are characteristic in that their products are large and have the nature of semi-stock or stock, and that they have a large impact on society. Therefore, their long-term safety, reliability, and functionality are verified from various angles. Unlike steel, these materials have no adequate evaluation methods as yet and take long time to win the confidence of customers. On top of that, their markets have their future outlooks visible to anyone, admit easy entry, and readily lead to excessive price competition. Joint development with customers is basic to securing a market in the germinal stage and pushing ahead with the development in a timely manner. Since the embryo stage is long, it may become necessary to drastically change the scenario of development halfway, depending on the transition of business environment.

(4) For near-future materials, R & D efforts should be aimed at lessening the expected load of our society, and be focused on the areas that are likely to play key roles in future problem solving. Superconducting materials and gas separation membranes are good examples. Incidentally, we have developed some of the world's top-level technologies in these areas. Utilizing such technologies, we intend to participate in the innovation of urban infrastructure systems that emphasize respect for humanity, such as information systems, transportation systems, security systems, waste disposal systems, environmental protection systems and "creative space" systems.
We intend to proceed with the innovation of structural materials, mainly steel, and take part in the development of chemical materials, innovation of electronic materials and the development of industrial machinery associated with transportation and production. Through all these activities the company can enhance its corporate capability in keeping with social vicissitudes and solidify its high-profitability corporate constitution. We will nurture scientists and engineers with rich human qualities through R & D in challenging fields and repay technological benefits to society. We think it important to know market changes by our own senses through the channel of new materials and incorporate the knowledge in our corporate strategies.

3. R & D Viewpoints of New Materials and Members for Future

The thought that runs through technology development is to accelerate the enhancement of efficiency and progress. It makes no allowance for the self-control of growth, harmony with the surroundings, recycling, or purification—keywords for the ecosystem that has lasted through geological periods to date. For our sustainable development, we are called upon to coexist with the ecosystem. If we give thought to the self-contradictions involved there, it will become clear what must be changed toward the future. We will shift the axis of our conception from the simple "logic of machines" to a multi-form and multi-dimensional "logic of living organisms" and pursue a new lifestyle accordingly.

In the specialized area of new materials and components, our R & D efforts will be focused on the following items: 1) Besides the analytical techniqus and microstructure control techniqus accumulated through the manufacture of iron and steel, peripheral, social adaptability elements are incorporated as part of technology in order to enhance the social compatibility of technology; 2) Technologies that allow for small-lot production of diverse products are established for the development of materials to support varied and fast-changing products; 3) In materials research, the smallest units that develop physical properties, namely, mesoscopic atom and molecule groups, are controlled to develop novel functions. This attempt is comparable to the challenge at the systematization of quantum material sciences based on quantum mechanics, and has the advantage of visualizing an interface with the ecosystem; 4) To alleviate the present incompatibility of technology with society that stems from the excessive technology specialization, overall technology harmonization is realized by means of transcendence over the boundaries of specialized fields across the board.

At the risk of presenting the future outlook of research and development only from the new materials point of view, I have stressed the importance of technology development focused on its social aspects as an essential measure to deal with new market transitions.