UNIVERSITI TEKNOLOGI MARA

EFFECT OF HYDROTHERMAL DURATION ON THE PROPERTIES OF IRON-COBALT-SELENIDE ($FECO_2SE_4$) AS COUNTER ELECTRODE FOR DYE-SENSITIZED SOLAR CELLS

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ABSTRACT

This work reports on the synthesis of iron selenide ($FeSe_2$), cobalt selenide (Co_3Se_4) and iron cobalt selenide ($FeCo_2Se_4$) via a two-step hydrothermal process. The formation of $FeSe_2$, Co_3Se_4 and $FeCo_2Se_4$ have been proven by sample characterization to support their catalytic activity as the counter electrodes for solid-state dye-sensitized solar cells (DSSCs). The poly(vinylidene fluoride-co-hexafluoropropylene) (PVdF-HFP)/ propylene carbonate (PC)/ 1,2-dimethoxyethane (DME)/ 1-methyl-3-propyl imidazolium iodide (MPII)/ sodium iodide (NaI)/ iodine (I_2) gel electrolytes were assembled into DSSCs with $FeCo_2Se_4$, $FeSe_2$, Co_3Se_4 or platinum (Pt) as the counter electrode. DSSC with $FeCo_2Se_4$ counter electrode shows the highest efficiency of 8.55 %, whereas $FeSe_2$, Co_3Se_4, and Pt counter electrode shows an efficiency of 4.26%, 5.24%, and 7.06 % respectively. This work also reports on the synthesis of $FeCo_2Se_4$ from $FeCo_2O_4$ by varying the duration of selenization process. The structure and crystallinity of the products were characterized using X-ray diffraction (XRD). Energy dispersive X-ray spectroscopy (EDX) analysed the compositions of the products. From field-emission scanning electron microscopy (FESEM) analysis, the $FeCo_2O_4$ presents a thinner and smoother nanosheets structure whereas the $FeCo_2Se_4$ forms a thicker and rougher nanosheets structure. The electrocatalytic effects of $FeCo_2Se_4$ and $FeCo_2O_4$ in comparison to Pt were examined by cyclic voltammetry (CV) and further supported by Tafel polarization. Electrochemical impedance spectroscopy (EIS) was employed to study the internal resistance and charge transfer kinetics. The $FeCo_2Se_4$ obtained after 12 h selenization treatment ($FeCo_2Se_4$ – 12 h) exhibits the highest electrocatalytic activity and the lowest charge transfer resistance, followed by Pt and $FeCo_2O_4$. Superior cell efficiency with $FeCo_2Se_4$ counter electrode can be attributed to the higher porosity, larger specific surface area, lower electron transfer resistance and higher I_3^- reduction rate of $FeCo_2Se_4$.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

Lately, the excessive use of fossil fuels revealed itself to be the cause of fatal consequences to our world. The combustion of fossil fuels may lead to pollution, global warming, and climatic changes (Farhana et al., 2021). Hence, alternative energy sources are needed to prevent this situation from happening. One type of energy that can be used as an alternative to replace fossil fuels is solar energy. Direct conversion of solar energy into electricity appears as an attractive and environmentally friendly solution to today's energy issue (Mary Rosana et al., 2015). Photovoltaic technology is the most attractive renewable energy technology because it is able to convert sunlight directly into high quality electricity (Sharma et al., 2018). Commercial solar cells used in the market today are silicon-based. However, silicon-based solar cells are limited to the terrestrial photovoltaic market due to high production costs (Theerthagiri et al., 2016). Due to this problem, dye-sensitized solar cells (DSSCs) are studied and widely recognized as cost-effective photovoltaic devices due to their low-cost materials and simple fabrication procedures (Cui et al., 2016). Their progress signifies a major achievement in the pursuit of clean and renewable energy sources. This study explores the research history of DSSCs, including their origins, significant achievements, and current progress that has positioned them at the forefront of solar energy research and development.

Regan & Gratzelt, (1991) were the first individuals to invent DSSC. Their work entitled "A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO_2 films, boasting an efficiency of 7.1%-7.9%" has been published in Nature. Calvin (1976) first proposed photosynthesis in photoelectric conversion in 1974. DSSCs are composed of crucial components such as a semiconductor photoanode, dye, an electrolyte, and a counter electrode. DSSCs operate by absorbing photons with the dye, creating electron-hole pairs. Excited electrons are transferred to the semiconductor photoanode, generating a current, as the electrolyte facilitates a redox process to replenish the dye. The counter electrode closes the electron circuit, facilitating in the production of electricity. The operating principle of DSSC can be compared to the process of photosynthesis with the dye functioning as chlorophyll (Adedokun et al.,