Nexceris Button Cell Test Fixture White Paper

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Executive Summary

Nexceris has developed a standardized button cell test fixture designed to enable reliable electrochemical evaluation of solid oxide cells under both fuel cell (SOFC) and electrolysis (SOEC) operating conditions. The fixture incorporates customer-driven design features to improve ease of assembly, sealing reliability, electrical contact quality, and overall data reproducibility while remaining flexible for a range of cell formats and test configurations.

Performance validation was conducted using a 25 mm anode-supported cell across temperatures from 700–800 °C and varying reactant compositions. The fixture enabled stable operation with high open-circuit voltages, confirming effective gas separation and robust sealing. High current densities were achieved in both SOFC and SOEC modes, with expected dependencies observed for temperature, steam concentration, and fuel dilution. Electrochemical impedance spectroscopy further demonstrated the capability of the fixture to generate high-quality data suitable for mechanistic interpretation.

Overall, the results validate the Nexceris button cell fixture as a robust and versatile platform for performance characterization and materials screening. With short-term performance established, the fixture is well positioned for long-term testing to assess durability under representative operating conditions.

Introduction

With growing global demand for power, efficient energy generation and storage remain critical challenges. Solid oxide cell (SOC) technologies are well positioned to play an important role because of their efficiency and operating flexibility. The same fundamental platform can be applied to power generation as a fuel cell (SOFC), hydrogen production as an electrolysis cell (SOEC), reversible operation for energy storage (rSOC), and syngas production through co-electrolysis.

For these applications, cell architecture and composition can be tailored to optimize performance, durability, material cost, and application-specific requirements. Other stack components, including current collectors, contact pastes, and contamination-mitigation materials, can also strongly influence these metrics. References 1–4 provide additional discussion of several of these considerations.

Significant R&D effort has been devoted to evaluating and screening key parameters at the cell and component levels through single-cell testing. As cell area increases, the number of factors contributing to measured performance and durability also grows. Button cell testing is often the first step because it requires fewer resources and is better suited to isolating variables in fundamental studies. Even at this scale, however, many testing choices can significantly affect the observed results. Here, Nexceris demonstrates the performance of a standard button-sized anode-supported cell (ASC) using its newly launched button cell fixture under a range of conditions in both SOFC and SOEC modes. The fixture incorporates customer feedback on ease of use, cost, performance, and data quality. It supports both ASC and electrolyte-supported cell (ESC) designs in 20 mm and 25 mm diameters and includes standardized components such as current collectors, seals, and contact pastes, while remaining highly customizable to customer requirements.

Methodology

A standard Nexceris 25mm diameter ASC was loaded into the button cell test fixture as shown in Figure 1. The full assembly process is explained in detail in the kit manual and features newly designed alignment pins and a contact paste application mask for improved ease of use [5].

The current collectors include nickel foam on the fuel side and silver foam on the air side. Contact pastes were applied between the current collectors and manifolds, as well as between the current collectors and cell electrodes to ensure proper electrical connections. The fuel side contact paste is a mixture of Ni and NiO, formulated to balance electrical conductivity and porosity for gas delivery to the electrode after fuel electrode reduction. The contact paste used on the air side is a copper-added lanthanum nickel cobaltite (LNC-Cu), which combines the high conductivity of LNC with a copper-based sintering aid that has provided excellent and consistent results [6].

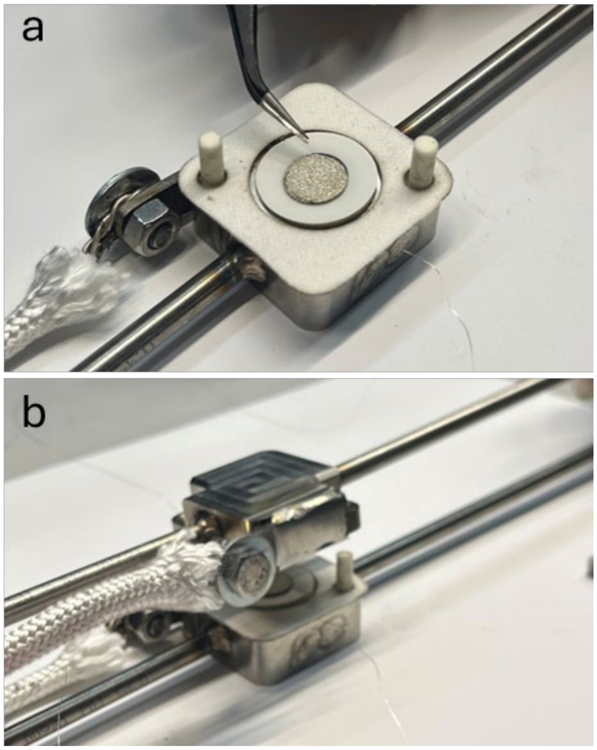

Figure 1. a) Mostly assembled fixture with an ESC, including placement of the silver foam current collector over the air electrode, and b) placement of air manifold, with the top seal affixed, onto the assembly to complete the build

