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Self-supported LDH-decorated Nanotube Networks as 3D Platforms for Electrochemical Applications

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Extended Abstract

Different classes of materials are emerging in the recently used catalyst electrode systems. The performance of such electrodes in different electrochemical applications is mainly attributed to the density of active sites and the conductivity of the electrode material. These two parameters can be controlled through the composition of the active material itself and the electrode design. Most of the common electrode systems include the use of assisting electrodes such as glassy carbon and/or a binder which may suppress the electrocatalytic activity. Metal nanotube/wire networks can provide not only a high surface area and efficient electron transport via the 1D nanoscale building blocks but also excellent mass transport and enhanced stability due to the highly porous 3D network, which in turn can improve the electrode performance. Layered double hydroxide (LDH) is one of the efficient redox structures but still suffers from fast agglomeration and limited conductivity, although their high electrocatalytic activity [1]. Herein, we tried tailoring a new architecture gathering the advantageous properties of the metal nanotube/wire networks, including efficient electron conduction paths and high porosity, with those of LDH nanosheets, including high redox-active sites, in an integrated design. In addition, this combination has been supported by a thick electrodeposited metal layer that works as a current collector forming a free-standing electrode system that is suitable for different electrochemical applications.

This approach depends on a simple and scalable technique, namely electrodeposition and electroless plating, for the fabrication of a new generation of self-supported electrodes. The as-prepared electrode can be utilized in different electrochemical applications depending on the compositional and geometric requirements of the active material. The good properties offered by that class of electrodes are reflected in the high performance established in different applications such as energy storage, catalysis, and electrochemical sensing.

Different LDH nanosheets such as NiCo and NiFe were successfully electrodeposited on a network of interconnected Ni nanotubes of 200 and 400 nm diameter. SEM micrographs and EDX spectra confirmed the loading of the LDH nanosheets over surfaces of Ni and the complete covering of the whole surface with a uniform layer of thin LDH sheets. Cyclic voltammograms revealed the characteristic redox peaks of the included metal hydroxides. The LDH-decorated networks showed enhanced performance as electrodes for supercapacitors and glucose sensing. For instance, The NiCo hydroxide-decorated nanotube networks showed high sensitivity (4.6 mA mM^{-1} cm^{-2}) and a very low detection limit of 0.2 µM which is nearly three times lower than the corresponding value of the pristine Ni nanotube network (~ 0.7 µM) [2]. Meanwhile, it demonstrated high capacity (~120 C cm^{-3}) and remarkable rate capability as electrodes for supercapacitors. Post analysis of the as-prepared LDH-based electrodes confirmed their prolonged stability in different applications and morphological analysis verified that the Ni backbone and the decorating LDH remain intact. Such high performance of the as-prepared electrodes is attributed to the good design of the hierarchical nanostructure which comprises a highly porous, well-interconnected network with synergetic effect upon inclusion of LDH-nanosheets.

Keywords: electroless plating, nanotubes, layered double hydroxides, electrodeposition, nonenzymatic glucose sensors, supercapacitors.

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