

## Supporting Information

# **Bimetallic Nickel/Ruthenium Catalysts Synthesized by Atomic Layer Deposition for Low-Temperature Direct Methanol Solid Oxide Fuel Cells**

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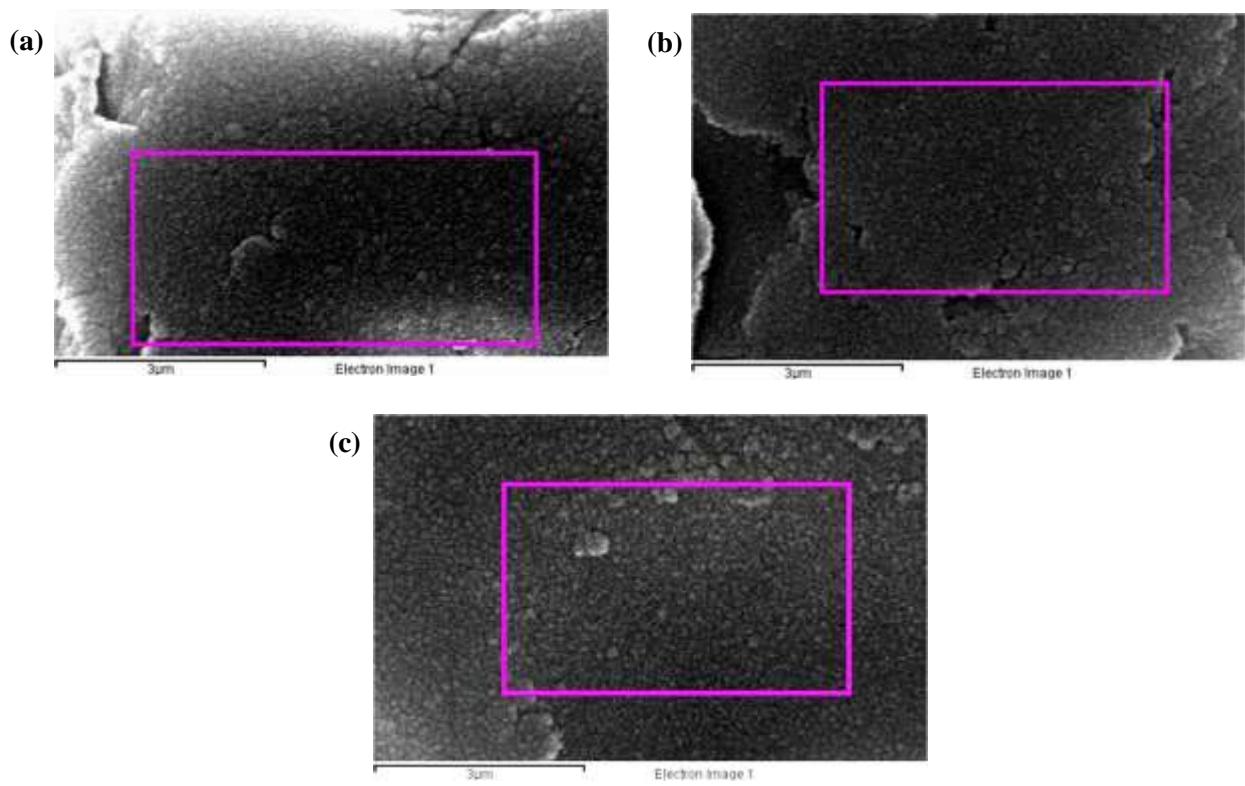
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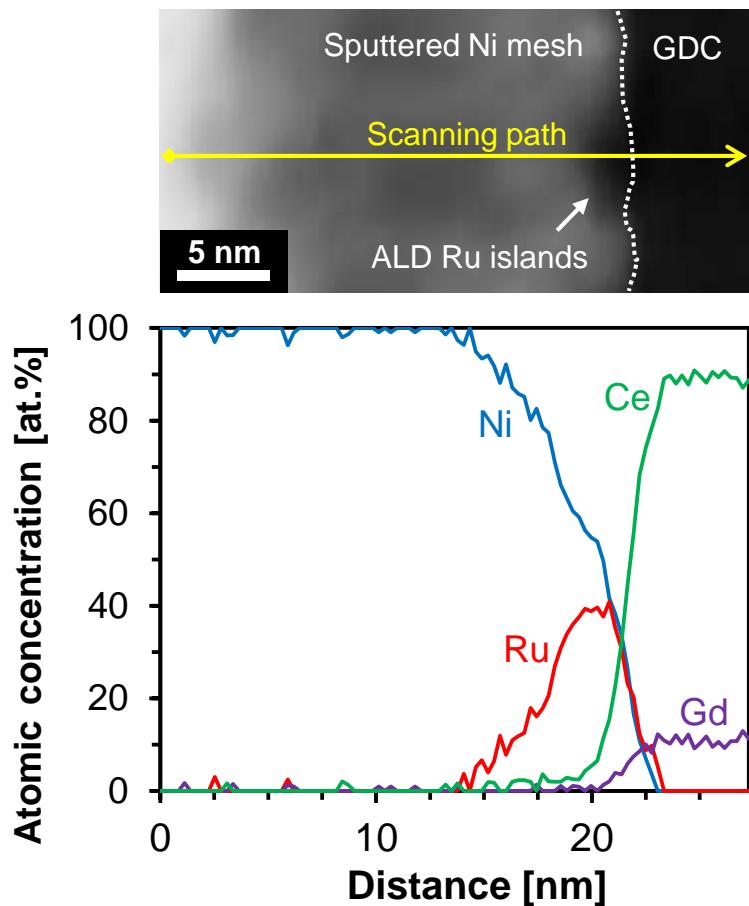
