



Modification of electrode/electrolyte interface by laser micro-processing for solid oxide fuel cell



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ABSTRACT

A strategy based on laser micro-processing was proposed to improve the solid oxide fuel cell performance by modifying electrode/electrolyte interface with a “dimples array” structure. Electrochemistry impedance spectroscopy (EIS) results showed that both ohmic and polarization resistance of single cell were decreased remarkably after interfacial modification. Moreover, the maximum power density of modified cell was increased by up to 58% at 800 °C. The microstructural images of electrode/electrolyte interface indicated that the structured interface extended the triple-phase boundary (TPB) length for electrochemical reaction, which led to the major improvement in the cell performance.

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1. Introduction

Solid oxide fuel cells (SOFCs) are expected to play a major role in a sustainable energy future because they combine the benefits of eco-friendly power generation with high-efficiency [1,2]. However, the necessity for high operating temperatures, which leads relatively high manufacturing cost together with short service life is a primary issue that needs to be addressed prior to the practical implementation of SOFCs [3,4]. Over the past few years, significant efforts have been devoted to lower their operating temperature by two main strategies. On one hand, extensive basic studies focus on the alternative materials, for instance, employing high ion conductive electrolyte materials and designing high-performance electrode materials [5,6]. On the other hand, a great deal of efforts have been devoted to the investigation of cell design to pursue higher power density. Mono-block layer built design is an example of cell's macroscopic shape modification, which succeeds in enlarging the active surface area, but it increases the cell's thickness at the same time, resulting in the increased power density per unit volume is still limited [7]. Compared with controlling the cell's macroscopic shape, micro-geometry control of the electrode-electrolyte interface [8–11] is more attractive because it is widely assumed that electrochemical reaction occurs more prominently at locations near the electrode/electrolyte interface, where the gas,

electrode and electrolyte phases are simultaneously in contact [12,13]. In this sense, creating an ideal electrode/electrolyte interface may be significant to enhance the cell performance. Recently, Konno et al. [9–11] have reported that electrode/electrolyte interface modification at mesoscale (10–100 μm) is an efficient way to improve the power density. Tsumori et al. [14] proposed a micro powder imprint method to modify the electrode/electrolyte interface. Zhang et al. [15] used breath figures method to prepare honey-comb porous cathode membranes which had a high specific surface area for electrochemical reaction. Hussain et al. [16] modified the electrode/electrolyte interface by introducing catalyst nanoparticles in the form of functional layer.

In our previous study [13], a nearly monolayer mesoscale dimples structure was introduced by spraying deposition to modify the electrode/electrolyte interface. However, with this method, the distribution of the dimples in the spraying layer was random and non-uniform. In the present study, we report a novel approach to modify the electrode/electrolyte interface at mesoscale by laser micro-processing [17,18]. The laser is employed to form a highly ordered “dimples array” structure in the electrode/electrolyte interface. We investigate the effect of this interface modification strategy experimentally and discuss the results subsequently.

2. Experimental

The YSZ (8 mol% Y₂O₃-ZrO₂) electrolyte substrates were prepared from commercial powders (TZY-8 M, TERIO, China) by press-

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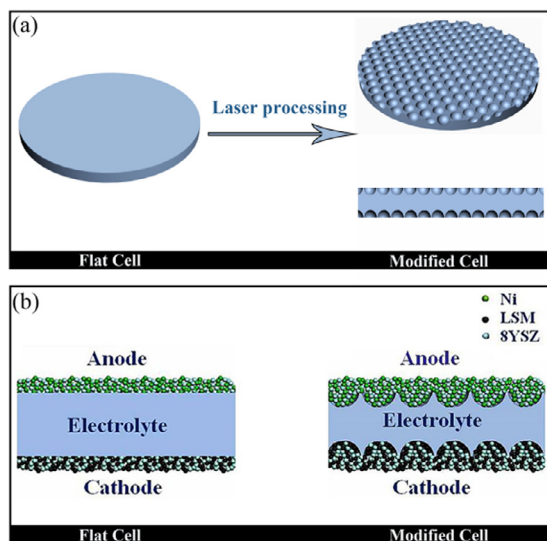


Fig. 1. Schematic illustrations of (a) electrolyte surface and (b) electrode/electrolyte interface with and without laser modification.

ing them into pellets under a pressure of 100 MPa. Both of the green-electrolyte pellet surfaces were subsequently modified to realize a highly ordered “dimples array” structure by using laser micro-processing. A schematic illustration of laser interfacial modification is provided in Fig. 1. The dimples in the surface were designed in the form of close-packed arrays and the number of dimples in the active area ($\sim 0.5 \text{ cm}^2$) of all modified cells was fixed and the same. To optimize the cell performance, the laser intensity was varied (0.5–2 W; interval: 0.5 W) to achieve the desired structure, while the other laser parameters were invariable. Four unique cells and a conventional flat cell were fabricated denoted as Cell P1, P2, P3, P4, and Flat Cell, respectively. After surface modification, the green-electrolytes were sintered in air at 1500 °C for 5 h. NiO/YSZ (wt. %: 60/40) anode was screen printed on the electrolytes with the active area of 0.5 cm² and sintered in air at 1300 °C for 2 h. Similarly, La_{0.8}Sr_{0.2}MnO_{3-δ}/YSZ (wt. %: 60/40) cathode was coated on the other side of the electrolytes with the same active area, followed by sintered in air at 1100 °C for 2 h.

