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Supporting Information

Nano-film coated cathode functional layer towards the high performance solid oxide fuel cells

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Figure S1. (a) Cross-sectional SEM image of infiltrated GDC CFL cathode and (b) schematics of various electrode structures.

Figure S1(a) shows a cross-section view of the infiltrated GDC CFL cathode composed by two layers, the GDC CFL and SSC current collecting layers with a thickness of ~6 and ~10 μ m, respectively. Together with the SEM image, simple schematics of symmetric cells with Ref-cathode, Ref-CFL, and infiltrated CFL cathodes (Discrete-CFL and Film-CFL) are shown in Figure S1(b).



Figure S2. XRD patterns of (a) GDC, (b) SSC, and (c) SSC infiltrated GDC scaffold.

To observe the desired phase formation of infiltrated SSC in the GDC scaffold, X-ray diffraction (XRD) patterns were conducted, as shown in Figure S2. Figures S2(a–c) represent the XRD patterns of the GDC, SSC, and SSC infiltrated GDC scaffolds, respectively, confirming the successful formation of SSC perovskite phase with infiltration and subsequent sintering at 800 °C for 3 h without secondary phases such as SmCoO₃, SrCoO₂, and CoO₄.



Figure S3. The SEM images of film-CFL with (a) 0.025 M, (b) 0.1 M, (c) 0.2 M, (d) 0.35 M, and discrete-CFL with (e) 0.1 M, (f) 0.3 M, (g) 0.5 M.

The SEM images of film-CFL and discrete-CFL is shown in Figure S3. In SEM images,

film-CFL did not present morphological differences with higher molar concentration in a range of $0.025 \sim 0.35$ M. The TEM images of higher concentration (0.1, 0.35 M) could confirm the film structure as shown in Figure S4. The SSC layer with the concentration of 0.1 and 0.35 M are uniform and conformal with the thickness of ~10 and 34 nm, respectively. Therefore, we concluded the uniform film formation of the SSC layer regardless of the SSC concentration once it formed the film.

For the discrete-CFL, the higher concentration leads to increase of not only the coverage, but also the particle size. Therefore, higher concentration could not enhance the cell performance as shown in main article. There exists compensation between loosing TPBs with larger particle size and increasing TPBs with higher coverage.



Figure S4. TEM images of film-CFL with (a) 0.1 M and (b) 0.35 M.



Figure S5. Coverage calculation process of infiltrated particles by Image J. (a) SEM images in an area of 500×500 nm in Lou et al.^[1] (b) Image processed by Image J.



Figure S6. Comparison of average particle size and surface coverage with references.^[1-4]

A systematic investigation of infiltrated particle features was conducted to verify that the discrete coated feature in this work is in a reasonable range. The infiltrated images from this work and four references were analyzed by image J as shown in Figure S5 and S6. The black and white zones represented the GDC backbone and infiltrated SSC particles, respectively. The calculated average size of the infiltrated particles and the calculated surface coverage onto the scaffolds from four references were 30 ± 5 nm and $17\pm3\%$, respectively. Discrete-CFL at the lowest R_p (0.3 M) shows the surface coverage of 20-21 % with a particle diameter of 36-38 nm, confirming that infiltration in this work was reasonably performed, under an optimum condition.



Figure S7. Cross-sectional SEM image of single cell configuration.

Figure S7 shows the cross-sectional image of a single cell after electrochemical measurements at 650 °C. The anode-supported cell consists of a porous Ni-YSZ anode support (~1 mm), a Ni-YSZ anode functional layer (~10 μ m), a dense YSZ electrolyte (~5 μ m), GDC CFL (~6 μ m), and the SSC current collecting layer (~10 μ m).



Figure S8. The SEM images of film-CFL. Left – before the stability test for 100 hrs, and Right – after the stability test for 100 hrs.

Combining with the EIS results in main article, the SEM images of film-CFL cells before and after the stability test for 100 hrs are shown in Figure S8. There are no observable changes in morphologies, substantiating the structural stability of film-CFL at elevated temperatures.

References

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