Electrodeposition of Hierarchical One-Dimensional ZnO Nanostructures

by Mohammad Reza Khajavi

In the last decade, arrays of vertically aligned one-dimensional (1D) ZnO nanostructures have emerged as promising building blocks for a new generation of devices in different technological domains such as optoelectronics, solar cells and gas sensing. The performance of most of the present pioneering devices is expected to be improved significantly through increasing the surface area of 1D nanostructure arrays. Hierarchical structures constituted of 1D ZnO nanowires have recently become the focus of intensive research due to the considerable increase in the surface area, keeping the special properties of 1D nanostructures such as the high electrical conductivity and enhancing the versatility in the architectural design. Although many interesting hierarchical structures of ZnO have been fabricated by different methods, the development of facile, efficient, and economical methods for creating novel architectures based on 1D nanostructures has remained an important challenge.

In view of that, a three-step, fully electrochemical process (Fig. 1) has been designed to obtain hierarchical ZnO nanostructures by combining the use of aqueous[1,2] and ionic liquid electrolytes.[3] In the first step, ZnO nanowire arrays were electrodeposited in aqueous media. Then a very thin conformal nanocrystalline ZnO layer was electrodeposited from ionic liquid-based electrolytes.[3] As a result, arrays of core-shell nanowire-nanocrystal structures were obtained. The third electrodeposition step, performed in aqueous media, resulted in the growth of secondary nanowires. The nucleation of the latter nanowires was determined by the properties of the nanocrystalline shell, acting as a buffer layer. The electrodeposition of ZnO in ionic-liquid based electrolytes exhibits a highly attractive versatility to act on the ZnO growth habit. This leads to an added value to act on the growth of the secondary nanostructures and consequently on the microstructural properties of the resulting 1D hierarchical nanostructures.

As an example, constant diameter and mushroom-like nanostructures (Fig. 2b, 2c) were obtained just by controlling

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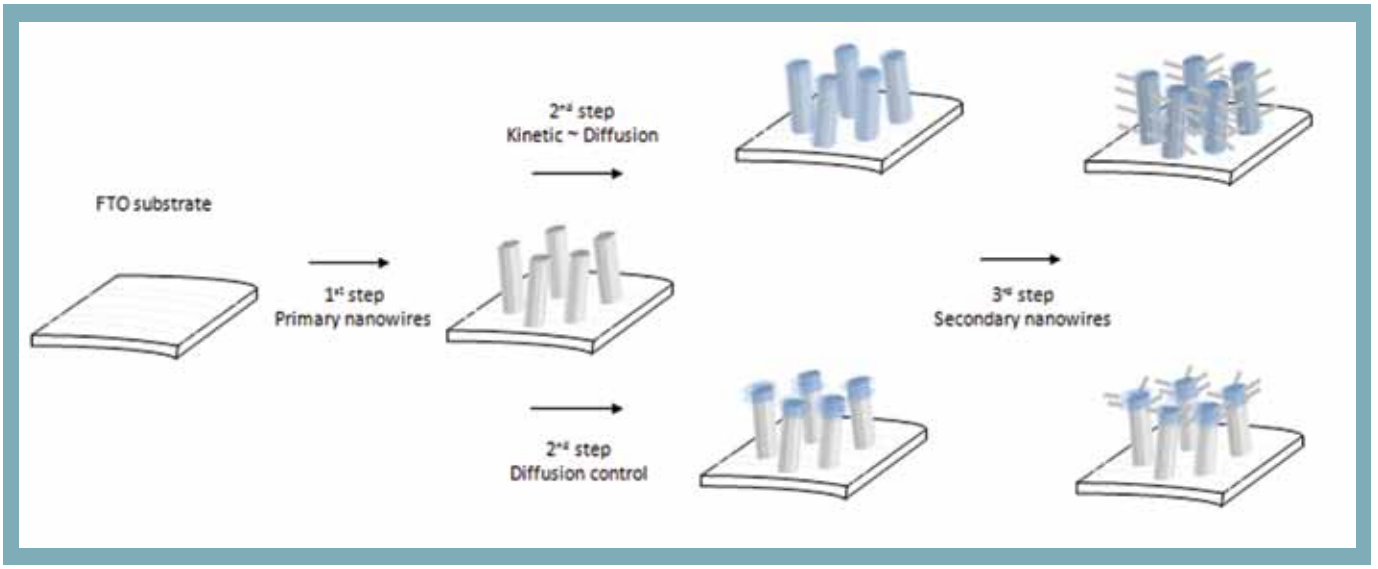

