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Ex-situ evaluation of PTFE coated metals in a proton exchange membrane fuel cell environment

A. Baroutaji [a,b,*], J.G. Carton [a], A.M. Oladoye [a], J. Stokes [a], B. Twomey [c], A.G. Olabi [d]

[a] Department of Mechanical and Manufacturing Engineering, Dublin City University, Dublin, Ireland
[b] Department of Process, Energy, and Transport Engineering, Cork Institute of Technology, Cork, Ireland
[c] EnBio Ltd., DCU Alpha Innovation Campus, Glasnevin Dublin 11, Ireland
[d] School of Engineering, University of the West of Scotland, Paisley PA1 2BE, Scotland, United Kingdom

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ABSTRACT

Metallic-based bipolar plates exhibit several advantages over graphite-based plates, including higher strength, lower manufacturing cost and better electrical conductivity. However, poor corrosion resistance and high interfacial contact resistance (ICR) are major challenges for metallic bipolar plates used in proton exchange membrane (PEM) fuel cells.

Corrosion of metallic parts in PEM fuel cells not only increases the interfacial contact resistance but it can also decrease the proton conductivity of the Membrane Electrode Assembly (MEA), due to catalyst poisoning phenomena caused by corrosive products. In this paper, a composite coating of polytetrafluoroethylene (PTFE) was deposited on stainless steel alloys (SS304, SS316L) and Titanium (G-T2) via a CoBlast™ process. Corrosion resistance of the coated and uncoated metals in a simulated PEM fuel cell environment of 0.5 M H_2SO_4 + 2 ppm HF at 70 °C was evaluated using potentiodynamic polarisation. ICR between the selected metals and carbon paper was measured and used as an indicator of surface conductivity. Scanning Electron Microscopy (SEM), 3D microscopy, Energy Dispersive X-ray (EDX), X-Ray Diffraction (XRD), and contact angle measurements were used to characterise the samples. The results showed that the PTFE coating improved the hydrophobicity and corrosion resistance but increased the ICR of the coated metals due to the unconductive nature of such coating. Thus, it was concluded that it is not fully feasible to use the PTFE alone for coating metals for fuel cell applications and a hybrid coating consisting of PTFE and a conductive material is needed to improve surface conductivity.

1. Introduction

Proton exchange membrane (PEM) fuel cells are an attractive power source for a variety of mobile and stationary power applications due to their high efficiency, fast start-up, relative lightweight, low operating temperature and low environmental impact [1,2]. Recently, PEM fuel cells have received an increased interest in the automobile sector as a potential alternative to the internal combustion engine [3]. However, in order to meet the full requirements of the automotive industry, the developers of PEM fuel cells have to address many essential issues related to cost, operation and durability of fuel cell components, particularly in comparison with internal combustion engines. One of the key strategies for improving the performance and durability, while reducing the cost of the PEM fuel cell, is to design and develop low-cost bipolar plates with high corrosion resistance and surface conductivity [4–7].

Bipolar plates are key components of a PEM fuel cell stack and perform vital roles such as distributing the fuel and oxidant to the catalyst layer, removing the water from the fuel cell and collecting the produced current [8]. Traditionally, bipolar plates are fabricated from graphite due to its high corrosion resistance, relatively low surface contact resistance and high surface conductivity in the PEM fuel cell environments. However, graphite is brittle, permeable to gases, and expensive to mass produce. Thus, metals and carbon-based composites have been considered to develop cost-effective and durable bipolar plates that can replace graphite. Metals and their alloys provide several advantages over the carbon-based materials, as they possess higher mechanical strength, can be made thinner to achieve higher power density, are more durable, not permeable, and have higher cost effectiveness, with respect to mass production. However, metals considered for bipolar applications are prone to corrosion and exhibit high contact resistance in PEM fuel cell environments (pH = 2–3 at ~70 °C) [9]. The dissolved metal ions, generated from corrosion, can poison the active sites of the membrane electrode assembly (MEA) resulting in decreased power output of the fuel cell [10,11]. Furthermore, these metals develop a passive oxide layer that increases ICR [12].

* Corresponding author at: Department of Process, Energy, and Transport Engineering, Cork Institute of Technology, Cork, Ireland.
E-mail address: ahmad.baroutaji2@mail.dcu.ie (A. Baroutaji).

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Table 1
Material samples.