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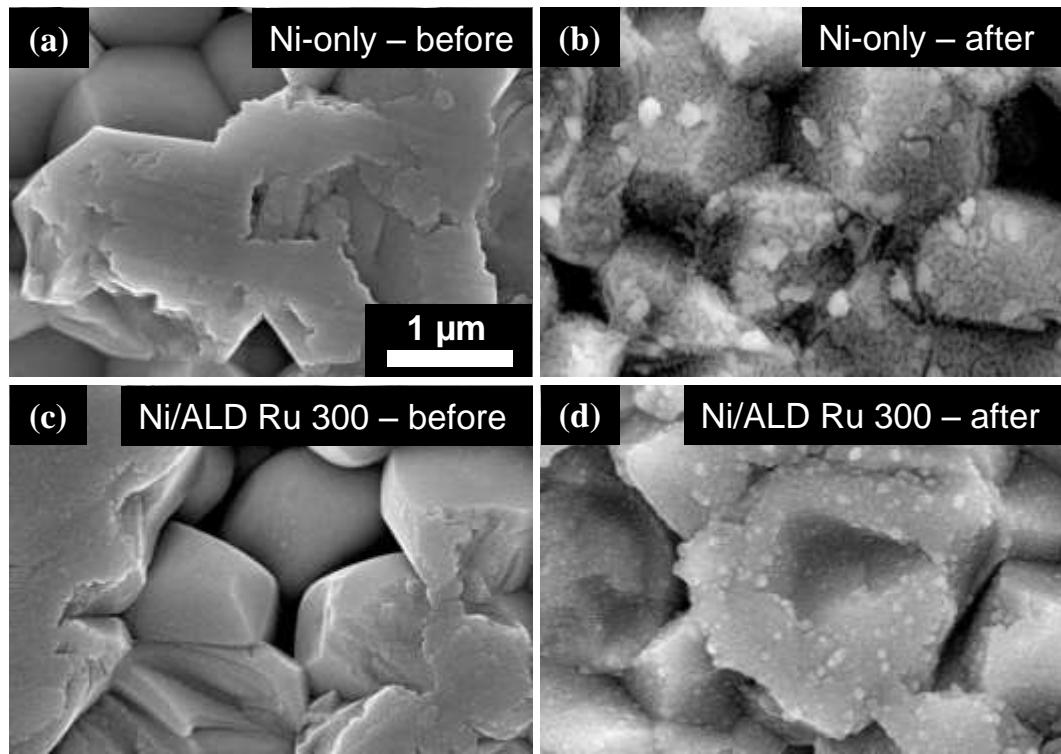
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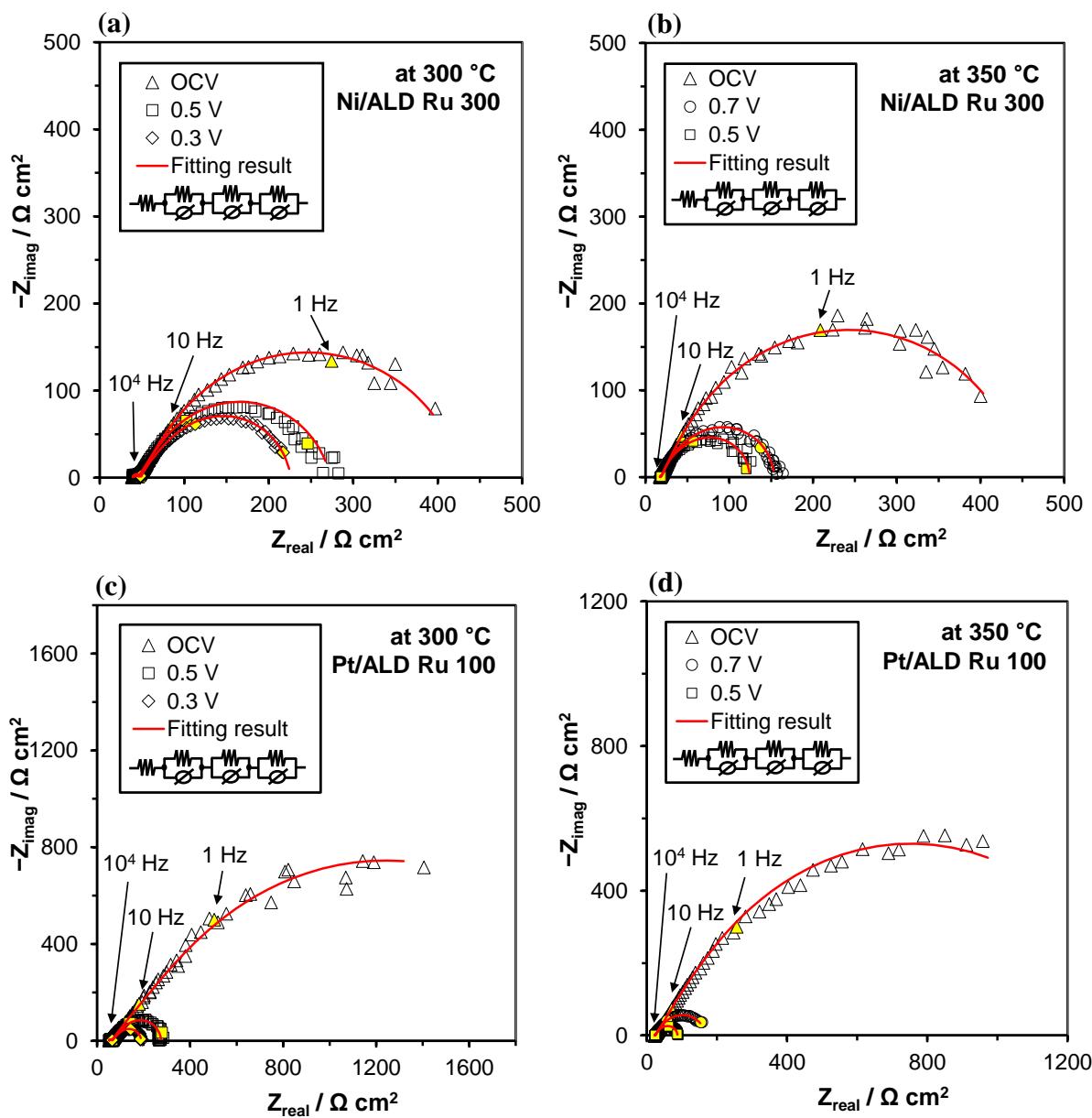
**Figure S1.** SEM surface images of a) Ni/ALD Ru 100, b) Ni/ALD Ru 300, and c) Ni/ALD Ru 500 samples. The purple-lined squares correspond to the areas of EDS composition analyses presented in **Figures 2(a)–(c)** of the main article.



