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Development of ecomaterials and materials technologies

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Materials

ABSTRACT

Purpose: This paper presents a development of ecomaterials particularly in materials technology. Using this materials make possible minimize the environmental load in a whole "life". The design criteria for ecomaterials include compatibility with humans and the environment in addition to the traditional physical, mechanical and chemical properties.

Design/methodology/approach: Using ecomaterials would help the manufacturers as well as consumers in material and product selection in the aim of achieving sustainable development (SD).

Findings: The concept of "ecomaterials" shows the necessary directions of materials development what allows protection the environment from resource depletion, global warming, ozone depletion and dioxin contamination, etc.

Research limitations/implications: More fundamental research and new ideas are needed in order for these materials (ecomaterials) to receive widespread use in the near future.

Practical implications: The most important thing is that all materials and their properties should be reconsidered from the ecomaterials viewpoint. It is necessary to demand materials (products) with less environmental load, improved recyclability and achieved maximum performance with the least material consumption. In order to establish the fundamental design and assessment techniques for ecomaterials, a research projects should be still organized.

Originality/value: In the paper ecomaterials as a key conception for materials technology what will help reduce the environmental impact of product produced and consumed and promote the emergence of a high-recycling-rate society.

Keywords: Multifunctional materials; Ecomaterials; Materials technology; Ecomaterials development

1. Introduction

The final decade of 20th century was the most important period in establishing a sustainable society for the coming century. After the Earth summit held in Rio de Janeiro in 1992, the world's population was challenged to decrease its environmental impact on the Earth. Fourteen years after the Rio summit we are living in a more dangerous and unsustainable world with a more resource consumption, more waste and more poverty, but with less biodiversity, less forest area, less available fresh water, less fertile soil, and less stratospheric ozone.

The large consumption of materials and energy causes rapid deterioration of the environment on a global scale. The increase of aging plants, facilities and machines threatens our safety.

Since the capacity of the earth is finite from both sides of input (resources) as well as output (disposal), the minimizations of the environmental load, as well as the most efficient use of resources and energy, are required for sustainable development of the world [1-4].

"Ecomaterials" are proposed as a key concept for materials technology that would harmonize with the environment, i.e. minimize the environmental load in a whole "life" [5-9].

The word "ecomaterial" is used for "environmentally conscious material" or "ecologically oriented material," which implies socially acceptable materials with minimal environmental impact. Conversion to ecomaterials is a decisive means of addressing the environmental issues of resource depletion, materials recycling and reuse, global warming, ozone depletion and dioxin contamination.

2. Conception of ecomaterials

The concept of ecomaterials was proposed in Japan one year before the Rio summit in 1992, through a discussion among materials scientists and materials engineers. From this time began to wonder about protection and preservation of the environment by means of materials functional properties. The consideration of environmental issues for all materials, including structural materials and special functional materials, was deemed new and significant (Fig. 1) [5].

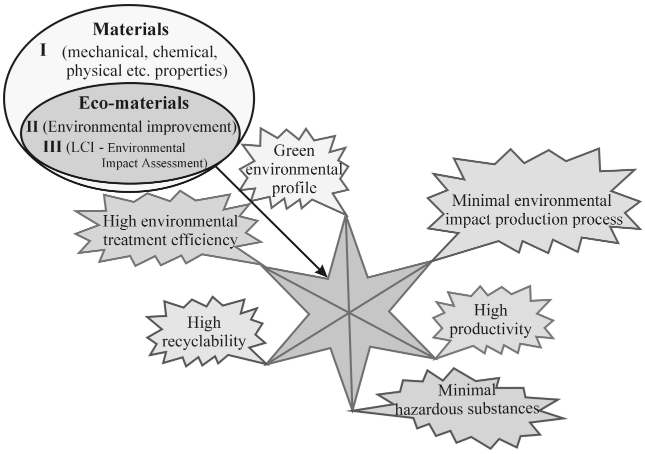

Fig. 1. Conceptual model of ecomaterials [8]

Among superior properties of ecomaterials distinguished [8]:

- reusability,
- biological safety,
- resource saving,
- energy saving,
- cleanability,
- recyclability,
- structural reliability,
- chemical stability,
- substitutability,
- amenity.

This ten properties can be reclassified in three indexes (Fig. 2) [9]:

1. Expansion of mankind's frontiers by enabling new technologies.

This is consistent with the traditional way of developing materials, in which mechanical, physical, chemical, thermal or functional properties are improved in order for the materials to be used.

2. Harmonious co-existence with the ecosphere by minimizing damage done to the natural environment.

From the viewpoint of sustainable development, consumption of materials and energy, emission of toxic gases and waste associated with materials processing should be reduced to ease our impact on the resource circulation system.

3. Optimizing technology and infrastructure to create a healthy life in a harmony with nature.

Materials should be friendly not only to nature but also to humans (amenities).

An integrated and holistic development taking into account all of these three indexes is the aim of ecomaterials research. This concept was developed by introducing the concept of life cycle analysis (LCA) [10-12] to materials technology i.e. by considering the performance of a material during its life cycle and its environmental impact from "cradle to grave" [13,14].

As materials are generally used as a part of a product, this concept of life cycle thinking is linked easily to the concept of life cycle designs of products [15]. Thus, ecomaterials can be referred to the materials usable for the life cycle product design developed in order to protect the environment.

The ecomaterials were classified into four main categories as:

1) nonlinear source materials;
2) materials for ecology and environmental protection;
3) materials for society and human health;
4) materials for energy, based on two main criteria as their sources and functions.

These four main categories were classified further to their subcategories (Tab. 1).

