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Editorial

Multifunctional Hybrid Nanomaterials for Energy Storage

Zhengping Zhou,[1,2] Jiawei Gong,[3] Yichen Guo,[4] and Linqin Mu[1,5]

[1] *Department of Chemistry, Virginia Tech, Blacksburg, VA 24061, USA*
[2] *Department of Mechanical Engineering, North Dakota State University, Fargo, ND 58108, USA*
[3] *Department of Mechanical Engineering, Penn State Behrend, Eire, PA 16563, USA*
[4] *Materials Science and Engineering, Stony Brook University, Stony Brook, NY 11794, USA*
[5] *Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China*

Correspondence should be addressed to Zhengping Zhou; zzhou85@vt.edu

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Over the past few decades, nanomaterials have played a crucial role in the development of energy storage. A tremendous progress in the design and preparation of new nanomaterials has brought a large number of solutions to the existing challenges in energy storage systems, such as high energy and power densities, high efficiency, long-term stability, and low-cost processes. As an emerging material, multifunctional hybrid nanomaterials, usually integrating two or more disparate nanomaterials (e.g., polymeric, semiconductive, carbonaceous, and inorganic materials), have been considered a promising candidate to address these challenges. In particular, the hybridization of these nanomaterials can lead to unique superior multifunctions and thus offers the vast promise of applications in chemical and biological sensing, heterogeneous catalysis, energy conversion and storage, and environment and human health.

Currently, people are learning to integrate different types of nanomaterials to tailor the structures and improve the properties including but not limited to a high specific surface area, a well-controlled pore or particle size, a homogeneous distribution, and a strong attachment between nanomaterial interfacial surfaces. The ability to tailor the structures and properties of hybrid nanomaterials over broad length scales suggests that researches on hybrid nanomaterials will have a tremendous impact in the fields of polymer, carbon, nanotechnology, physical chemistry, and electrochemistry. However, the design and preparation of multifunctional hybrid nanomaterials remain challenging and their introduction into practical applications is not yet satisfactory. Therefore, it is highly desirable to provide a breakthrough on the state-of-the-art nanomanufacturing and scale-up nanotechnology to design and synthesize advanced multifunctional hybrid nanomaterials with improved performance.

In this special issue, we present an elegant collection of high-quality reviews and original articles that illustrate the importance of developing multifunctional hybrid nanomaterials for energy storage and related applications. A deep understanding and relevant theoretical calculations for exploring the behaviors of integrated nanomaterials at their interface have also been obtained by fundamental investigations. The purpose of this editorial is to provide a brief introduction for each published or accepted paper and highlight their major findings and discoveries. In the following, we review all the articles in our special issue, and we believe this editorial will interest the broadest possible section of readership.

Traditional mesoporous metal oxide materials for supercapacitor electrodes undergo either high cost or performance limits (e.g., specific capacitance and cycle life). A new kind of cost-effective complex materials was designed and synthesized by L. Song et al. through an internal template method. This innovated material made of mesoporous nickel-based capsule complex with Fe_3O_4 was used as a supercapacitor electrode, exhibiting a high specific capacitance of 739.8 F/g at a current density of 1 A/g in a 6 M KOH electrolyte solution. They demonstrated a good capacitance retention of

72.8% after 1000 cycles of charge/discharge processes, indicating this new complex material as a promising electrode material for use in supercapacitors. The work by T.-S. Chen et al. presented a C-TiO_2-Pd composite electrode for use in a semivanadium/iodine redox flow battery (semi-V-I RFB) system. The authors found out that the C-TiO_2-Pd electrodes enhanced the electrocatalytic activity of the designed semi-V-I RFB system and then led to an improved energy storage ability. A high energy efficiency of 81.23% was obtained. This excellent work could bring us a new design and assembly technology to further improve the overall efficiency of energy storage systems.

To break up the performance limits of anode materials in Li-ion batteries, C.-C. Lin et al. have designed and prepared carbon nanotubes/graphene deposited with cobalt. A good understanding on how the sputtering power levels/time periods influence the specific capacity of Li-ion batteries has been explored. This study tells us that a longer time period of cobalt sputtering will lead to a higher capacity. Differently, the specific capacity increased at the power level range of 50-100 W, but decreased at the range of 100-150 W. X. Pan et al. have reported a direct template-free electrodeposition method to synthesize hexagonal CuSn prism electrodes for Li-ion batteries. The batteries exhibited an initial discharge capacity of 345 mAh/g and still maintained a high capacity of 210 mAh/g after 10 cycles. When the electrodeposition time was increased, the diameter of CuSn prism increased, but the structure converted to be inhomogeneous and unsteady. Moreover, the size of CuSn prism strongly influenced the capacity and cycle performance of Li-ion batteries.

A study of a microbistable piezoelectric energy harvester is reported by L.H. Chen et al. Based on Hamilton's principles, they have established a nonlinear oscillation differential ?equation by investigating thermoelectromechanical coupling effect. With the size effect, the strain gradient theory is extended to the nonlinear problem of microbistable piezoelectric energy harvesting. When the ambient vibration frequency was increased, the microscale bistable energy harvester led to a snap-through phenomenon. Gao et al. have investigated the relationship between the electrical tree development and the partial discharges of cross-linked polyethylene cables. According to their calculation, an early warning caused by the defects in cable insulation can be detected, which helps to effectively monitor the cable conditions.

Paraffin wax has been proven to be a very promising phase-change material for the purpose of latent heat thermal storage. However, the low intrinsic thermal conductivity of paraffin restrains its performance. To improve the thermal conductivity, A. Badakhsh et al. produced a paraffin composite reinforced with the AlN-coated SiC ceramic powder (SiC@AlN). Due to the high affinity between AlN and paraffin, SiC@AlN powder can be evenly dispersed within the paraffin matrix, which creates the conductive networks to enhance the thermal conductivity of the composite. In addition, this paraffin composite is proven to be cost-effective and easily processable.

Another interesting research is reported in detail by W.-N. Wang et al., who explored a facile two-step solution method for the synthesis of upconversion nanoparticles with $Zn_{0.5}Cd_{0.5}S$ (UCNPs@$Zn_{0.5}Cd_{0.5}S$) core-shell and yolk-shell nanostructures. They demonstrated that the UCNPs@$Zn_{0.5}Cd_{0.5}S$ core-shell nanostructures can be converted to the yolk-shell nanostructures through a calcination at 400°C. In addition, the UCNPs@$Zn_{0.5}Cd_{0.5}S$ yolk-shell nanostructures substantially improved the photocatalytic activity for reduction of Cr(VI) under near-infrared light. The paper by Amin et al. investigated the band gap changes of Ge/CdS bilayer films under different annealing temperatures. At high temperatures, Ge diffused into a CdS layer, forming a mixed phase of CdGeS. It was found that the optical band gap of the bilayer has a linear relationship with the annealing temperature. Increasing the temperature led to a wide band gap. This finding proposed a practical method of engineering the band gap of Ge/CdS bilayer films, which paves a way to their applications in optoelectronic devices.

In view of the above review and discussion, we believe that the present special issue explored the latest research on multifunctional hybrid nanomaterials including fundamental theory and experiments together with reviews and articles. More efficient designs and synthesis processes, as well as the further understandings on the interfacial chemistry of integrated materials in energy storage systems, are needed.

Conflicts of Interest

The guest editors declare that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Authors' Contributions

All the guest editors wrote the editorial and contributed to and approved the final editorial.

Zhengping Zhou
Jiawei Gong
Yichen Guo
Linqin Mu