UNIVERSITI TEKNOLOGI MARA

SUPERCAPACITOR AND DYE-SENSITIZED SOLAR CELL BASED ON QUASI-SOLID STATE POLYMER ELECTROLYTE AND IRON COBALTITE ELECTRODE

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ABSTRACT

Electrochemical devices based on liquid electrolytes are known to have high performance. However, problems associated with liquid electrolytes are electrolyte leakage, volatilization and corrosion of the electrode. The quasi-solid state polymer electrolytes (QSSPEs) are used in these devices to overcome the shortcomings of liquid electrolytes. In this work, the QSSPEs were used in both supercapacitor and dye-sensitized solar cells (DSSCs). For supercapacitor, a typical QSSPE was prepared by incorporating 0.4 g polyvinyl alcohol (PVA) in a 2 M potassium hydroxide (KOH) dissolved in distilled water. Whereas for DSSC, an optimize QSSPE was prepared by incorporating poly(vinylidene fluoride-co-hexafluoropropylene) (PVdF-HFP) in a propylene carbonate (PC) / 1,2-dimethoxyethane (DME) / 1-methyl-3-propylimidazolium iodide (MPII) liquid electrolyte. The semi-crystalline PVdF-HFP was used as a gelling agent because crystalline VdF provides mechanical strength to the electrolyte, whereas the amorphous HFP entraps the liquid electrolyte. Conductivity decreases gradually with increasing PVdF-HFP from 1.3×10^{-2} to 2.0×10^{-3} S cm^{-1} due to decreased ion mobility. No-flow "jelly-like" electrolyte samples were obtained for PVdF-HFP ≥ 0.2 g. The fabricated DSSC without PVdF-HFP shows higher efficiency than DSSCs with PVdF-HFP. The presence of PVdF-HFP deteriorates the performance of DSSCs, but problems associated with liquid electrolytes are eliminated. Presence of sodium iodide (NaI), 4-tert-butylpyridine (TBP) and guanidine thiocyanate (GuSCN) further increases the efficiency of DSSCs. Apart from electrolytes, electrodes also play a significant role in electrochemical devices. Platinum (Pt) is an expensive material commonly used as a counter electrode in DSSC. Commercial supercapacitors are commonly made from carbonaceous materials and they generally exhibit low specific capacitance (C_{sp}). Therefore, in this works, iron cobaltite ($FeCo_2O_4$) has been explored as an alternative material for the counter electrode in DSSC and cathode in supercapacitor. $FeCo_2O_4$, iron oxide (α-Fe_2O_3) and cobalt oxide (Co_3O_4) were synthesized by a simple hydrothermal process. Field-emission scanning electron microscope (FESEM) images show that Fe_2O_3 and Co_3O_4 exhibit different morphology even though they were synthesized via a similar method. The electrochemical properties of the α-Fe_2O_3, Co_3O_4 and $FeCo_2O_4$ electrodes were obtained in a 6 M KOH electrolyte solution. The $FeCo_2O_4$ electrode has the highest C_{sp}, followed by Co_3O_4 and α-Fe_2O_3. The highest C_{sp} of $FeCo_2O_4$ is because of its large nanosheets morphology, better transportation of ions through its expanded crystal structure, and weak crystallinity, which facilitates the intercalation of ions. By varying the duration of hydrothermal reaction, four different $FeCo_2O_4$ structures, namely nanoneedles, nanorods, nanosheets and microcubes, have been obtained. The morphological evolution of $FeCo_2O_4$ is well-explained based on FESEM and high-resolution transmission electron microscopy (HRTEM) analysis. The $FeCo_2O_4$ nanosheets have the highest C_{sp}, followed by nanorods, nanoneedles and microcubes. The highest C_{sp} of $FeCo_2O_4$ nanosheets is attributed to its highest specific surface area and porosity. A solid-state asymmetric $FeCo_2O_4$ nanosheets / PVA-KOH / reduced graphene oxide (rGO) supercapacitor was fabricated. The supercapacitor exhibits a maximum power density of 3202 W kg^{-1} and a maximum energy density of 24.5 Wh kg^{-1}. It demonstrates 70% capacitance retention after 3000 cycles. The optimised PVdF-HFP QSSPEs were assembled into DSSCs with $FeCo_2O_4$ nanosheets as the counter electrodes. It shows an efficiency of 6.04 %.

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