

## The effect of gas compositions on the performance and durability of SOECs

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In terms of materials and cell components, HTSE technologies are based on solid oxide fuel cells [1]. The single cell is composed of Ni-YSZ as a steam electrode, YSZ as an electrolyte and Sr-doped LaMnO<sub>3</sub> as an air electrode, all of which are primarily considered SOEC components. During the HTSE operation, water is pumped into the steam electrode, where it decomposes to hydrogen (H<sub>2</sub>) and oxygen ions (O<sup>2-</sup>). The electrochemically split oxygen ions (O<sup>2-</sup>) travel through the electrolyte to the air electrode, where they recombine as oxygen molecules (O<sub>2</sub>). The gas composition of the steam electrode in the electrolysis mode, compared with the fuel cell mode, is highly complicated because of the existence of a water molecule, a carrier gas (Ar or N<sub>2</sub>) and a deoxidizing agent (H<sub>2</sub>). Therefore, the steam electrode's gas composition is difficult to optimize because the operating conditions, which are researcher-dependent, are diverse, as evident from Table 1 [2-6].

In our previous work, we reported that SOECs' efficiency improved when the humidity of the steam electrode increased. In the short term, the electrical splitting of water is stimulated by a high steam flow rate due to enhanced gas diffusion through the electrode. However, nickel phases are readily oxidized by a gas interruption or a seal leakage or by a dilution hydrogen concentration in the electrolysis mode due to the rapid kinetics at an elevated temperature [7]. Therefore, this paper aims to provide a more detailed study of the electrochemical properties of solid oxide water electrolysis cells as functions of the gas composition and steam concentration.

The maximum power density of the button cell was 0.48 W cm<sup>2</sup> at 750 °C, and the air and humidified hydrogen flow rate was 100 cc min<sup>-1</sup>. By changing the gas flow rate of the steam electrode from mode 1 (H<sub>2</sub> 100 cc min<sup>-1</sup>, H<sub>2</sub>O(g) 40 cc min<sup>-1</sup>) to mode 3 (H<sub>2</sub> 10 cc min<sup>-1</sup>, Ar 90 cc min<sup>-1</sup>, H<sub>2</sub>O(g) 40 cc min<sup>-1</sup>), the cell's OCV decreased from 0.973 V to 0.877 V, and the cell's charge transfer resistance (R<sub>ct</sub>) increased from 1.126 Ω cm<sup>2</sup> to 1.645 Ω cm<sup>2</sup>. Diluting the hydrogen with carrier gas decreased the OCV and increased the overpotential during the HTSE (Fig.1). The electrolysis's conversion efficiency was closely related to the reactive gases' steam composition. When the steam contents decreased from 40 vol% to 3 vol% at the applied voltage of 1.3 V, the R<sub>ct</sub> increased from 0.381 Ω cm<sup>2</sup> to 1.056 Ω cm<sup>2</sup>, and the resulting overpotential was observed even at a low current density. Finally, the long-term operation of a flat-tubular solid oxide electrolysis cell with a high steam flow rate was performed to establish the water content limit and to investigate the oxidation of steam electrode at an extremely low H<sub>2</sub> partial pressure. In the short term, the electrical splitting of water was stimulated, and the steam to H<sub>2</sub> ratio was maintained between 10:1 and 20:1. However, in the long term, the Ni-YSZ electrode was damaged to the extent that catastrophic failure occurred. For long-term performance, the gas composition of the reactive gas should be optimized because of the trade-off

between performance and durability, which depends on the water concentration of steam electrodes.

Table 1. Gas compositions of steam electrodes for long-term operation of high-temperature

%H <sub>2</sub> O/%H <sub>2</sub> /%Ar	Reference
50/23/27	[2] Briss et al.
80/20/0	[3] Bo et al.
54/23/23	[4] Lohsoontorn et al.
50/50/0	[5] Ebbesen et al.
60/40/0	[6] Liang et al.

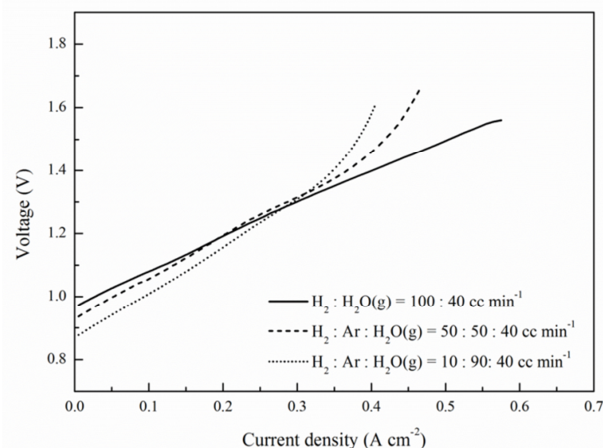


Fig. 1 The current-voltage test results for investigating the effects of the gas composition on the performance of solid oxide electrolysis cells

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