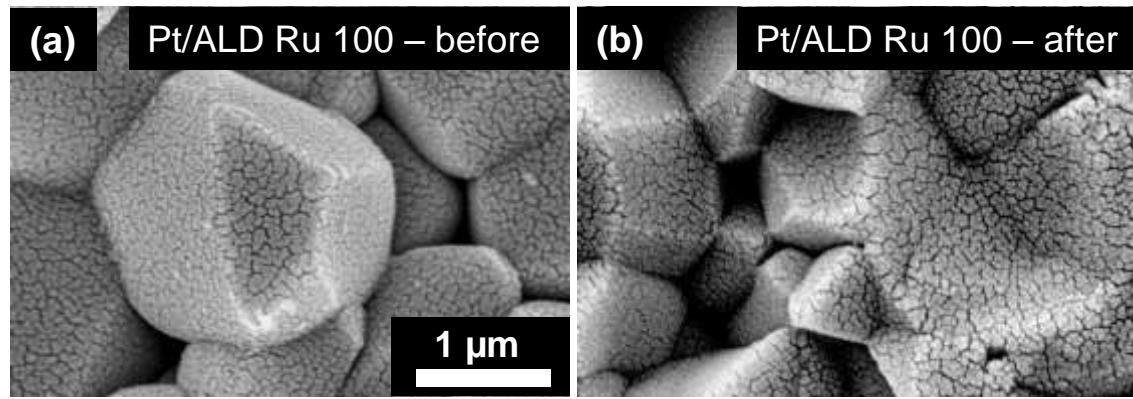
**Figure S2.** Line EDS mapping of Ni and Ru concentrations in the dark-field STEM image of Ni/ALD Ru 300, where the ALD Ru islands are clearly visible along the scanning line.