Once assembled, the fixture was placed on a flat platform in the test furnace, and a dead weight was applied to the top manifold. After the assembly was secured and the gas lines and electrical leads were connected, the leads were checked with a multimeter to confirm that no shorting had occurred between the air and fuel sides. The furnace was then packed with insulation around the gas tubes and electrical leads before heating began.

The cell was heated and reduced according to the procedure described in the testing manual. After reduction, the fuel composition was adjusted to 3% steam and 97% H_2, and sealing quality was assessed. For 3% steam delivery, fuel was passed through a bubbler, while a Nexceris vaporizer was used in SOEC tests to deliver higher steam concentrations. Several fuel-side gas compositions were evaluated in both SOFC and SOEC modes. For SOFC testing, the total fuel flow rate was 0.2 nLPM through the bubbler set to 25°C to achieve 3% steam. Two SOFC conditions were evaluated: undiluted H_2 and a 50/50 H_2/N_2 mixture. For SOEC testing, 80% and 50% steam compositions were delivered at total flow rates of 0.4 nLPM and 0.2 nLPM, respectively. These rates were selected based on OCV stability to confirm proper steam delivery. In all tests, the air flow was held constant. Polarization curves and potentiostatic electrochemical impedance spectroscopy (EIS) were collected at 700°C, 750°C, and 800°C under both OCV and bias conditions (0.8 V in SOFC and 1.3 V in SOEC). EIS spectra were collected from 200 kHz to 100 mHz with a ±20 mV amplitude.

Results & Discussion

Figure 2 shows the first 35 hours of the cell through the reduction conditioning. No steam was flowed until after the voltage stabilized to an OCV of about 1.17V, after which the OCV dropped to 1.14V when flowed through a bubbler to achieve the 3% steam composition. This high OCV indicates good sealing, and similar verifications were made at each condition to ensure good agreement between observed and expected OCV.

Once the cell was confirmed to be well sealed and fully reduced, performance testing proceeded at each temperature. After each gas-composition change, the cell was allowed to equilibrate for at least 10 minutes, and typically longer when transitioning from higher to lower humidity conditions.

