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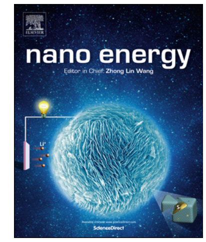

REVIEW

Template-directed construction of nanostructure arrays for highly-efficient energy storage and conversion

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Abstract
To ensure the future highly efficient utilization of various sustainable and renewable energy sources, nanostructured electrodes have become more and more important. This review provides a comprehensive summary of recent research progress in template-directed synthesis of nanostructured arrays for highly-efficient energy storage and conversion. We especially focus on nanostructure arrays based on porous anodic aluminum oxide (AAO) template and colloidal crystal template (CCT), because they possess numerous structural advantages resulting from the highly-ordered and highly-oriented structural features of AAO and CCT, such as nanoscale structural tunability, high regularity and predefined spatial orientation/alignment. All these advantages make AAO and CCT template-directed nanostructure arrays as attractive candidates for highly-efficient energy storage and conversion. This review starts with a brief introduction on template-directed construction of nanostructure arrays, including the fabrication and structural features of both the templates (AAO and CCT) and the corresponding as-achieved nanostructure arrays. Then, the advantages, the progress and the challenges of AAO and CCT template-directed nanostructure arrays for the construction of highly-efficient electrochemical energy storage and solar energy conversion devices are summarized, respectively, followed by present status and the prospects for future research.

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Contents

Introduction

The development of highly-efficient energy storage and conversion systems is critical for addressing the crucial problems of climate change, limited availability of fossil fuels and environmental pollutions, and it also plays a key role in efficient utilization of sustainable and renewable energy (such as solar and wind energy). Currently, the research about energy storage and conversion is mainly focused on electrochemical energy storage devices (especially, supercapacitors and batteries) and solar energy conversion devices (mainly, photovoltaics and solar water splitting cells). Aiming at pursuing improved efficiency for these energy storage and conversion devices, many efforts have been devoted to the applications of nanostructured materials because of their unusual physical and chemical properties endowed by the nanoscale dimensions [1-11]. It is well accepted that nanostructures with high structural regularity and tunability are desirable for constructing energy devices with optimized performance. Moreover, realizing large-scale arrays of self-standing nanostructures with well spatial orientation and arrangement is another key point to further improve the performance of energy devices. Particularly, the spatial orientation/arrangement of arrayed nanostructures and the corresponding interactions between the neighboring nano-units have large influences on the overall device performance [12]. It is well known that spatially oriented nanostructures with well alignment will not only decrease the barriers of ion transport in electrochemical energy storage devices [12-15], but also improve light absorption resulting from anti-reflection, photonic crystal effect, surface plasmon resonance, etc. in solar energy conversion devices [4]. Over the last decade, numerous examples have sufficiently evidenced the advantages of large-scale well-aligned nanostructure arrays applied for energy-related devices [4-10].

Template-directed construction just offers a convenient and versatile approach to produce nanostructure arrays with the above-mentioned distinguished advantages for energy-related device applications (Figure 1) [16-18]. First, template-directed method could be used to produce nanostructure arrays of many materials in large scale because of its easiness and maneuverability, which is important for practical applications of nanostructures in energy devices. Second, template-directed nanostructure arrays have controllable morphological features in nanoscale dimensions, including shape, size, interspace, etc. The flexible structural controllability is highly beneficial for the performance optimization of energy-related devices. Third, the spatial orientation and arrangement of template-directed nanostructure arrays is predefined according to the spatial structure of fixed template, and such structure can be retained to form a self-standing array on a substrate even after the template removal. The self-standing nanostructure arrays with certain spatial orientation and alignment are promising building blocks for energy storage and conversion [4,12-15]. By tuning the spatial orientation and alignment of these nanostructure arrays, the performance of energy devices can be further improved. Fourth, template-directed approach is an efficient way to fabricate

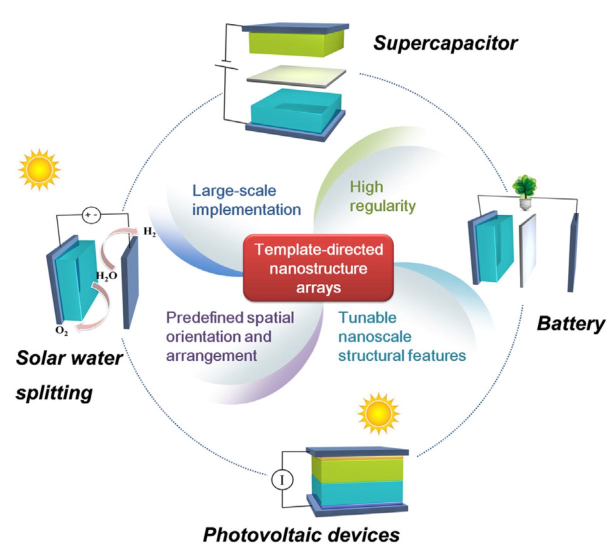

Figure 1 Schematic representation of the advantages of template-directed nanostructure arrays and their potential applications in energy storage and conversion.