Fig. 1. *Schematic three-step electrochemical deposition of hierarchical 1D nanostructures.*

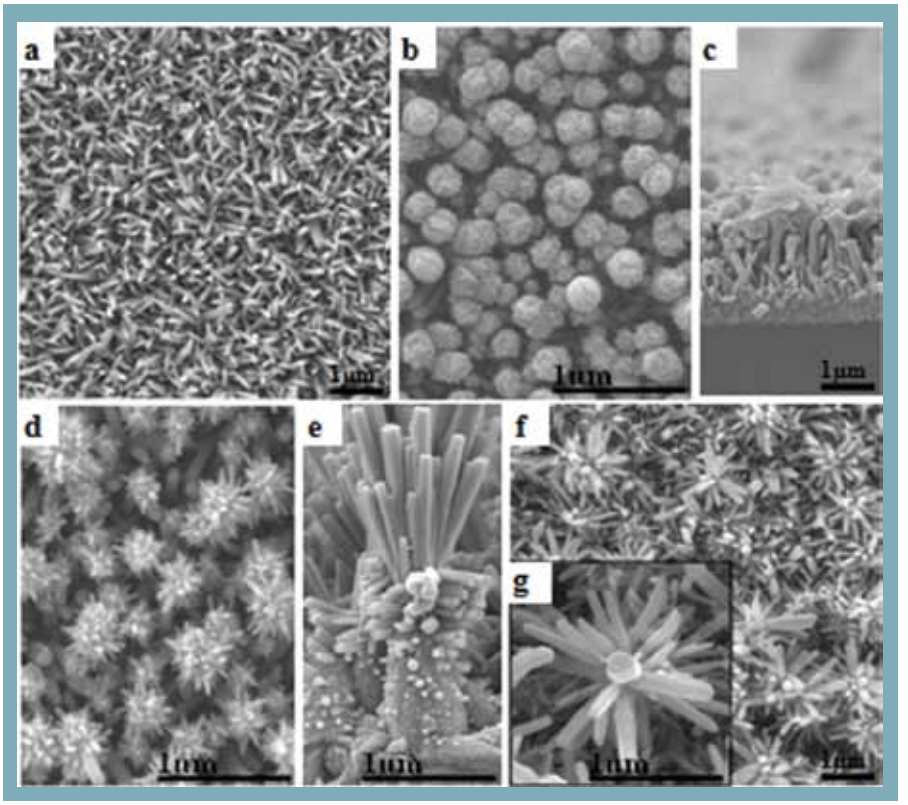

Fig. 2. *Scanning electron micrographs of some of the obtained ZnO nanostructures.*

the kinetics of ZnO deposition and the diffusion of the species in the ionic liquid electrolytes. Similar strategies were also applied in the third deposition step to control the distribution of the secondary nanowires along the core-shell 1D nanostructures. Arrays of nanostructures with secondary nanowires only present at the top were successfully obtained (Fig. 2d, 2e) when the third step deposition occurred under mass diffusion limitation.

All in all, an electrochemical based multi-step deposition process has been successfully developed to obtain hierarchical structures with high control on the morphology and structural features at the nanoscale. This process is expected to provide new opportunities for technological applications such as photovoltaics, photonics, and smart surfaces. In line with this expectation, the prototype dye sensitized solar cell is now under investigation.

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