METAL-OXIDE NANOROD-BASED SUPERCAPACITORS

Department of Physics, National Dong Hwa University, Hualien 97400, Taiwan

Duy Van Pham (33.33 %)
Ranjit A. Patil (33.33 %)
Yuan-Ron Ma (33.33 %)

Yuan@ndhu.edu.tw

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Figure 1 | | (A) Future application of 1D metal-oxide nanostructure-based supercapacitor in vehicles. (B) Schematic diagrams of a sandwich metal-oxide nanorod-based supercapacitor (left panel) and an energy-storage mechanism with a single metal-oxide nanorod (right panel). (C) Ragone plot for three regions of capacitor, supercapacitors, and batteries. The power and energy density of the MoO3 and NiO nanorods and thin films fall in the supercapacitor region.

Since most metal oxides are functional semiconducting materials, nowadays metal-oxide electrochemical energy storage devices, e.g., batteries and supercapacitors, are very popular for application in portable electronics[6,7]. Specifically, electrochemical supercapacitors have the power and energy densities larger than those of batteries, fuels cells, and conventional electrochemical capacitors with the extraordinary ability of characteristic energy storing[8]. Hence, the electrochemical metal-oxide supercapacitors can be strongly used in industrial equipment, renewable energy systems, storage hybrid vehicles[8,9], and vehicles as demonstrated in Figure 1A. One-dimensional (1D) metal-oxide nanostructures possess large surface areas, which give them versatile and unique optical, electrical, and electrochemical properties[10]. A few 1D metal-oxide nanostructures-based supercapacitors, including RuO2[11], MnO2[12], NiO[10], MoO2[13], and Magnéli-phase Mo4O11[11], etc., have been fabricated with excellent stabilities over thousands of cycles in high specific energies and power densities. Some important factors, including surface area, crystallinity, valences, barrier-free exchange of ions/electrons etc., can affect the performances of the 1D metal-oxide nanostructures-based supercapacitors[10,13]. It is crucial that effort should be taken to reduce resistive elements and minimize the exchange ion barrier for attaining large specific energy and high power densities in the nanostructured supercapacitors. Nevertheless, the 1D morphology, crystallinity, and valences of the metal-oxide nanostructures enhance the charge storing ability and give the 1D metal oxides good potential for application in electrochemical energy storage devices.

An ideal setup for metal-oxide nanorod-based supercapacitors, as shown in the left panel of Figure 1B, is a typical sandwich device, which is comprised of two metal-oxide-nanorods/ITO/glass substrates (as two electrodes) and an electrolyte. The right panel of Figure 1B illustrates the energy-storage mechanism with a single metal-oxide nanorod. It is well known that any supercapacitor involves two electrochemical capacitors, namely an electrochemical double layer capacitor (EDLC) and a pseudocapacitor. The EDLC possesses a non-faradaic energy storage mechanism, which does not allow any ion charge transferring across the interfaces between the electrode and electrolyte to occur. However, the pseudocapacitor is strongly related with a faradaic redox reaction, which can generate and drive the cations and anions transferring across the interfaces between the electrode and electrolyte. The faradaic reactions happen not only on the surfaces of electrodes but also in the interiors of the electrodes, indicating that pseudocapacitors can provide larger specific capacitance (Cp) than that (Cdl) of the EDLCs.

The energy and power densities of the metal-oxide nanorod-based supercapacitors can be acquired from \( E = \frac{1}{2} C_p (\Delta V)^2 \) and \( P = \frac{3600 E}{\Delta t} \), where \( E \) (Wh/kg) is the energy density; \( C_p \) (F/kg) is the specific capacitance; \( \Delta V \) (V) is the operational voltage range; \( P \) (W/Kg) is the power density; and \( \Delta t \) (h) is the discharge time. Figure 1C shows a Ragone plot for the energy and power density results of the NiO[10], Mo4O11[11], MoO2[13], and Mo3S[11] nanorod-based supercapacitors and the NiO thin-film[10] supercapacitor. These metal-oxide nanorod-based and thin-film supercapacitors clearly have the highest energy and power densities amongst all kinds of supercapacitors. For example, the power and energy density of the NiO thin-film supercapacitor are \(~6240\) W/kg and \(~11.93\) Wh/kg at a high current density of 20 A/g[10], and those of the 1D NiO nanorod-based supercapacitor are \(~5855\) W/kg and \(~6.2\) Wh/kg at a high current density of 20 A/g. The MoO2 nanorod-based supercapacitor has the power and energy density of \(~1800\) W/Kg and \(~7\) Wh/Kg at a current density of 4 A/g[11]. Clearly, the supercapacitive performance of the NiO thin-film supercapacitor is better than that of the 1D NiO nanorod-based supercapacitor. This is due to the fact that 2D NiO thin-films supply no resistive elements that exist in the 1D nanorods. However, the high values of the energy and power density apparently make the metal-oxide nanorods or thin-films excellent candidates for use in supercapacitors.

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REFERENCES

Review Editor’s Comments | Pham et al. demonstrates the potential of metal-oxide nanorods as supercapacitor and its application in energy storage |