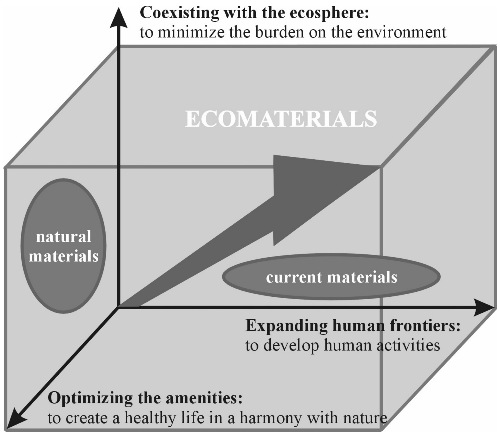

Fig. 2. Schema of the ecomaterials concept [9, 16]

3. Development of ecomaterials

Since environmental influences became significant, companies began to undertake workings in the direction of improvement of used materials what is necessary for environment protection.

The approaches of materials technology to improve the environment cannot be generalized from one viewpoint.

Table 1.
Examples of ecomaterials [5]

	Sub-categories	Examples
I.A	Recycled Materials	Eco-cement, coal ash concrete, glass ceramics from wastes, recycled plastics, silica fertilizer, marine block
I.B	Renawable Materials	Wood ceramics, wood based materials, soil ceramics, biodegradable plastic made of a vegetable base
I.C	Material for efficiency	Waste reduction materials, wear resistant metals and alloys, pre-paint steels, corrosion-resistant steel and alloy
II.A	Materials for Waste Treatment	Membranes for exhausted gas separation, ion-exchange resins, microbial enzymes, absorbent materials for oil and grease removal
II.B	Materials for Reduction of Environmental load	Catalysts and biological membrane materials for fuel cells, carbon-fiber composites, photo-catalyst coating materials for construction
II.C	Materials for Ease Disposal or Recycle	Biodegradable plastics, functionally graded material, colorbetos which replace asbestos
III.A	Hazardous free Materials	Lead-free solder, halogen flame retardant-free plastics, chromium-free steel, VOCs-free adhesive, heavy metals-free polyesters
III.B	Materials for reducing human health impacts	Vibration damping steel sheet, sound proof panels, anti-bacteria coating materials, boneceram for orthopedic surgery and brain surgery
IV.A	Materials for Energy Efficiency	Ultralight steel, Al-Mg lightweight alloys, heat resistant alloy for turbines, high magnetic induction steel sheets, highly endothermic steel, chromophobic fibers, heat mirror film for household energy saving
IV.B	Materials for Green Energy	High grade silicon for solar cells, thermoelectric conversion materials, selective transparent glass, highly durable sealing sheets for solar batteries

They can be divided into three categories based on the relation between a material's properties and its role in improving the environment [9]:

1. Functional materials for environmental protection;
   Materials properties are optimized to improve each environmental problem.
2. Materials supporting low-emission systems;
   Materials properties are needed to support environmentally benign systems.
3. Materials of strategic substitution for an environment friendly social system;
   Materials are used for a given property but society demands that they have lower environmental burden.

These categories are shown in Fig. 3.

Catalysts for cleaning up toxic waste, alternative materials to replace toxic substances, CO_2-absorbing substances - they belong to the first group (A: Environmental Function Type).

The second group (B: System-Element Type) consists of e.g. materials for energy-saving or new energy systems, such as high-temperature turbine blades, thermoelectric materials, low-temperature steel pipes for hydrogen transportation and superconductors.

The third group (C: Strategic Substitution Type) consists of materials strategically substituted for materials that place more of a burden on the environment. This group is the ecomaterials in a restricted sense.

Ecomaterials have created a new field for materials-designers with the strategic approach of substituting currently used materials with materials placing less burden on the environment throughout their lifecycles.

Ecomaterials of Type I and Type II have relatively clear targets for development and assessment.

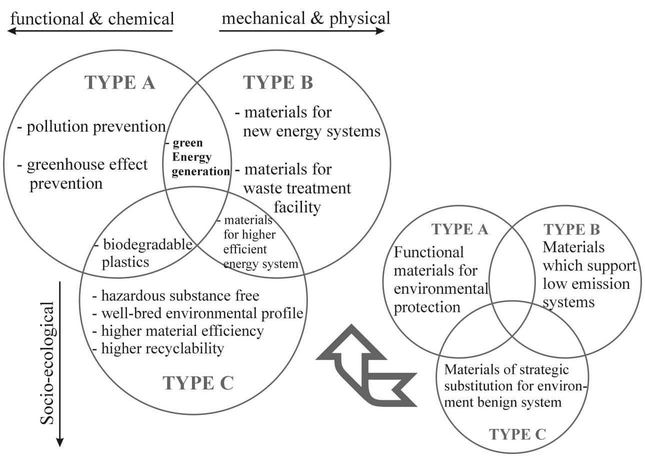

Fig. 3. Schema of three groups of environmental approaches to materials technology [9, 16]

Examples of ecomaterials shown on figure 4, 5 and 6.

Fig. 4. Photo of eco-tire - IA group [8]

Fig. 5. Photo of lead-free lens - IIA group [8]

Fig. 6. Photo of ultra high strength steel sheet for car body - IVA group [8]

4. Conclusions

Considering the finiteness of the Earth and the biosphere, we should be conscious of the environmental load that our products and materials place on them.

Materials used in manufacturing are first extracted from the environment, manufactured into products, and finally returned to the environment as wastes.

Ecomaterials are used to minimize the environmental impact over their life cycle of manufacture, distribution, use and disposal. Life-cycle assessment (LCA) facilitates development of ecomaterials by providing a quantitative measure of the environmental impact of materials and products over their respective life cycles.

This holistic approach to evaluation allows the development of materials and materials technologies with minimal environmental impact.

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