Developments of Novel Metal Nanostructured Materials for Energy/Catalysis Applications

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Currently 118 known elements are represented on the periodic table. Of these 118 elements, only about 80 elements are stable, nonradioactive, and widely available for our society. From the viewpoint of "Elements Strategy", we need to make full use of the 80 elements to bring out their latent ability and create innovative materials. Furthermore, there is a strong demand that the use of rare or toxic elements be reduced or replaced, while their important properties are retained. Advanced science and technology could create higher-performance materials even while replacing or reducing minor or harmful elements through the combination of more abundant elements.

The properties of elements are correlated directly with their electronic states. In the present age, more attention has been paid to improving materials properties by means of alloying elements. In particular, the solid-solution type alloy has the advantage of being able to control the properties continuously by changing compositions and/or combinations of constituent elements. However, the majority of the bulk alloys are of the phase-separated type at ambient conditions, where constituent elements are immiscible with each other. To overcome the challenge of the bulk phase metallurgical aspects, we have focused on the nanosize effect and developed "non-equilibrium synthesis" or "a process of hydrogen absorption/desorption" methods.

Here, we introduce some novel solid-solution alloys in which constituent elements are immiscible in the bulk state, or multifunctional composite nanomaterials including metal-organic frameworks (MOFs) for energy storage (hydrogen storage)/catalysis (CO_2 hydrogenation) applications. We also introduce our recent research on surface-confined solid solution alloys (surface alloy) for electrochemical CO_2 reduction catalysts.