Material	Grade	Sample name	
		Uncoated	CoBlast PTFE coated
Stainless steel	316L	SS316L	CSS316L
	304	SS304	CSS304
Titanium	G2	TiG2	CTiG2

Therefore, a considerable amount of research has investigated the corrosion behaviour of metal alloys such as stainless steel (SS) [11,13–18], titanium (Ti) [19–21], and aluminium (Al) [22,23]. SS alloys have been considered as the reference materials for metal bipolar plates [11,24–26]. The performance of SS in the PEM fuel cell environment is strongly depended on alloying elements such as Cr, Ni and Mo [25,26]. The SS alloys with higher Cr and Ni content exhibit thinner oxide layer resulting in lower ICR which make such alloys recommended for bipolar plate applications [25]. Ti and its alloys were also considered as a suitable material for bipolar plate applications due to its high strength to weight ratio and also its outstanding chemical stability in acidic environments. It was indicated through many investigations that uncoated Ti has better anti-corrosion properties than the uncoated SS316 in PEM fuel cell environments, but the power output was lower due to the thicker oxide layer formed on the surface of Ti and the released ions such as Ti^{+2} [19,25,27]. Al and its alloys are attractive metals for metallic bipolar plates due to low density, cost effectiveness and ease of fabrication features [28]. However, Al and its alloys are not as good as SS and Ti due to its higher corrosion rate and shorter life.

To overcome the corrosion and high ICR problems, significant research efforts have been directed into improving the corrosion resistance via surface modifications. Surface coatings/treatments for metallic bipolar plates applications are mainly divided into: carbon-

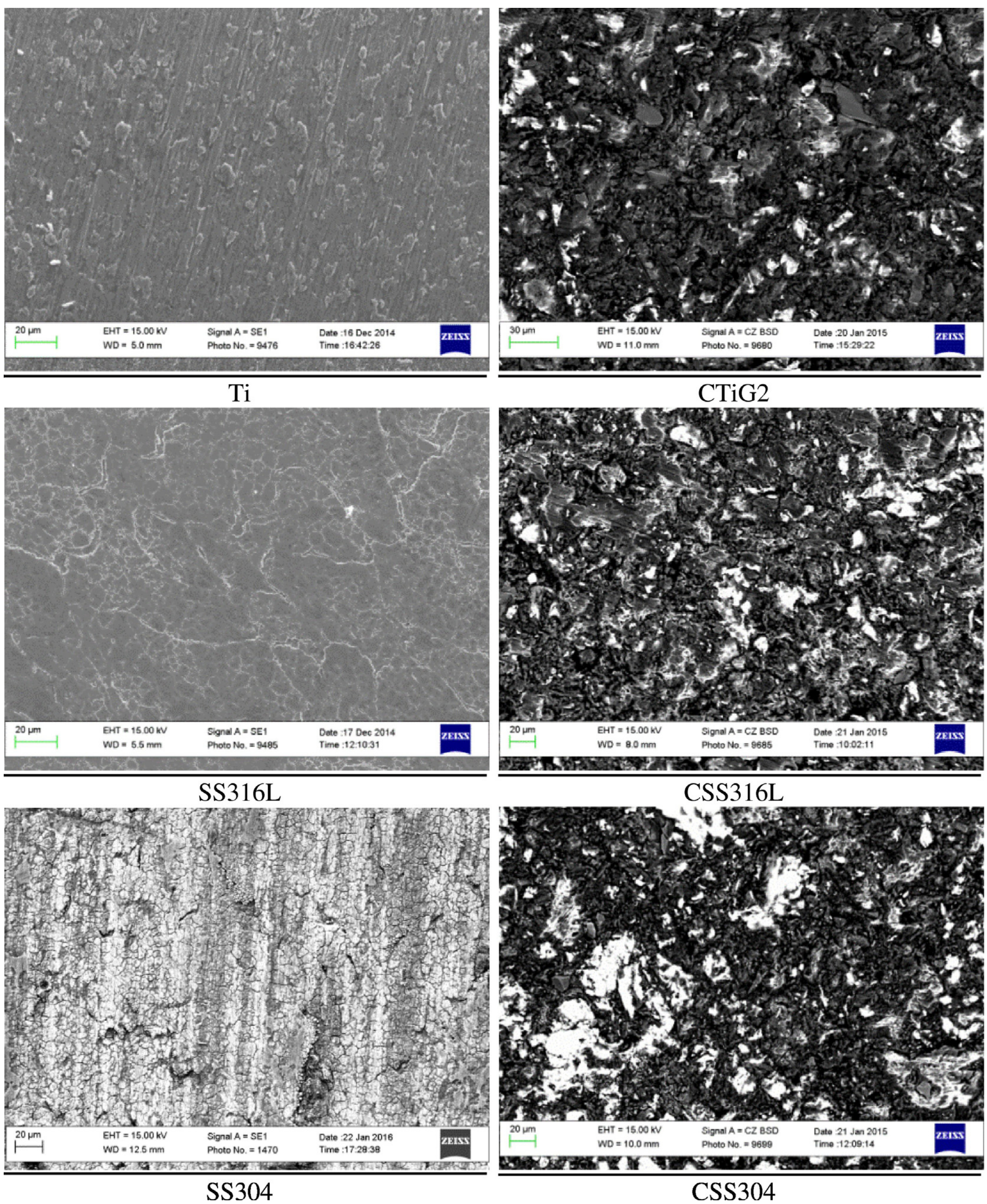

Fig. 1. Topographical view of the coated and uncoated samples.