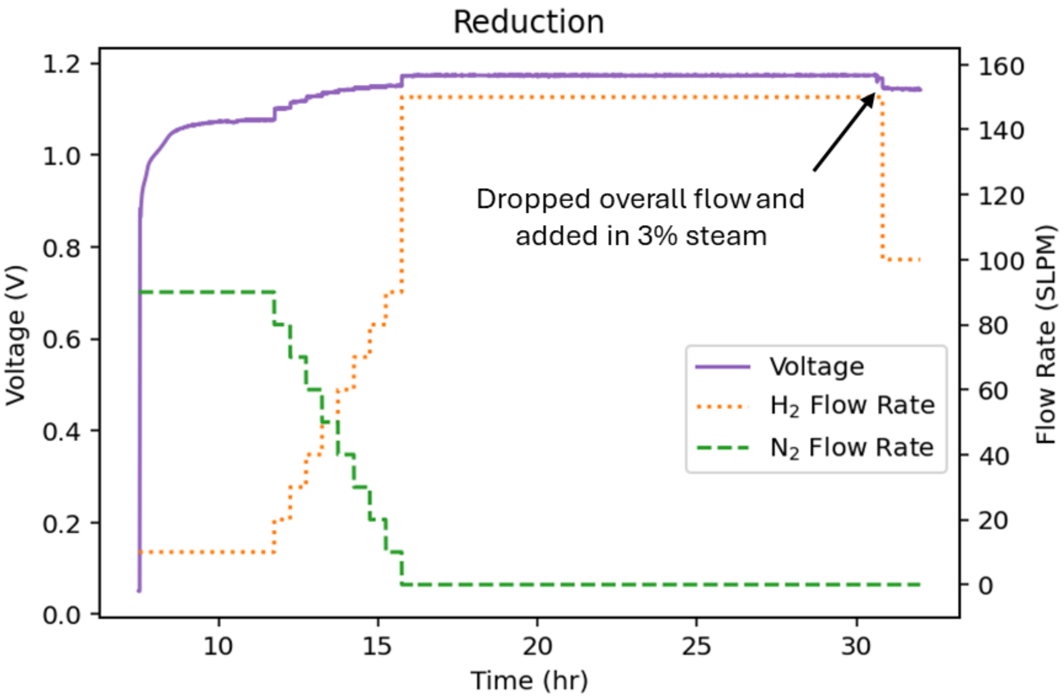

Figure 2. Voltage change as gas composition is shifted to 100% H_2

Figure 3 below shows the polarization results of the SOFC and SOEC tests collected at each temperature and for each flow condition. This cell achieved exceptionally high current densities during the polarization tests in both modes. Also in both modes, the fuel composition had a significant impact on the performance. In SOEC, the maximum current density was about 1 A/cm2 higher at 750°C and 800°C with 80% steam over those seen with 50% steam, while at 700°C the polarization behavior showed only marginal differences. This suggests that at 700°C, the steam conversion is sufficiently low in both conditions that the main rate limiter is not mass transport.

In SOFC operation, similar behavior was observed at 700°C, but the increase in maximum current density was more pronounced than in SOEC mode. Under diluted fuel conditions, performance at each temperature increased consistently with temperature, whereas the undiluted tests showed different behavior. At intermediate voltages, the current responses at 750°C and 800°C overlapped until the potential was approximately 0.76 V, after which mass-transport limitations reduced performance at 750°C.

