RAW MATERIALS USE REDUCTION, REPLACEMENT, AND RECYCLING

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Summary

This article discusses the development of ecomaterials, which is a trend in material industrial development. Furthermore, life-cycle assessment, life-cycle engineering design, and methods of reducing and replacing raw materials are also presented.

Natural resources are not inexhaustible, and there are limits in terms of quantity and time to acquiring raw materials from the natural world. Industrial progress, economic development, and population growth in the twentieth century has led people to exploit natural resources in a predatory manner. With regard to mineral resources, statistics indicate that the rate of mineral resources consumption has always been higher than the rate of population growth. For example, while the world's population doubled between 1950 and 1990, the products using the major six minerals (aluminum, copper, lead, nickel, tin, and zinc) increased more than eight times. Although shortage of resources cast a shadow over the twentieth century, there was no continuous shortage of mineral resources. Nonetheless, unless we change our extravagant way of tapping and using resources, we cannot be certain that a shortage of resources will not happen in the future. Fortunately, at present, humankind has noticed the depletion and destruction of natural resources and has realized that we should live in harmony with nature and value the endowments of nature. On this account, some have advanced the idea of sustainable development, hoping to maintain common and sustainable development in social, economic, resources, and environmental terms. Materials are used directly or indirectly to manufacture useful things. Therefore, in respect of material utilization, the strategy of reduction, substitution, and recycling has been proposed to bring about a sustainable supply of raw materials.

1. The Direction of Development—Ecomaterials

Ecomaterials emerged as a new field in international research on hi-tech new materials in the early 1990s. The development of ecomaterials is of great importance to the reduction, substitution, and recycling of raw materials. Ecomaterials are those materials with good performance or good functions that can be used in harmony with the environment. They consume fewer resources and less energy, cause less pollution to the ecology and the environment, have a high rate of reproduction, and are in accord with the ecological environment throughout their whole life cycle, from materials manufacture, use, and discarding to recycling. Increasing attention is being paid to vigorously developing ecomaterials, evaluating the way they coordinate with nature, developing new technologies of zero emission and zero scrap, and the comprehensive utilization of materials. The development and exploitation of ecomaterials can to a certain degree reduce humankind's demand for natural resources, substitute environment-friendly products in place of pollutant products, and raise the efficiency of resources utilization and save natural resources through reproduction and cyclic utilization of materials. Today, research on ecomaterials and ecological products mainly concentrates on pure natural materials, bionic materials, green packing materials, and ecological building materials.

One of the trends of the materials industry is to substitute renewable resources for non-renewable resources. For example, high-purity silicon and its compounds are necessary raw materials for such hi-tech industries as semiconductors and optical fibers. In the past, this material was basically abstracted from minerals. In the 1980s, it was found that high-purity silicon compound powder can be abstracted through deep-processing of millet husk, and this worked even better than mineral silicon powder. In 1997, the estimated output of millet husk was roughly 110 million tons worldwide, and if it was used comprehensively, it can produce 20 million tons of high-purity silicon compound powder. Hence, the comprehensive utilization of millet husk has been widely adopted in Japan and the United States, and large-scale industrialized processing plants have been built.

As is well known, substituting biological materials for non-biological materials has broad application. Biological material research has shifted from manufacturing joint prostheses and artificial organs made of metal, ceramics, and plastics to developing materials that have more biological compatibility or adopting biologically compatible surface processing technology. For example, in making joint prostheses, biologically compatible elements have replaced niobium, tantalum, tin, and other elements in the titanium alloys that are harmful to the human body, or a membrane of hydroxyl phosphorite has been added on the top of the above-mentioned products to ensure complete compatibility with the biological body, thus avoiding the harm caused by non-biological materials.

Some raw materials themselves are acquired from renewable resources. But the supply of renewable resources is still very limited. In order to meet constant increases of demand, when tapping and using these raw materials, performance, durability, and efficiency of utilization should all be increased. For example, along with the increasing use of environmental materials, the development and utilization of wood is receiving more attention. Using phenolic resin for surface processing of low-quality woods can significantly prolong the life and improve the durability of facilities made from wood.

Another goal of the research on ecomaterials is to reduce the effect on the environment in the production and application of raw materials. This is also one of the goals of sustainable development. To illustrate, at present, the building materials sector not only pursues lightness, intensity, and durability of materials, but also deems it important to research the ecological effect and environmental compatibility of building materials from the perspective of sustainable development. The materials with these features are called ecological building materials. The research mainly focuses on the effect of building materials and building activities on the environment, efficient utilization and recycling of building materials resources, development of environmentally compatible paint, design of ecological building materials, development of environment-friendly cement materials, disposal of slag, and reduction of waste water and gas generated in the production of cement, etc. There are also projects on performance improvement and comprehensive utilization of cement and concrete products, use of wood instead of steel to produce reinforced concrete, the use of waste polyester plastics to produce organic enhanced concrete, the use of solid urban garbage to produce cement, etc. In America, a major assistance project in the Advanced Cement Materials Technological Center under the U.S. State Science Fund is being conducted to develop super intensive and durable cement materials.

The research and development of ecomaterials targets purifying the environment, preventing pollution, replacing harmful materials, reducing wastes, turning materials into resources, and utilizing natural energy, and great achievements have been made. The sense of environmental protection has penetrated the whole process of researching, developing, processing, preparing, and utilizing new materials. A starting point of the Japanese research scheme of “limiting functional materials” is to simplify the design of alloys and improve performance so as to save resources.

Many countries give legal, policy, and financial priority to research and development into enhancing the efficient utilization of resources and energy and cyclic production and utilization of materials. The German government began to draft the *Cycle Economy Law* in 1995 and released it at the end of 1996. The basic thinking in this law was that the raw materials in social production should be cyclically used in the process of production and consumption to decrease the generating of wastes to the minimum. For the purpose of this law, the production sectors are obliged to reclaim the wastes of their own products every year and dissolve, substitute, and reuse. The government is negotiating with the associations representing these sectors, encouraging them to formulate their own methods and put them into force after approval by the government. In sectors without self-discipline methods, the government will enforce implementation.

The German Automobile Makers Association has decided to reclaim waste automobiles with a service life of 12 years, free of charge, and bring them to their own disposal place. This has put Germany’s waste automobile re-utilization work ahead other countries.

2. Life-Cycle Assessment

In diverse forms, raw materials exist throughout the entire process of the life cycle of products. Research into the reduction, replacement, and recycling of raw materials has to start from analysis into the entire life cycle of the products and find the existing problems in materials utilization, energy consumption, waste generating, and emission of pollutants in order to innovate and raise the efficiency of raw material utilization.

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Biographical Sketch

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