

Fabrication of BSCF-Nanotube as Cathode Layer for a PCFC Single Cell

NASEEM BIN RAPIAN

**Final Year Project Report Submitted in Partial Fulfilment of the Requirements for
the Degree of Bachelor of Science (Hons.) Physics in the Faculty of Applied
Sciences
Universiti Teknologi MARA**

FEBRUARY 2026

This Final Year Project Report entitled **“Fabrication of BSCF-Nanotube as Cathode Layer for a PCFC Single Cell”** was submitted by Naseem Bin Ropian in partial fulfilment of the requirements for the Degree of Bachelor of Science (Hons.) Physics, Faculty of Applied Sciences, and was approved by:

Prof. Dr. Nafisah Mohd Isa @ Osman

Supervisor

B. Sc. (Hons.) Physics

Faculty of Applied Sciences

Universiti Teknologi MARA

02600 Arau, Perlis

Dr. Siti Zulaikha Mohd Yusof

Project Coordinator

B. Sc. (Hons.) Physics

Faculty of Applied Sciences

Universiti Teknologi MARA

02600 Arau, Perlis

Dr. Rosyaini Afindi Zaman

Head of Programme

B. Sc. (Hons.) Physics

Faculty of Applied Sciences

Universiti Teknologi MARA

02600 Arau, Perlis

Date: 6th February 2026

ABSTRACT

Fabrication of BSCF-Nanotube as Cathode Layer for a PCFC Single Cell

PCFCs have gained interest as a prospective energy device because of their capability of operation at intermediate temperature, leading to better efficiency and lower materials degradation. A great impact on the performance of PCFCs is the type of cathode used (structure and microstructure) and, in particular, the cathode material. In the present work, the influence of cathode composition on PCFC single cell performance was studied by using the homogeneous BSCF cathode and heterogeneous BSCF–nanotube cathode with 10% of nanotube addition. Both cathodes were prepared via identical electrolyte-supported cell configuration and spin coating method, ensuring a fair comparison. Structural characteristics were investigated by using X-ray diffraction (XRD) for phase formation and crystallographic stability. The XRD patterns also confirm that both cathodes share the same perovskite BSCF structure without any secondary phases and suggests that the addition of nanotube does not affect the long range crystal structure. The polarization curves are used to analyse electrochemical activity. Maximum power density ($P_{\max}$) for the homogeneous BSCF cathode was higher ($531.06 \text{ mW cm}^{-2}$) than that for the heterogeneous BSCF–nanotube cathode ($494.66 \text{ mW cm}^{-2}$). We interpret these results as indicating that the performance difference is largely a microstructural/interfacial effect and not one of phase alteration. This work provides new understanding on the impact of cathode architecture in PCFC and surrenders a promising methodology for the development and optimisation of nanotube-based cathodes.

ACKNOWLEDGEMENT	III
ABSTRACT	II
ABSTRAK	III
LIST OF FIGURES	Error! Bookmark not defined.
LIST OF ABBREVIATIONS	Error! Bookmark not defined.
 CHAPTER 1	 2
1.1 Background study	2
1.2 Problem Statement	4
1.3 Objectives of the Study	5
1.4 Research Questions	5
1.5 Scope of the Study	6
1.6 Significance of the Study	6
 CHAPTER 2	 7
2.1 Introduction	7
2.2.1 Structure and Basic Principles of PCFC	7
2.2.2 Advantages and Challenges of PCFC	11
2.3.1 Properties of BSCF	12
2.3.2 BSCF-Nanotube Structure and Potential	14
2.3.3 Studies and Comparisons of Nanospherical Powder and Nanotube Powder with Spin Coating Application	16
2.4.1 Nanoporous Anodic Aluminium Oxide (AAO) Template BSCF and Nanotubes.	18
2.5.1 Spin Coating Technique	20
2.5.2 Spin Coating in Technique for a unit Fuel Cell Fabrication	22
2.6 XRD Characterisation	24
2.6.1 Equipment Description	24
2.7 Electrochemical Testing Setup	25
2.8 Field Emission Scanning Electron Microscopy (FESEM) Characterisation	27
2.9 Summary of Literature Review	29

CHAPTER 3	31
3.1 Introduction	31
3.2 Preparation of AAO Template	32
3.3 Synthesis of BSCF Sol and Powder	33
3.4 Templating Approach for BSCF Nanotube by Spin Coating	35
3.5 Fabrication of BSCF Heterogeneous Structure	37
3.6 Cathode Layer Coating by Spin Coating	38
3.7 Summary of Overall Research Methodology	40
 CHAPTER 4	 42
4.1 INTRODUCTION	42
4.2 X-RAY DIFFRACTION	43
4.3 I-V Polarization Curve Analysis	47
4.2.1 I-V Polarization Curve of Homogeneous BSCF Single Cell	48
4.2.2 I-V Polarization Curve of Heterogeneous BSCF Nanotube Single Cell	49
4.3 Power Density Analysis	52
4.4 Comparison of Electrochemical Performance	53
4.5 FESEM Morphological Analysis of BSCF-Nanotube Cathode	55
 CHAPTER 5	 57
5.1 CONCLUSION	57
5.2 RECOMMENDATIONS	59
 CITED REFERENCE	 61
APPENDICES	64
CURRICULUM VITAE	74