ARTICLE IN PRESS

INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2017) 1–6

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Surface coating and texturing on stainless-steel plates to decrease the contact resistance by using screen printing

Eiichi F. Mine [a,*], *Yoichi Ito* [a], *Yoshikazu Teranishi* [a], *Motohiko Sato* [b], *Tatehiro Shimizu* [b]

[a] *Composite Materials Development Sector, Tokyo Metropolitan Industrial Technology Research Institute, 3-6-1 Azuma-cho, Akishima-shi, Tokyo, 196-0033, Japan*

[b] *Chemix Co. Ltd, 3481 Asamizodai, Minami-ku, Sagamihara, Kanagawa, 252-0328, Japan*

ARTICLE INFO

Article history:
Received 4 April 2017
Received in revised form 16 June 2017
Accepted 19 June 2017
Available online xxx

Keywords:
Interfacial contact resistance
Polymer-electrolyte-membrane fuel cells
Bipolar plates
Screen printing
Texturing

ABSTRACT

Stainless steel is an attractive material for use in bipolar plates of polymer-electrolyte-membrane fuel cells, except for its high interfacial contact resistance (ICR). Inexpensive surface treatment is required to decrease the ICR. A carbonaceous conductive composite was coated on stainless-steel plate surfaces by using a screen-printing technique. A grid-like texture of the same material as the coating was also printed on the coated plate surface. The cross section showed that conductive carbon particles were well dispersed in the coating layer, which favors through-plane electrical conductivity. The coated and textured plates exhibited a much lower ICR than that of bare stainless steel. The ICR of textured plates was lower than that of coated plates under lower compaction pressures. A single cell with coated and textured bipolar plates exhibited higher power densities than that of bare stainless-steel bipolar plates.

Introduction

Polymer-electrolyte-membrane fuel cells have received wide attention because of their low emissions, high energy-conversion efficiency and their potential applications in vehicles and residential power systems. Decreasing costs and improvements in fuel-cell performance are expected to increase fuel-cell use. Bipolar plates (or separators) in polymer-electrolyte-membrane fuel cells require a high electrical conductivity, corrosion resistance and a high mechanical strength. Stainless steel (SS) bipolar plates offer many advantages, such as a high electrical conductivity, a high mechanical strength, ease of formability and manufacturability. However, major drawbacks of SS bipolar plates are their high interfacial contact resistance (ICR) and corrosive degradation [1,2]. The use of conductive coatings is a surface-modification technique to overcome the drawbacks. Various materials have been proposed for use as conductive coatings and work has been reported in the literature [3–10]. However, many deposition methods in the studies use costly material or large-scale devices for deposition, such as vapor deposition, sputtering

* *Corresponding author.*
E-mail address: mine.eiichi@iri-tokyo.jp (E.F. Mine).

http://dx.doi.org/10.1016/j.ijhydene.2017.06.154
0360-3199/

Please cite this article in press as: Mine EF, et al., Surface coating and texturing on stainless-steel plates to decrease the contact resistance by using screen printing, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.06.154

and pressing. Few reports exist on the coating of carbonaceous composites from conductive carbon particles and polymer matrix by using blade or splay coating [11,12]. Carbonaceous composites and the coating process are thought to be inexpensive. These coatings increase the metal bipolar-plate durability and decrease the ICR. The ICR between bipolar plates and the gas-diffusion layer is determined by the material properties of contacting pairs, surface topology, assembly pressure and operating conditions. The effects of surface topology of the metal and composite bipolar plates on the ICR are examined by surface polishing the bipolar plates [1,13–16]. Unlike for bipolar plates, it is difficult to control the surface topology of coated bipolar plates by surface polishing because of the thin coating. In addition, it is difficult to control directly the surface topology regardless of the deposition technique. Therefore, as far as we know, no studies exist on the changing topologies of carbonaceous coatings.

In this study, SS plates were provided with a carbonaceous conductive coating by using screen printing. Printing methods have been highlighted as a promising technology because of the simpler production process, the requirement for less manufacturing equipment and space, and the lower material consumption [17,18]. Screen printing allows for patterned deposition, which changes the substrate-surface texture. Carbonaceous conductive texturing is achieved on the surface of coated plates by using screen printing. Coating compositions were characterized by Raman and energy-dispersive X-ray (EDX) spectroscopies. The dispersion state of electrically conductive carbon particles was evaluated from cross-sectional observations of the coating. Electrical properties of the coating and texturing of the plates was examined by measuring the ICR and the single-cell performance.