**Figure S3.** SEM images of a), b) Ni-only and c), d) Ni/ALD Ru 300 samples before and after cell operation, respectively, with pure methanol at 300–350 °C.



**Figure S4.** Nyquist impedance spectra measured at 300 and 350 °C under different cell voltages (OCV, 0.7 V, 0.5 V, and 0.3 V) using pure methanol: a) and b) Ni/ALD Ru 300; c) and d) Pt/ALD Ru 100 samples. Reproduced with permission.<sup>1</sup> Copyright 2015, American Chemical Society.



**Figure S5.** SEM images of Pt/ALD Ru 100 sample a) before and b) after cell operation with pure methanol at 300–350 °C. Reproduced with permission.<sup>1</sup> Copyright 2015, American Chemical Society.

**Table S1.** Comparison of measured and reference lattice spacings of ALD Ru, and the resulting calculated error.<sup>2</sup>

Plane	Measured Ru	Reference Ru	Error / %
	<i>d</i> -spacing / Å	<i>d</i> -spacing / Å	
(100)	2.3–2.4	2.333	1.5–2.8
(002)	2.1–2.2	2.146	2.2–2.5

**Table S2.** Ohmic and polarization ASRs of the Ni/ALD Ru 300 sample at different cell voltages of OCV, 0.7 V, 0.5 V, and 0.3 V, at 300 and 350 °C.

Temperature (°C)	OCV		0.7 V		0.5 V		0.3 V	
	Ohmic ASR (Ω cm <sup>2</sup> )	Polarization ASR (Ω cm <sup>2</sup> )	Ohmic ASR (Ω cm <sup>2</sup> )	Polarization ASR (Ω cm <sup>2</sup> )	Ohmic ASR (Ω cm <sup>2</sup> )	Polarization ASR (Ω cm <sup>2</sup> )	Ohmic ASR (Ω cm <sup>2</sup> )	Polarization ASR (Ω cm <sup>2</sup> )
300	44.13	388.60	-	-	45.80	227.45	48.25	178.36
350	17.07	439.78	17.26	136.82	17.26	107.49	-	-

**Table S3.** Ohmic and polarization ASRs of the Pt/ALD Ru 100 sample at different cell voltages of OCV, 0.7 V, 0.5 V, and 0.3 V, at 300 and 350 °C. Reproduced with permission.<sup>1</sup> Copyright 2015, American Chemical Society.

Temperature (°C)	OCV		0.7 V		0.5 V		0.3 V	
	Ohmic ASR (Ω cm <sup>2</sup> )	Polarization ASR (Ω cm <sup>2</sup> )	Ohmic ASR (Ω cm <sup>2</sup> )	Polarization ASR (Ω cm <sup>2</sup> )	Ohmic ASR (Ω cm <sup>2</sup> )	Polarization ASR (Ω cm <sup>2</sup> )	Ohmic ASR (Ω cm <sup>2</sup> )	Polarization ASR (Ω cm <sup>2</sup> )
300	62.65	2225.16	-	-	64.74	211.30	64.20	126.44
350	21.88	1387.22	21.92	147.89	21.99	65.71	-	-

## References

- (1) Jeong, H. J.; Kim, J. W.; Bae, K.; Jung, H.; Shim, J. H. Platinum-Ruthenium Heterogeneous Catalytic Anodes Prepared by Atomic Layer Deposition for Use in Direct Methanol Solid Oxide Fuel Cells. *ACS Catal.* **2015**, *5*, 1914–1921.
- (2) Wang, H.; Gordon, R. G.; Alvis, R.; Ulfig, R. M. Atomic Layer Deposition of Ruthenium Thin Films from an Amidinate Precursor. *Chem. Vap. Deposition* **2009**, *15*, 312–319.