Tackling the Catalyst Challenge for Hydrogen-based Energy Applications

Li-Chyong Chen
Center for Condensed Matter Sciences, National Taiwan University

Among the alternative energy sources, hydrogen-based energy and power devices, via electrochemical (EC) route, such as supercapacitors and fuel cells, are advantageous due to their low environmental impacts. From material perspective, the role of a catalyst is critical in the creation of hydrogen-based energy or solar-fuel processes. Not only there are only a few materials that function well enough, as measured by its hydrogen-production rate, power/energy output, selectivity and durability; but also the champion catalysts reported so far are not earth-abundant or costly in process. Material/process solutions to replace or reduce the usage of precious metal catalyst are desirable. A number of energy-conversion/storage devices that utilize nanostructures (in forms of nanoparticles, nanowires and ultrathin films) of various materials, such as carbon, group III-nitrides, metal oxides, conducting polymers, non-precious metal catalysts, as their key components have been demonstrated. A critical part of these efforts involves the development of catalyst/electrode, *via* innovative material or nano-architecture design, towards efficient carrier-generation and subsequent transport. In this presentation, a number of systems will be highlighted: for instance, (1) fuel cells using carbon nano-architectures, as efficient electrocatalyst supports, or novel nitrogen-containing non-noble metal complex compounds, to reduce or replace the usage of Pt; (2) on-board hydrogen generation through methanol micro-reformers using metal oxides nano-architectures; (3) photo-electrochemical cells or solar-hydrogen devices with improved photon conversion efficiency using III-nitrides and metal oxides, with and without co-catalyst; and (4) flexible supercapacitors using conducting polymers and related hybrids. For all these seemingly diversified subtopics, the emphases will be placed on the following three aspects: (i) the energetic and formation kinetics of the architectures-by-design of these electro-catalysts and related hybrid nano-composites; (ii) designing nano-devices with specific attributes such as architecture- and surface/interface-controlled properties; (iii) functionalizing the surface and interface structure and analyzing its correlation with the resultant physical and chemical properties. In practical power/energy generation and storage devices, heterogeneous structures or phases with different functionalities are always involved. Therefore, understanding the physics and chemistry of the interfaces and junctions, be it solid-solid, organic-inorganic, or even liquid-solid, is crucial for ultimate device performance. I will use these case studies to illustrate how research is executed, from goal-setting, planning to completion, at least, stage-wise, showing some promise or shedding light for future directions.