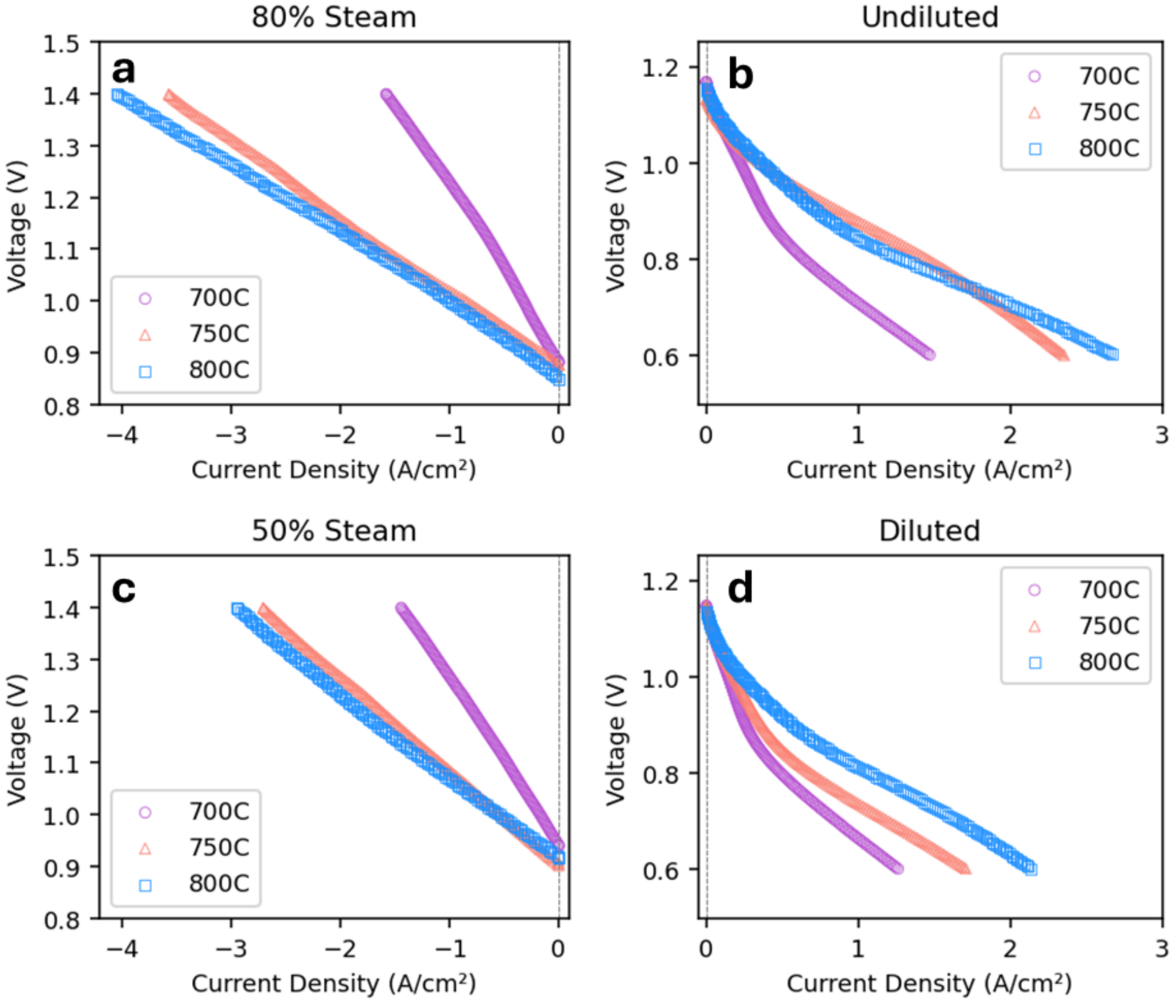

Figure 3. Polarization curves at each temperature for a) SOEC with 80% steam, b) undiluted SOFC, c) SOEC with 50% steam, and d) diluted SOFC tests

EIS provides additional insight into the processes occurring under each condition. Figure 4 shows the biased Nyquist plots for each electrolysis condition, along with the equivalent circuit (panel a) used to fit the data. Fit lines are shown as solid black curves within each data set. In the circuit, R1 is assigned to ohmic resistance, while R2–R4 represent non-ohmic resistance associated with charge-transfer and mass-transport processes. The fitted resistance elements should be interpreted as effective, linearized responses of coupled electrochemical processes under specific operating conditions rather than as single elementary reaction steps [7].

Generally, impedance values are consistent between OCV and biased tests, indicating that the underlying electrochemical processes are stable and not strongly affected by the applied bias. As

