

COPPER-PLATED STAINLESS STEEL FOR BIPOLAR PLATES IN DIRECT-OXIDATION SOFC

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In our laboratory, we have focused on the development of Cu-based anodes for SOFC because Cu, unlike Ni, does not catalyze the formation of graphite fibers in the presence of dry hydrocarbons (1,2).

In the present study, we demonstrate that it is possible to obtain gas-tight seals for an SOFC with a Cu-based anode in a stainless-steel bipolar plate. While stainless steel catalyzes carbon formation that blocks the gas flow when pure n-butane is fed to the anode at 973 K, carbon formation is prevented when the steel is electroplated with a thin Cu film.

A yttria-stabilized zirconia (YSZ) wafer, with one side porous and the other dense, was prepared by tape-casting methods, with graphite and poly-methyl methacrylate (PMMA) pore formers. The thickness of the dense electrolyte layer was 60 μm and this was supported by the 600-μm porous layer. The cathode material, a 50-wt% YSZ and LSM (La_{0.8}Sr_{0.2}MnO₃, Praxair Surface Technologies) mixture, was applied as a paste onto the dense side of the wafer, then calcined to 1400 K. Because Cu is catalytically inert, it is necessary to add a catalyst, CeO₂, to the anode in order to oxidize the hydrocarbon fuel (3). To prepare the anode, the porous YSZ layer was impregnated with aqueous solutions of Ce(NO₃)₃·6H₂O and Cu(NO₃)₂·3H₂O and calcined to 723 K to form the oxides. The final composition of the anodes was 20 wt% Cu and 10 wt% ceria. The fabricated cell having an anode area of 2.5 × 2.5 cm² and a cathode area of 1 cm², was sealed over a fuel channel recessed into a stainless steel plate.

The cell potential and power densities are plotted in Fig. 1 as a function of current density for a cell operating on H₂ and n-butane at 973 K. The open-circuit voltages (OCV) were 1.1 V for H₂ and 0.96 V for n-butane. In this study, the maximum power density was 0.16 W/cm² for H₂ and 0.09 W/cm² for butane, about 20% lower than we have reported previously for small button cells.

As a demonstration of cell stability, Fig. 2 shows the potential and current density as a function of time for the SOFC with pure n-butane as fuel for a period of 24 hour. The data show that the current and potential did not change during the run. To gain insight into the mechanism for carbon formation on the Cu-coated plates, the tar-like substances were analyzed by GC-MS after they were dissolved in toluene. The GC trace and an identification of major compounds are shown in Fig. 3. It was found that the deposits consist primarily of poly-aromatic hydrocarbons having between 2~6 aromatic rings. These compounds are probably form as a result of gas-phase, free-radical reactions. It is important to note that these deposits are very different from what is formed in the presence of a metal catalyst such as Ni or Fe.

References

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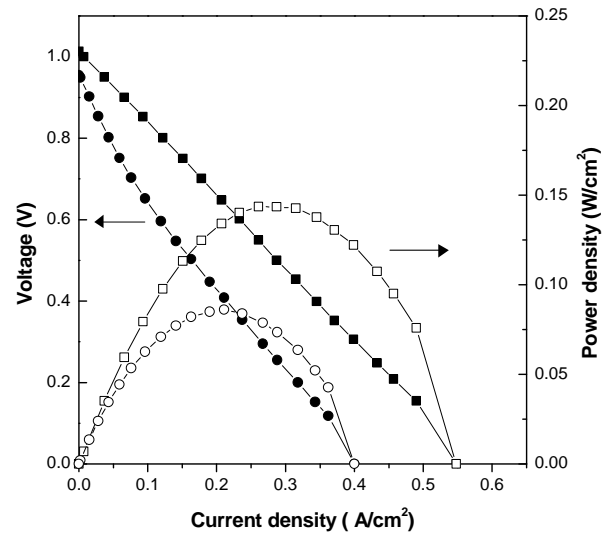


Figure 1. Cell potential and power density vs. current density while running on H₂ and n-butane at 973 K. The squares are for H₂ and the circles for n-butane.

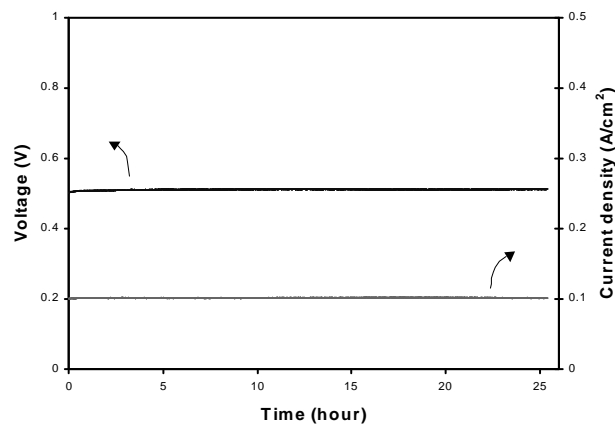


Figure 2. Cell performance in n-butane as a function of time at 973 K while holding the cell potential at 0.5 V.

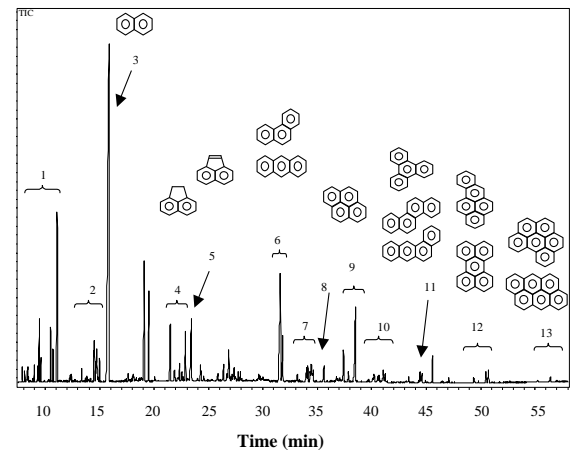


Figure 3. The GC trace obtained from the carbonaceous deposits formed on Cu-plated stainless steel following exposure to n-butane at 973 K for 24 hours. The structures of selected species are given, along with numbers .