The Role of Nanomaterials Systems in Energy and Environment: Renewable Energy

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Throughout the millennia materials have always played a most important role in answering societal and national challenges and ambitions and defining their future. Advances in civilization have been associated with the discovery, development, and deployment of new materials, such as the Stone Age, the Bronze Age, the Iron Age, and so on. The role of materials has been crucial not only in societal evolution, progress, and living standards, but also sometimes materials play in an intrinsic role in ensuring survival. Nanomaterials are now beginning to play an important role in answering some of our current global challenges. Among these, the challenges presented by energy and environment have considerable urgency.

Global energy demand is growing at an alarming and unsustainable rate, drawing mainly on the use of fossil fuels. The associated emissions of greenhouse gases and other toxic pollutants are becoming environmentally unacceptable. Energy security has become a major issue as fossil fuels are confined to a few areas in the world and their availability is controlled by political, economic, and ecological factors. In the short term, focus should be placed on achieving higher energy efficiency and increasing supplies from all forms of renewable energy. In the long term, focus should be placed in developing an effective hydrogen-based economy.

Because the properties of nanomaterials are very different from those of their conventional counterparts they have capabilities not offered by conventional materials. The reasons for this difference include (1) dimensional changes experienced at the molecular level, (2) a consequent degree of perfection where the absence of all kinds of defects allows intrinsic properties to reach the highest values ever measured, and in certain cases the theoretical limit, (3) a considerable change in surface area and properties like surface tension and surface concentration, and (4) the capability of development of nanoarchitectures not feasible in conventional materials. Among the properties to be considered are strength, stiffness, toughness, and thermal and electrical conductivity and specific surface area.

As a consequence of these outstanding properties the potential capabilities of nanomaterials are extensive but only now are being discovered at a more fundamental level. In order to fully develop the potential of all forms of renewable energy, current challenges in fundamental and applied issues dealing with energy harvesting, storage, and conversion have to be met. The four articles assembled here explore the harvesting of some of these fundamental discoveries and their application in renewable energy. They present typical examples of the current and potential role of nanomaterial systems on renewable energy.

M. Ramachandran and R.G. Reddy's article, "Thermodynamics of Nanoscale Materials," focuses on the evolution of properties at the nanoscale and shows how the surface tension and the melting point of the Ag-Cu system changes extensively as a function of the grain size.

Fernand D.S. Marquis's article titled "Carbon Nanotube Nanostructured and Hybrid Material Systems for Renewable Energy Applications" presents key fundamental properties of carbon nanotubes and their consequent potential for integration in hybrid nanomaterials systems for applications in direct energy harvesting: wind and solar, and in energy storage: supercapacitors, batteries, and fuel cells and addresses the benefits of a system design approach.

Hui Xia's article, "Nanostructure Manganese Oxide Thin Films as Electrode Material for Supercapacitors," offers an interesting review and insight on the synthesis of nanostructured manganese oxides by different methods and on the supercapacitive performance of different nanostructures so obtained.

H.Y. He's article, "Hydrogen Generation from $H_2O/H_2O_2/MnMoO_4$ System" discusses the synthesis of $MnMoO_4$ by sol-gel methods at low temperatures and develops new mechanisms of hydrogen generation for applications in fuel cells using the $MnMoO_4$ semiconductor as an integrated system component.

Although there are still many challenges ahead in these areas the articles presented here show that nanomaterials and hybrid nanomaterial systems have the potential to play a major role in harvesting the full potential of renewable energy resources and associated energy storage needs and in the long term to contribute to an eventual transition into an effective hydrogen-based economy.

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