Experimental

Sample preparation

Carbonaceous coating and texturing on the surface of SS304 plates and bipolar plates was performed by using a screen-printing technique. An electro-conductive ink that contained graphite, carbon black, insulating polymer binder and organic solvent was used in the printing. The screen was placed above the surface of the plate. Electro-conductive ink on the mesh was swept by a squeegee, and ink was forced through the mesh openings of the screen to the top surface of the plates. The sample preparation procedure is shown in Fig. 1. SS plates and SS bipolar plates of 50 mm × 50 mm × 2 mm and 60 mm × 60 mm × 2 mm (excluding a lug for current collection), respectively, were prepared by machining. The SS bipolar plate had a single-serpentine flow field channel with a width and depth of 1 mm. SS plate and SS bipolar plates were degreased with acetone before characterization and printing. To prepare the coated plate, screen printing was performed on both sides of the SS plate. All printings were performed manually with a polyester screen mesh (EX-screen 79-048/200PW, NBC Meshtec). Once the plate had been printed, the plate was dried at 423 K for 30 min. A textured plate was prepared by additional printing on the coated plate with a patterned mask and was dried in the same manner. To prepare the coated and textured bipolar plates, only a contact surface with a membrane electrode assembly (MEA) was printed by using stencil pattern on the screen (Fig. 1(b)).

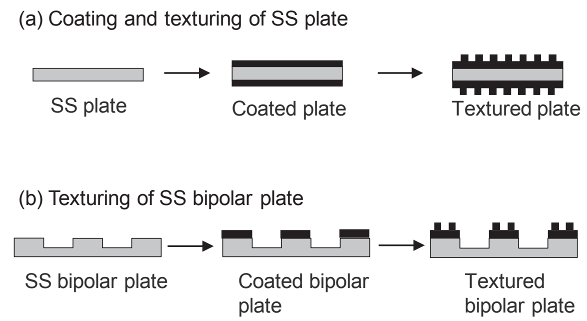

Fig. 1 – Sample plate preparation procedure.

Sample characterization

To characterize the printed carbonaceous coating, EDX analysis and Raman measurements were performed with an EDX analyzer JED-2300 (JEOL, Tokyo, Japan) and a confocal Raman microscope InVia Reflex (Renishaw, Wotton-under-Edge, United Kingdom), respectively. The coating microstructure and cross section were studied by using a high-resolution field-emission scanning electron microscope (Quanta 3D FEG, FEI, Hillsboro, Oregon, USA). A coating cross section was obtained by using a focused ion beam (FIB) system equipped with a Quanta 3D Field Emission Gun. The sample surface topography was studied by laser scanning microscopy (LEXT OLS4000, Olympus, Tokyo, Japan) through a 100 × objective lens.

Interfacial contact-resistance measurements

The interfacial contact resistance (ICR) between samples and the carbon paper was measured by a method similar to that applied in other studies [2,3]. The SS, coated and textured plates were used as a sample plate. A schematic of the set-up to measure the ICR between these plates and carbon paper is shown in Fig. 2. Two pieces of carbon paper (TGP060, Toray, Tokyo, Japan) were sandwiched between the plate and two

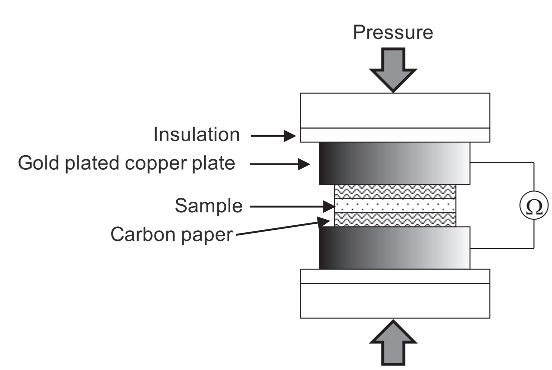

Fig. 2 – Schematic of setup for interfacial contact-resistance measurement.

Please cite this article in press as: Mine EF, et al., Surface coating and texturing on stainless-steel plates to decrease the contact resistance by using screen printing, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.06.154