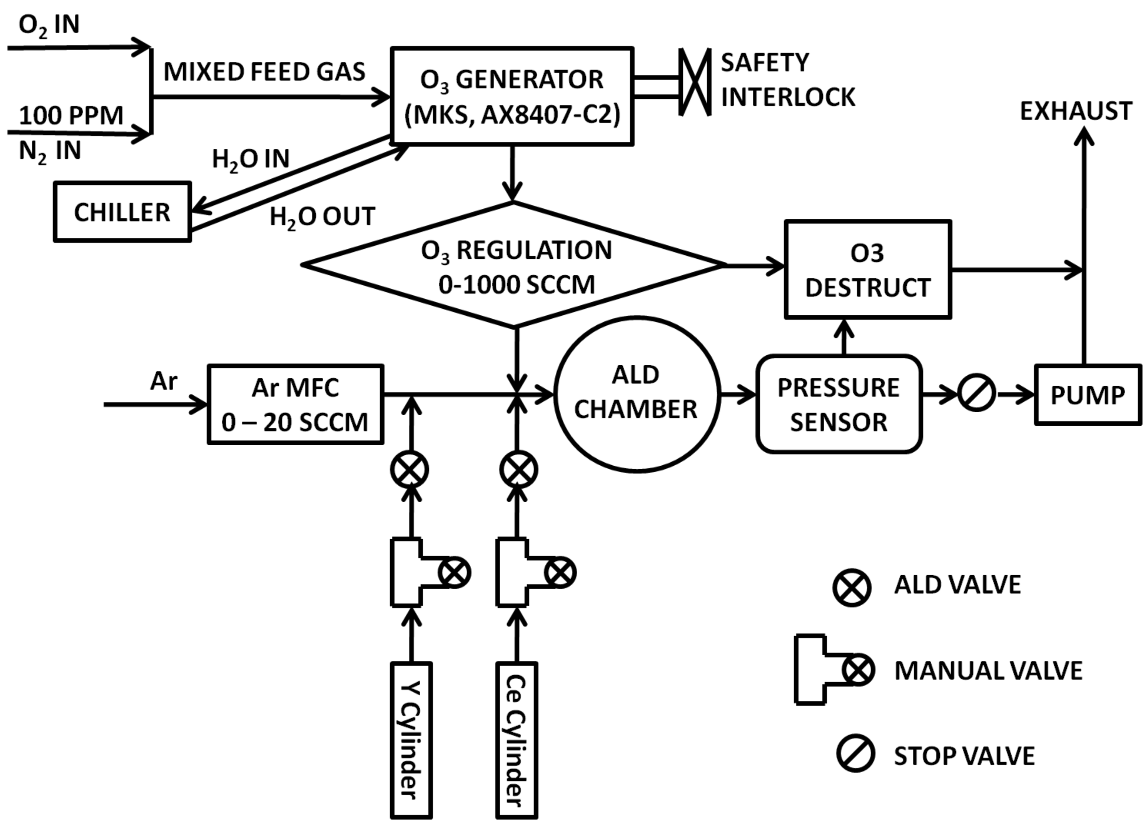
Electronic Supplementary Material (ESI) for Journal of Materials Chemistry

