Novel Materials for Intermediate-Temperature Solid Oxide Fuel Cells
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Introduction
The need to develop new cathode materials for intermediate-temperature solid oxide fuel cells (IT-SOFCs) is driven by the temperature conditions required for IT-SOFC operation. Designing SOFCs to operate at lower temperatures with comparable production to SOFCs at higher temperatures requires new materials that can maintain favorable properties at the more intermediate range, and regarding cathodes, one promising material to emerge is Ba0.5Sr0.5Co0.8Fe0.2O3−δ (BSCF) [1,2]. In the present study, we have investigated Nb-doped BSCF (Ba0.5Sr0.5(Co0.8Fe0.2)1−xNbxO3−δ (x=0–0.1)) as cathodes for IT-SOFCs. The electrochemical behavior, phase stability and cell performance at low temperature range is studied.

Experimental Methods
Three BSCF powders with compositions of x = 0, 0.05, and 0.10 were mixed, ball-milled, and tested through XRD to confirm a pure cubic perovskite phase. From these powders, cathode pellets and slurries were then fabricated. The pellets were used in four-point conductivity tests as described by Pauw et al. [3]. Additionally, the pellets underwent CO2 stability tests (1% CO2, 3 hr, 600°C) and phase stability tests (air, 300 hr, 600°C). Meanwhile, the slurry was used to make symmetric cells that underwent electrochemical impedance spectroscopy (EIS) measurements, and it was also used as the cathode in an anode-supported full fuel cell setup (with Ni-GDC serving as the anode and a thin layer of GDC as the electrolyte) designed to test for performance.

Results and Discussion
Figure 1 gives the XRD pattern of the initial calcined powders. The agreement between the results for Nb = 0%, 5%, and 10% (from here on designated as BSCF0, BSCF5, and BSCF10) indicates that the material maintains a pure cubic perovskite phase even after doping. The slight shift of the BSCF10 pattern to the left of the peaks for the other patterns is possibly the result of the larger ionic radius of Nb compared to that of the ions it replaces, which may increase the lattice parameter and thus decrease the diffraction angle.

Results from the CO2 stability tests showed obvious formation of a carbonate layer on the BSCF pellets for all three compositions. Thus, Nb doping does not improve BSCF resistance to CO2 contamination at higher CO2 levels. In the XRD patterns of BSCF pellets that underwent phase stability testing, the clear, consistent peaks seen in all three patterns shows that there is no phase transformation in any of the samples, implying that the cubic phase of BSCF, both pure and Nb-doped, is potentially kinetically stable at 600°C. Further, it should also be noted that since the BSCF samples were annealed in air, there was a trace amount of CO2 present (roughly 0.03%) during the process, and yet no carbonate formation was detectable, either visually or through XRD analysis. Thus, the samples are indeed stable in the presence of CO2 when the CO2 levels more closely resemble natural conditions (i.e. the composition in air). Furthermore, the results of the conductivity and EIS measurements indicate that an increased level of Nb doping reduces BSCF’s conductivity and also its Rp values at lower temperature ranges. Finally, Figure 2 displays the performance of the full fuel cell. BSCF10 produced a higher power density than BSCF0, reaching a value of 0.71 W/cm2 at 600°C, a density about 0.13 W/cm2 higher than that obtainable by BSCF0 under similar conditions.

Figure 2: Plot of power density and voltage against current density for BSCF0 and BSCF10

Conclusions
Several properties of Nb-doped BSCF were explored through the operation of various tests. BSCF, both pure and Nb-doped, has poor CO2 resistance at relatively high levels of CO2, but it can resist carbonate formation at lower, more realistic levels (e.g. 0.03% CO2). In addition, BSCF shows good phase stability at 600°C, indicating that the cubic phase is kinetically favorable at this lower temperature. The electrochemical performance of BSCF, meanwhile, appears to potentially benefit from Nb substitution in the B-sites of the perovskite structure. Finally, higher power density is achieved in full fuel cell tests when BSCF is doped with 10% Nb, resulting in a value of 0.71 W/cm2, 0.13 W/cm2 higher than that normally achievable with pure BSCF.

Further experiments will supplement these results and create a more complete documentation of Nb doping’s effect on BSCF. Among the properties that remain to be tested are the cell performance of BSCF5, the long-term stability of a full fuel cell with a BSCF-based cathode, and the phase stability of Nb-doped BSCF for longer periods of time than was attempted in this and previous studies.

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References