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Importance of soft processing (low-energy production) of advanced materials for sustainable society

Masahiro Yoshimura[a,b,*]

[a]*Department of Materials Science and Engineering, National Cheng Kung University, Tainan, Taiwan*
[b]*Prof. Emeritus. Tokyo Institute of Technology, Japan*

Abstract

In recent years, advanced materials (such as, engineering plastics, polymers, metals, alloys, semiconductors and ceramics) have been required to be produced used and then wasted in our modern lives. Those materials have been hardly produced in nature (bio-system), thus they have had been produced by artificially in industries. The industry systems are generally uses sophisticated artificial machines, parts and materials. Moreover, these industrials production have used fossil fuels and fine resources with high chemical potentials. Therefore, one must challenges to eliminate to use of fossil fuel(s) and fine resource to establish sustainable society. Here, I propose one of such challenges to produce advanced materials, particularly advanced ceramic materials by Soft-processing (Green method) using low-energy with low wastes, heats and exhausts.

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Keywords: low energy production; soft processing; advanced material; sustainable society.

1. Water cycle on the earth and the production of Biological Materials [1-4]

As we know, the earth is unique "water planet" where water can be kept and cycled on the earth including, Hydrosphere, Atmosphere, and even Geosphere. These water-cycle could create organic materials then lives: viruses microbes, planktons, plants and animals. We, any life including humans can survive eating those organic polymers as foods, and using them for clothing, housing and fuels for heat and light developing from gathering natural foods products, human could artificially grown favorite food by “agriculture” and “pastoralism” in addition to

* Corresponding author. Tel.: +886-6-2757575; fax: +886-6-2346290.
E-mail address: yoshimur@mail.ncku.edu.tw

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hunting/fishing/catching wild plants and animals. He/she could make such biologically producible organic polymers in larger scale but never successful to produce Advanced Engineering Materials: organic plastics, engineering polymers, metals & alloys, semiconductors, and ceramics expect several exceptional bio-minerals, as seen in Table 1 and 2. Therefore, those engineering materials being used in modern our societies must be produced and /or fabricated by artificial "Industry" using particular machines, chemical resources and energy resources. It is the principle and essential that environmental problems cannot be solved by sole biological systems because the advanced materials have seldom been produced by biological systems, but produced by artificial industrial systems on the earth. The latter have seldom been based upon water-cycle, as like in biological systems. Therefore, the industrial systems for advanced materials hardly possible to accommodate with the biological system based upon water cycle. However, one can apply water-cycle systems (=solution processing) to industrial ones by learning from biological systems. That is the key to consider a sustainable society on the earth. Some people have proposed (a) recycle of materials is also important as well as (b) reduced and (c) re-use, that is for sustainable society [5].

Table 1. Bio-producible Materials

Material	Examples
Organic Materials	1. Bio-molecules: Lipids, fatty acid, amino acid, Vitamins, Hormones, etc.
	2. Bio-polymers: Polypeptides, nucleic acids, sugars, cellulose, etc.
	3. Bio-plastics:
Inorganic Materials	Bio-minerals: Amorphous SiO_2, Fe oxides, Fe hydroxides, $CaCO_3$, Ca-phosphates, $SrSO_4$, etc.

**No other materials are able to be biologically produced!*

***Most of engineering materials and advanced materials as follows have never been biologically produced!!*

Table 2. Biologically non-producible Materials

Material	Examples
Organic Materials	1. Synthetic molecules: Many organic compounds
	2. Synthetic polymers: PE, PP, PET, ABS, etc.
	3. Synthetic plastics: Ployethylene, Ploypropylene, Nylon, Vinylon, etc.
Inorganic Materials	1. Semiconductors: Si, Ge, GaAs, InP, Carbons, etc.
	2. Metals & Alloys: Fe, Al, Cu, Steel, Bronze, etc.
	3. Ceramics: Al_2O_3, MgO, TiO_2, $BaTiO_3$, $NiFe_2O_4$, etc.

However, our modern materials cycle have rather over weighted to the environment of the Earth. As you see in the Figure. 1a, we can recycle the materials, waste and exhaust heats but they cost environmentally because more energies based upon like fossil fuels must be consumed to these recycle systems. That is (b), reduce and (c) re-use have less environmentally impacts but (a) re-cycles would not contribute to reduce the waste heats and materials. Because, one cannot reduce the Entropy in any thermodynamics process. Therefore, low-energy production of materials Figure. 1b. In this proposal review's title, is the more important than re-cycle.

2. Thermodynamic Principles of Advanced Materials proceeding

Processing of advanced materials generally consists of two steps: (I) the synthesis of substances (ceramic, metallic, organic) that can be characterized by (1) a particular chemical composition, (2) a physical state including crystal structure, and (3) specific properties; and (II) materials fabrication (i.e., shape-forming and shape-fixing by firing/sintering, pyrolysis, melting, or casting) as shown schematically in Figure. 2 (right side). In this regard, it is very difficult to give desired shape, form, and size to inorganic ceramic materials, owing to their intrinsic brittleness. Organic materials, such as polymers and plastics, or metallic materials can be generally deformed when local stresses are applied over their yield stresses, but ceramics are susceptible to brittle fracture rather than plastic deformation.