UNIVERSITI TEKNOLOGI MARA

MORPHOLOGY AND ELECTRICAL PROPERTIES OF $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (BSCF) AS CATHODE MATERIALS FOR PROTON CONDUCTING FUEL CELLS (PCFCs)

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of the requirements for the degree of
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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

The era of a new green energy technology to afford the fuel flexibility and reliability have been anticipated, with the impression of solid oxide fuel cells (SOFCs). When working with the SOFCs, one of the crucial components is generally a cathode, for instance, $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (BSCF) – a perovskite that exhibits a superior ion conductivity, electrocatalytic activity towards oxygen reduction reaction (ORR), and low polarization resistance. In order to boost up the cathodic performance, the design and fabrication of BSCF to nano-scaled size has been the area of interest in this work. In fact, one-dimensional nanotubes structure is being employed due to high surface-to-volume ratio and increased number of reactive sites for ORR. Herein, an elucidation of synthesizing the BSCF nanotubes (NTs) to improve the electrochemical properties of the cathode was realized by templating from nanoporous anodic aluminium oxide (NAAO). As a starting point in this work, the fabrication of NAAO template via an electrochemical anodization of aluminium (Al) with different applied voltage and time was employed. From the field emission scanning electron microscopy (FESEM), the fabricated NAAO anodized at different voltage and time (40 V – 6 and 10 hours; 80 V – 2 and 3 hours; and 100 V – 1 minute and 2 minutes) resulted in different pore diameter, ranging from 25 to 155 nm. Next, the second part is directed towards the BSCF NTs via NAAO template synthesis. Specifically, the optimized NAAO sample anodized at 80 V for 2 hours with 95 nm pore diameter was selected to be adopted as a template. We have developed a facile and simple approach to synthesize BSCF NTs by a combination of sol-gel template synthesis with different techniques: (1) impregnation, (2) sonication treatment, and (3) spin coating. Those techniques proved the versatility of this templating approach to produce nanostructured material with uniform pore diameter (85-90 nm). From the X-ray diffraction (XRD) analysis, a single crystalline phase of BSCF NTs was attainable at relatively low temperature (700-900°C). Additionally, thermogravimetric analysis (TGA) shows that the thermal decomposition of intermediate compounds has completed at ~700°C. The possible formation mechanism of BSCF NTs inside the NAAO template was also discussed in this work. Particularly, the spin coating technique is time-saving compared to the impregnation and sonication treatment. Therefore, for the last part in this work, BSCF NTs from the spin coating technique was chosen as the optimized sample and was inspected for its electrochemical performance. In order to improve the contact layer between the cathode and $BaCe_{0.54}Zr_{0.36}Y_{0.1}O_{2.95}$ (BCZY) electrolyte, BSCF NTs was further integrated with BSCF nanopowders (NPs) at different weight ratio. The FESEM and Brunauer Emmet Teller (BET) revealed a finer particle size with larger specific surface area 15.02 m^2g^{-1} was obtained for the composite structure of 10 wt. % BSCF NTs: 90 wt. % BSCF NPs ($BSCF_{10NTs:90NPs}$). Meanwhile, the porosity of the cathode has been significantly increased (27 %) for $BSCF_{10NTs:90NPs}$. By means the electrochemical impedance spectroscopy (EIS), the $BSCF_{10NTs:90NPs}$ at 800°C showed a significantly reduce of polarization resistance and area specific resistance (ASR) value of 0.02 $\Omega.cm^2$ – signifies a good cathode performance. This ASR value in an average of five folds lower as compared to the bare BSCF NPs. Apart from that, the FESEM after the electrochemical testing for 100 hours showed the adherence and good compatibility of $BSCF_{10NTs:90NPs}$ with BCZY. Hence, this indicates the well-connected and its robustness for long-term operation. Therefore, the advances of the cathode in this work show a great potential for the development of the next generation of invented SOFCs devices.

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TABLE OF CONTENT