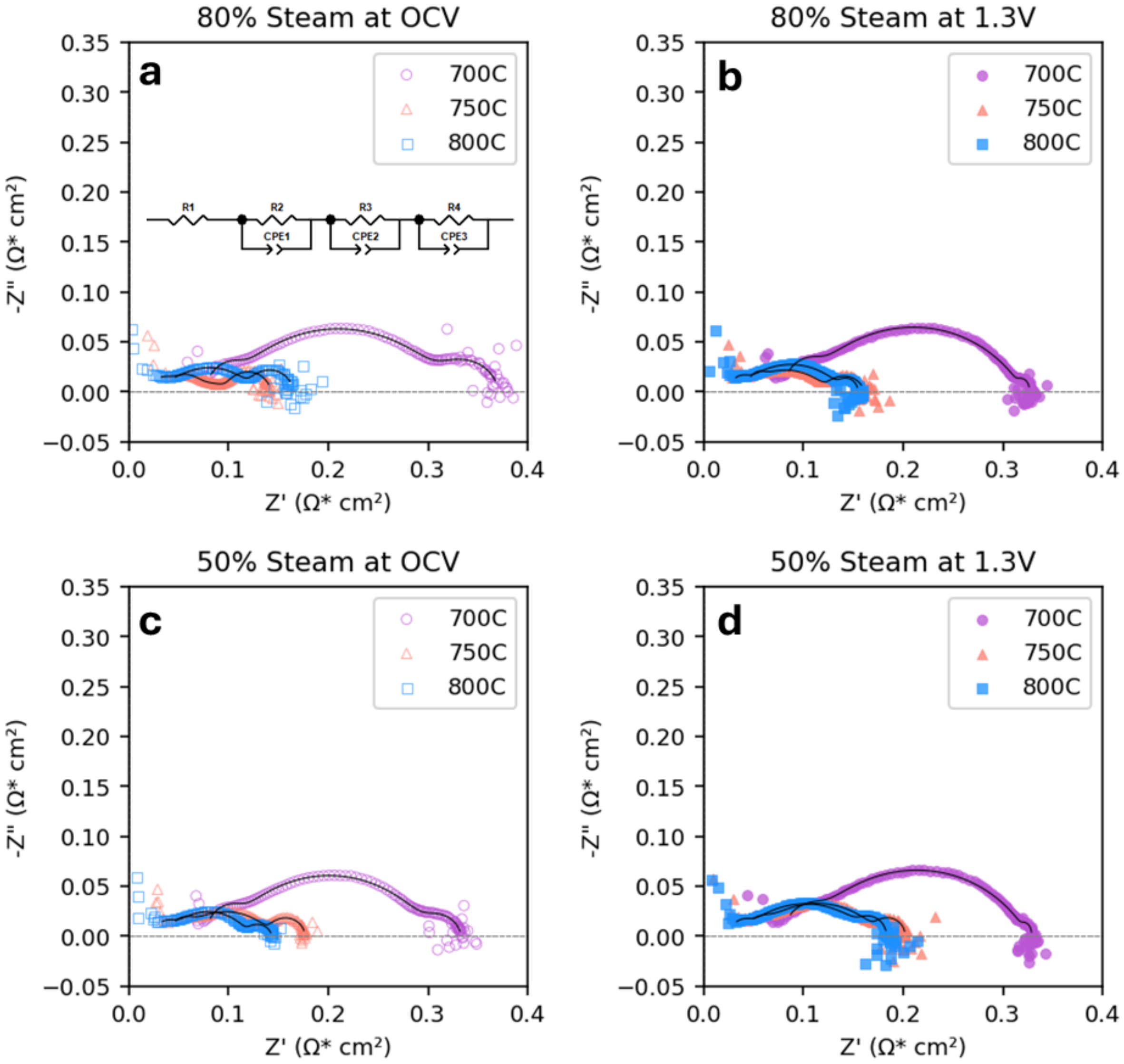

Figure 4. SOEC Nyquist charts for each temperature and condition; a)80% steam at OCV, b) 80% steam biased to 1.3V, c) 50% steam at OCV, and d)580% steam biased to 1.3V.

expected, R1 exhibits clear Arrhenius behavior and is consistent across both gas conditions, supporting its assignment as the ohmic resistance. R2 can be associated with relatively fast charge-transfer processes, such as interfacial transfer at the electrolyte/electrode interfaces. R3 likely encompasses several intermediate processes, including gas adsorption and desorption on the electrodes, surface exchange, and reaction kinetics. Finally, R4 can be associated with the slower process of mass transport through the cell [8].

Separating non-ohmic resistance contributions is challenging because temperature-dependent processes shift relative to one another [9]. For example, the relative magnitudes of R3 and R4 can switch between measurements at 800°C and 750°C. This behavior suggests a transition between kinetically controlled and transport-coupled regimes, where the characteristic timescales of surface exchange and gas transport become similar. More advanced experimental designs or analysis methods, such as a reference electrode or distributed relaxation time (DRT) analysis, are generally needed to resolve these contributions. Even so, the data quality from this test fixture is sufficient for equivalent-circuit fitting and suitable for DRT analysis.

Figure 5 shows the Nyquist plots for the SOFC conditions. OCV data at 750°C with undiluted fuel and at 700°C with diluted fuel were incomplete and were therefore excluded from the analysis. For both fuel conditions, the OCV impedance is substantially higher than the impedance measured at 0.8V, indicating that the equilibrium operating point is highly sensitive to perturbation and becomes strongly stabilized under applied bias [7]. This behavior arises from the lower PO_2 on the fuel side, which creates a steep oxygen chemical potential gradient across the cell and strongly constrains defect chemistry near the air electrode. Although the absolute oxygen-vacancy concentration remains high, the linearized response to small perturbations becomes thermodynamically stiff, leading to higher polarization resistance. As in the SOEC results, the non-ohmic resistance cannot be cleanly separated into distinct physical processes, but it can still be quantified through equivalent-circuit fitting.