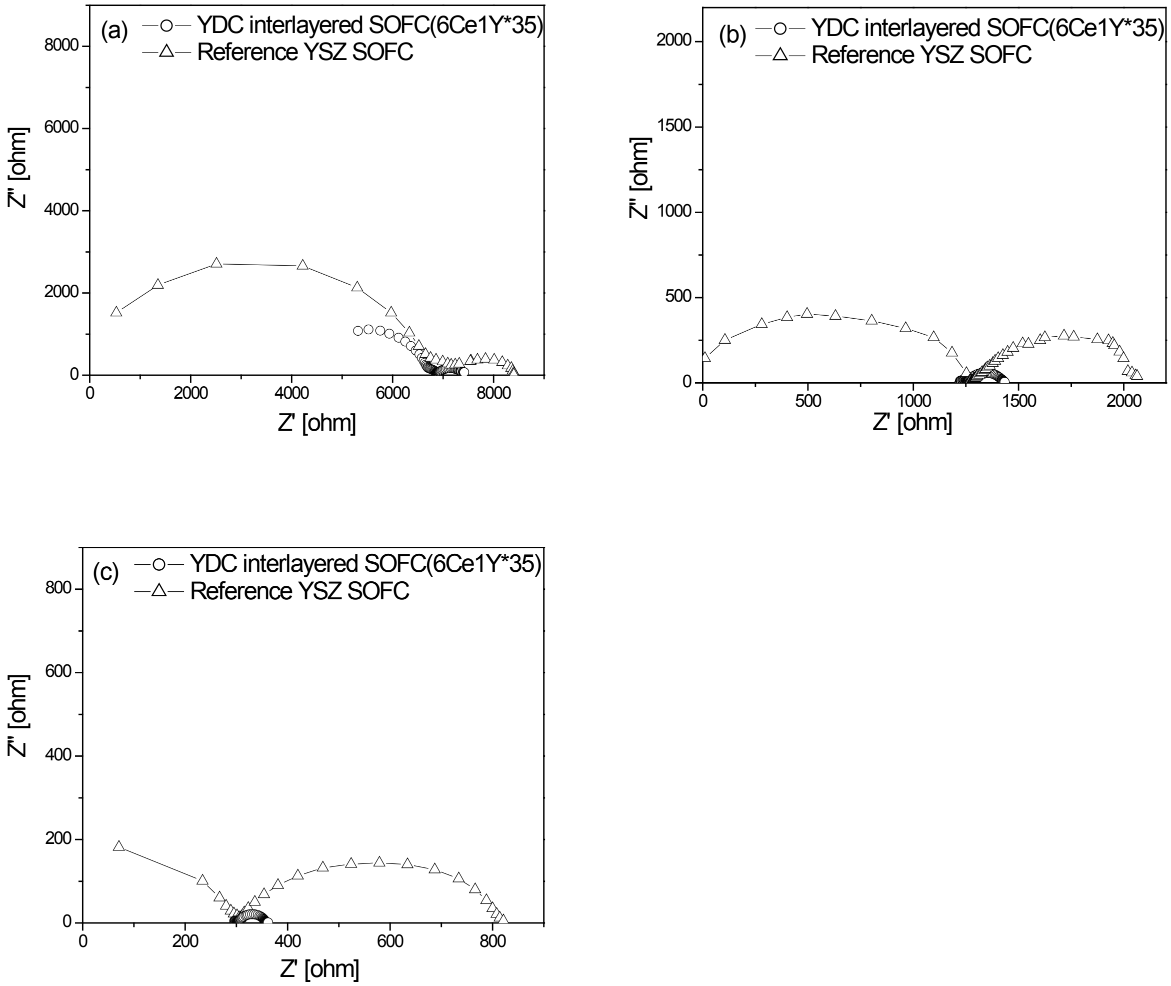
Supplementary Information

Fan, Z.; Chao, C. C.; Hossein-Babaei, F.; Prinz, F. B. "Improving Solid Oxide Fuel Cells with Yttria-Doped Ceria Interlayers by Atomic Layer Deposition"



Supplementary Figure 1. Schematic drawing of the customized ALD - O_3 system with brief explanation.

Ozone generator from MKS (model number AX8407-C2) was used to generate ozone for the ALD experiments. O_2 (99.9999%) with 100 ppm N_2 (99.999) was used as mixed feed gas for the O_3 generator. The produced O_3 could be precisely adjusted between 0 – 1000 sccm after it went through the flow regulation system. Yttria and ceria precursors were attached to the manifold, as shown above. Argon, used as purge gas, was connected to a mass flow controller before it flew into the chamber. Stop valve was critical for exposure mode deposition, which could enhance the possibility of full chemical reactions inside the ALD chamber. Safety interlock was installed onto the O_3 generator in case of an ozone leakage, and O_3 destruct unit was integrated into the system to remove excessive O_3 from the exhaust. The whole ALD – O_3 station was designed and tested to be ozone compatible as well as satisfy the lab safety standards.



Supplementary Figure 2. Impedance spectra for YDC interlayered sample (YDC recipe: 6Ce1Y*35) and YSZ reference sample (no YDC interlayering). (a) 300 ^{o}C, (b) 350 ^{o}C, (c) 400 ^{o}C.

Fuel cells with the YDC interlayer of the recipe 6Ce1Y*35 have the biggest performance enhancement. Here, we chose the EIS spectra of fuel cells with YDC interlayer for this condition as the contrast. Supplementary Figure 2 shows the comparison of EIS spectra of the YDC interlayered (6Ce1Y*35) and YSZ reference fuel cells at 300 ^{o}C, 350 ^{o}C and 400 ^{o}C. While the 2nd loop representing the electrode /electrolyte interfacial resistance shrank significantly, the 1st loop representing the electrolyte resistance remained almost the same. Therefore, the added YDC layers were "thin enough" to avoid any significant increase of the electrolyte resistance, while effectively reducing the electrode /electrolyte interfacial resistance.

Note: The above EIS spectra and more detailed discussions are presented in another paper which is accepted by Nano Letters.

