IMPORTANCE OF SOFT PROCESSING (=LOW-ENERGY PRODUCTION) OF INORGANIC MATERIALS FOR SUSTAINABLE SOCIETY

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ABSTRACT

As well as organic and/or bio- materials, advanced inorganic materials, most of metallurgical materials, semiconductors and ceramic materials have been used in wide area of applications like structural, mechanical, chemical, electrical, electronic, optical, photonic, biological, medical, etc. They have never been produced in natural processes nor biological systems. Thus they have generally been fabricated artificially and/or industrially by so-called high-technology, where high temperature, high pressure, vacuum, molecule, atom, ion, plasma, etc. have been used for their fabrications. In particular semiconductor and ceramic materials are difficult in shape forming and fixing due to their intrinsic rigidity and brittleness. Even though nano-sized particles of such materials could be synthesized by low-energetic route, i.e."soft chemistry" or "green chemistry", their shape forming and fixing cost energetically and environmentally. High-technology for the production/fabrication of such artificial advanced inorganic materials favors fast and large production where large amounts of resources and energies based upon fossil fuels. Fossil fuels have been produced from biological resources during millions-billions years on the Earth, thus they cannot recycle in our life time. We cannot allow to continue for even 50-100 years for such high-technology consuming large amount of energies based upon fossil fuels. Real environmental problems are based upon waste heats rather than CO2 itself. The most essential factor in environmental problems should be"How we can eliminate total energy consumption for the production of advanced materials?"

Considering the lowering of total energy consumption, we have challenged to fabricate those advanced inorganic materials with desired shape/size/location, etc. directly in low energetic routes using aqueous solutions since 1989 when we found a method to fabricate BaTiO3 film on Ti substrate in a Ba (OH) 2 solution by Hydrothermal Electrochemical [HEC] method at low temperatures of 60-200 C. We proposed in 1995 an innovative concept and technology, "Soft Processing" or "Soft Solution Processing," which aims low energetic (=environmentally friendly) fabrication of shaped, sized, located, and oriented inorganic materials in/from solutions. It can be regarded as one of bio-inspired processing, green processing, or eco-processing.[1, 2)]

When we have activated/stimulated interfacial reactions locally and/or moved the reaction point dynamically, we can get patterned ceramic films directly in solution without any firing, masking nor etching. They can be called Direct Patterning methods which differ from previous patterning methods consisting of multi-step processes. The notable feature of Direct Patterning is that each reactant reacts directly on site, at the interface with the substrate. Therefore, the chemical driving force of the reaction, A+B=AB, can be utilized not only for synthesis but also for crystallization and/or consolidation of the compound AB. It is rather

contrasting to general patterning methods where thermal driving force of firing is mostly used for the consolidation of the particles.[3)]

We have developed the Direct Patterning of CdS, PbS and CaWO4 on papers by Ink-Jet Reaction method and LiCoO2 by electrochemically activated interfacial reactions.[3)] Furthermore, we have succeeded to fabricate BaTiO3 patterns on Ti by a laser beam scanning and carbon patterns on Si by a needle electrode scanning directly in solutions.[4)] Recent success in TiO2 and CeO2 patterns by Ink-Jet Deposition, where nano-particles are nucleated and grown successively on the surface of substrate thus become dense even below 300 C[3)] will be presented. Nano-structured films will be also talked [4-6)].

A recent novel subject, Soft Processing for various nano-carbons including Graphene and functionalized Graphene, [7-8)] will be introduced.

If I have a time,I will talk about [A]"How we can learn from literature then exceed it to create true originality in our research?"
and [B]" Importance of writing in own notebook(s) to improve one's understanding for efficient study/research."

References

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