The cell performance was measured with humidified hydrogen (3% H₂O) as a fuel and static air as an oxidant. The impedance spectra and power density of the cells were obtained through an impedance analyzer (PARSTAT 2273) and a digital source meter

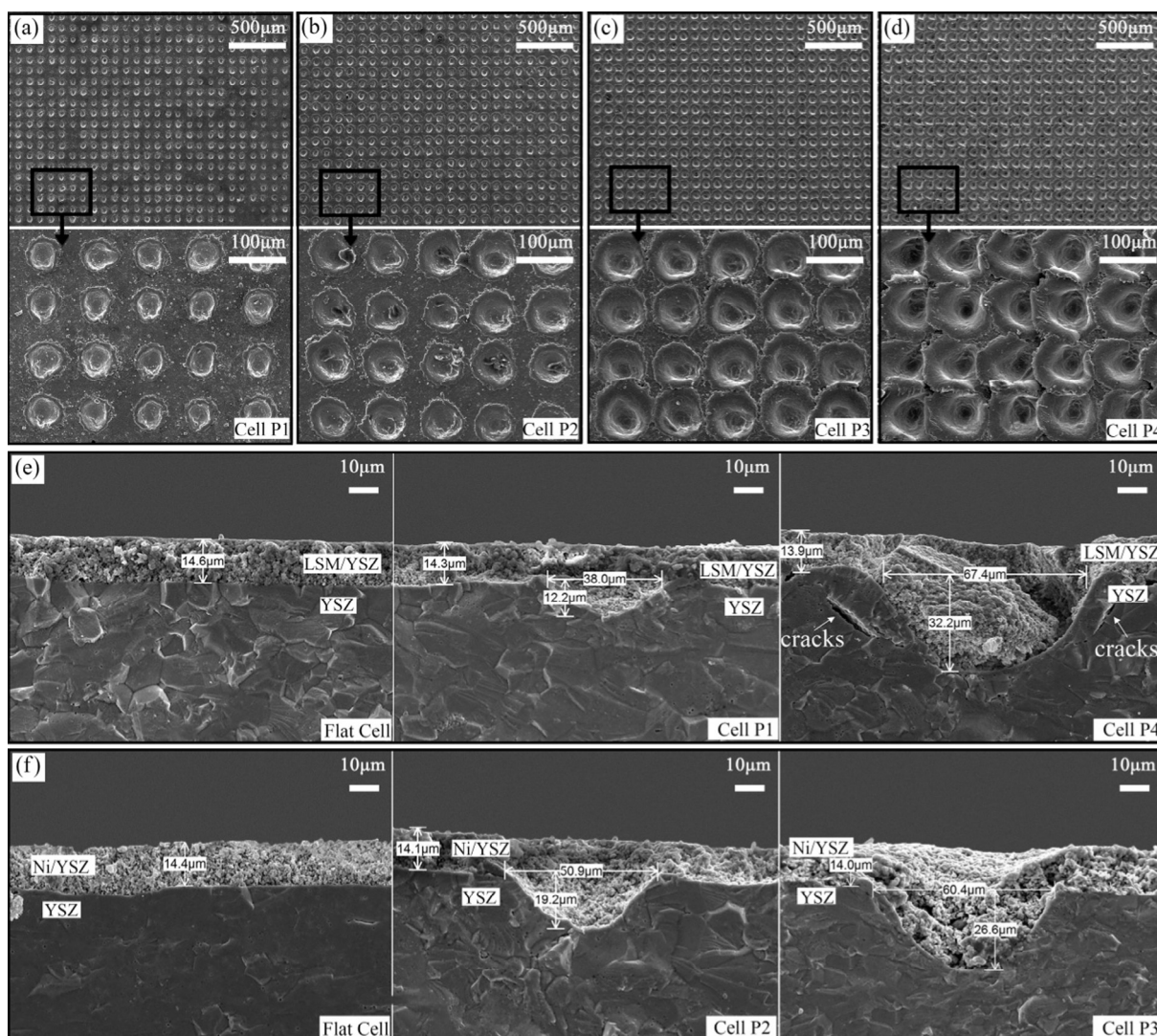


Fig. 2. SEM images of the modified electrolyte surfaces after sintering without coating electrodes: (a) Cell P1, (b) Cell P2, (c) Cell P3 and (d) Cell P4; Cross-section SEM images of electrode/electrolyte interface with and without laser modification from: (e) cathode side and (f) anode side.

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