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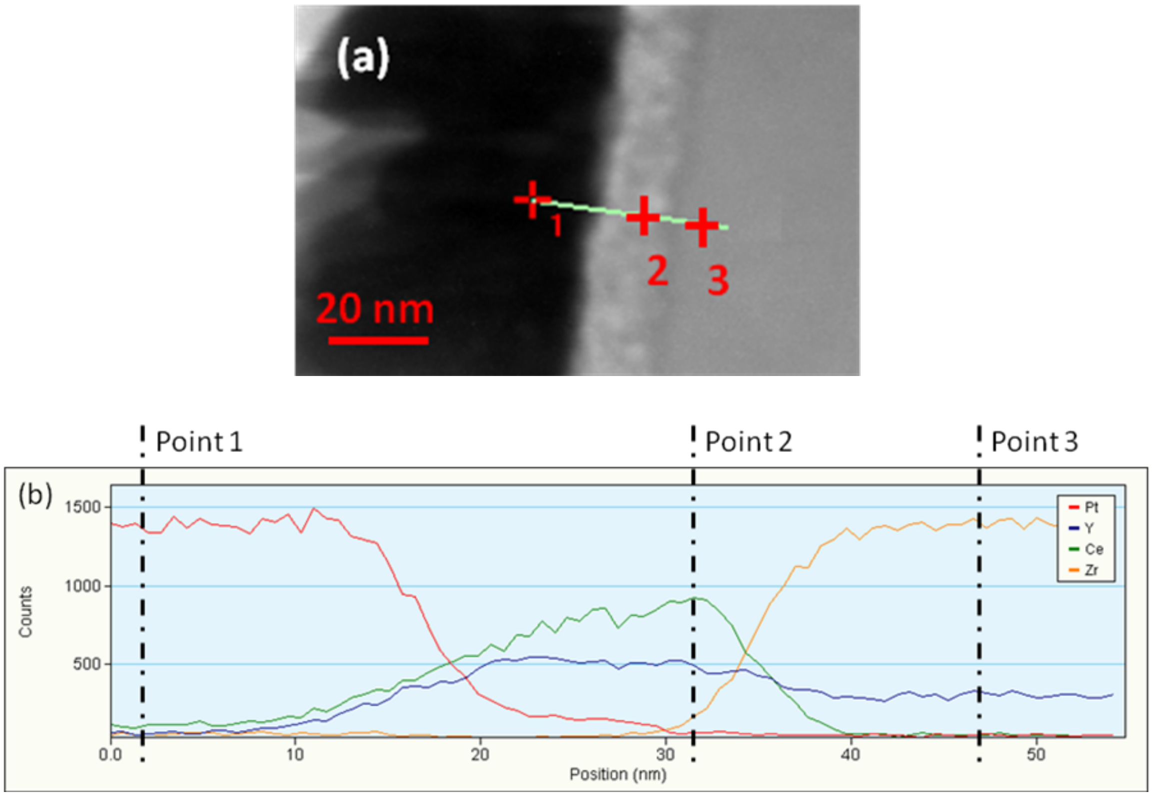

(c)

Point 1:	Point 2:	Point 3:
O(K): 3% (± 0.13%)	O(K): 53% (± 0.58%)	O (K): 63% (± 0.90%)
Y(K): 0 (± 100%)	Y(K): 16% (± 1.48%)	Y(K): 4% (± 0.78%)
Zr(K): 0 (± 100%)	Zr(K): 3% (± 0.62%)	Zr(K): 33% (± 2.01%)
Ce(L): 0 (± 100%)	Ce(L): 26 % (± 1.55%)	Ce (L): 0 (± 100%)
Pt (L): 97% (± 2.34%)	Pt(L): 2% (± 0.80%)	Pt (L): 0 (± 100%)

Supplementary Figure 3. EDS line scanning results across the Pt – YDC and YDC – YSZ interfaces.(a) Spectrum profile scanning area, with indications of scanned line and points; (b) EDS line scanning profile with respect to Pt, Y, Zr and Ce elements; (c) The respective concentrations for the above 4 elements at point 1, 2 and 3.

Energy Dispersive Spectroscopy (EDS) line scanning was performed to yield more boundary information. EDS spectra were obtained along a line of 54 nm in length covering both the YSZ/YDC and the YDC/Pt layers' interfaces. Supplementary Figure 3 shows the compositional distribution of the elements Y, Zr, Ce, and Pt along the measured profile. STEM-EDS analysis parameters (e.g., gun lens current, beam spot size, pixel size, analysis area, and pixel dwelling time) were selected so EDS elemental profiles with a 1. 5 ~ 2 nm resolution would be obtained. Eight second dwelling times were used per pixel for collecting the EDS spectra along the profile, which were used for constructing the compositional profile based on each element's Kα or Lα peak filtered from the spectra.

EDS usually yields a 5 - 10 % uncertainty regarding the compositional profile, and its uncertainty has an almost inverse relationship with the content of the given element. The accuracy of EDS is influenced by a variety of factors: Each element's probability of being excited by the incoming electron, its probability of emitting an X-ray, and the overlapping peaks from different elements.