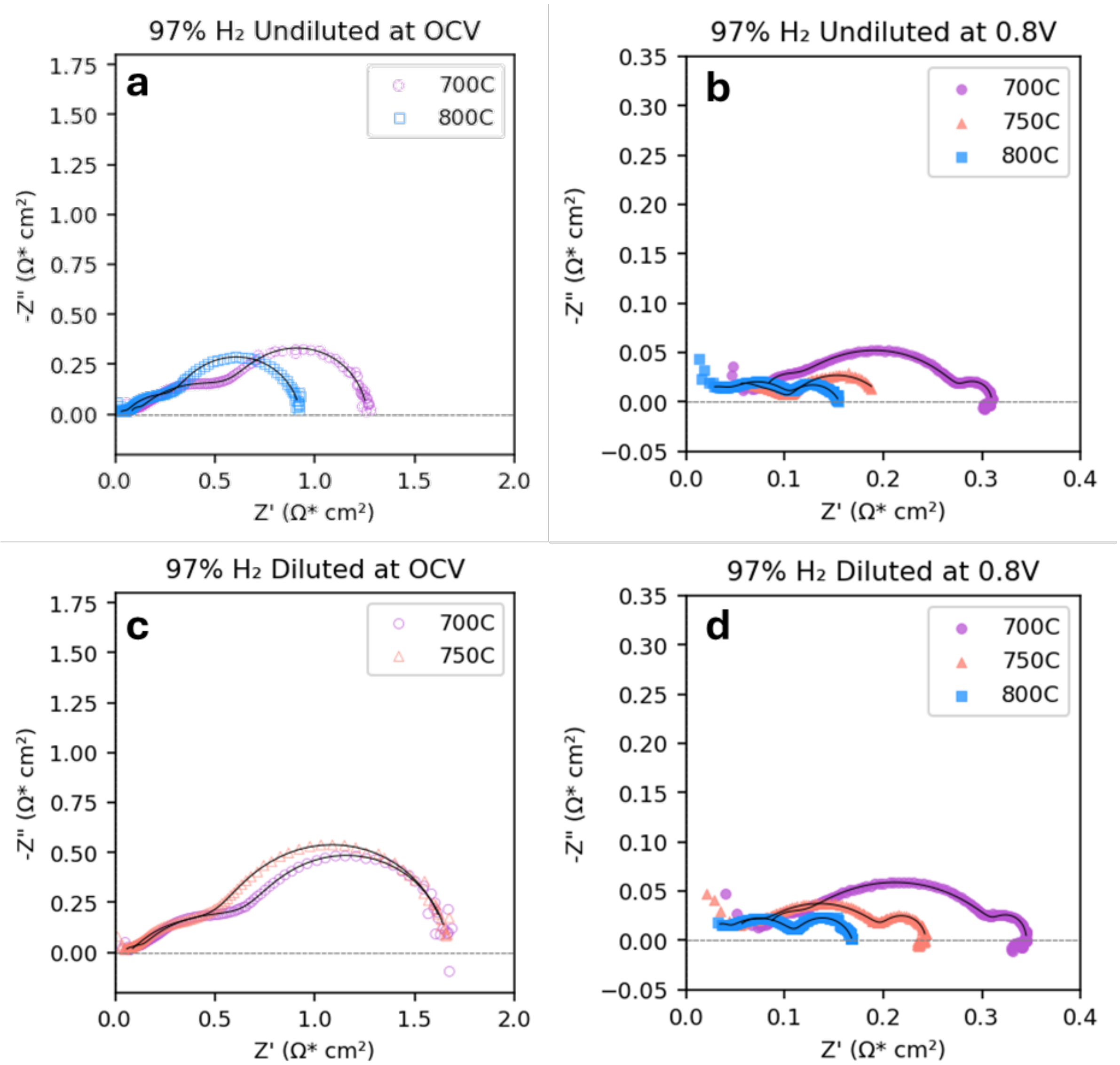

Figure 5. SOFC Nyquist plots for each temperature and each condition. a) Undiluted fuel at OCV, b) undiluted fuel and biased to 0.8V, c) diluted fuel at OCV, and d) undiluted fuel and biased to 0.8V.

Conclusions

A standardized button cell test fixture was demonstrated for electrochemical evaluation of solid oxide cells in both SOFC and SOEC modes. Using a 25 mm anode-supported cell, the fixture provided reliable assembly, robust sealing, and stable electrical contact across a range of temperatures and gas compositions. High open-circuit voltages confirmed effective sealing at both manifolds.

The cell delivered high current densities from 700–800°C in both operating modes, with performance varying predictably with temperature and gas composition. These trends were consistently reflected in both polarization and impedance measurements. Higher steam concentrations improved SOEC performance at elevated temperatures, while fuel dilution in SOFC mode affected polarization behavior and introduced mass-transport limitations.

Impedance analysis likewise showed expected behavior. The data collected with the fixture was of sufficient quality to resolve ohmic and non-ohmic resistance contributions. Deconvolution of non-ohmic processes is challenging with equivalent circuit fitting alone, but that is a limitation of the experimental parameters and not the fixture itself.

Overall, the results demonstrate that the Nexceris button cell fixture enables high-quality performance and impedance measurements without introducing artifacts related to sealing, contact instability, or misalignment.

References

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