A Platinum Nanowire Network as Highly Efficient Current Collector for Intermediate Temperature Solid Oxide Fuel Cells

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†Electronic Supplementary Information (ESI)

1. Experimental Section

Charaterizations of platinum coated carbon black: The initial combustion temperature, the weight loss regime and exothermic behavior of the commercial platinum loaded carbon black powders (Alfa Aesar) were examined using thermo-gravimetric analysis (TGA, NETZSCH STA) in air between room temperature and 1030 °C with a heating rate of 10 °C min^{-1}. The micro-morphology and microstructure of the carbon black supported platinum powders, button cells, and current collectors were observed using transmission electron microscope (TEM, Hitachi H-8000) and field-emission scanning electron microscope (FESEM, Zeiss ultra plus), respectively.

Preparation and polarization measurement of symmetric cells: The citrate and ethylenediaminetetraacetic acid (EDTA) combustion method was used to synthesize the $PrBaCo_2O_{5+\delta}$ (PBCO) cathode and $Sm_{0.2}Ce_{0.8}O_{1.9}$ (SDC) electrolyte powders. The details were described in the separate paper.[10] The SDC pellets formed by the dry-pressing method were sintered at 1400 °C for 5 h to form dense SDC electrolyte with the thickness of 240 μm and the diameter of 12 mm. The pellets were then polished with sand paper. The fine PBCO powders were mixed thoroughly with a 6 wt% ethylcellulose-terpineol binder to form the slurry. The slurry was painted on both sides of the SDC pellets, which were subsequently sintered at 1000 °C in air for 3 h.The platinum coated carbon black powders were dispersed into the ethanol solvent, which was then ultrasonically vibrated for 2 h to form the well-dispersed ink. The platinum coated carbon black ink was sprayed on the cathode surface with an ejecting gun to form symmetric cells. The ink load was controlled by the spraying time. The electrochemical impedance spectra (EIS) in air at different temperatures were measured using a Solatron 1260 frequency response analyzer in combination with a Solartron 1287 potentiostat over the frequency range from 0.01 Hz to 10^5 Hz.

Fuel cell fabrication and test: The anode-supported anode-electrolyte assembly was prepared by a simple dry-pressing/co-firing method. The powder mixture of NiO + SDC + starch (60%:40%:20% in weight) was first pre-pressed at 200 MPa as an anodesubstrate. Then the loose SDC powder was uniformly distributed onto the anode substrate, co-pressed at 250 MPa and sintered subsequently at 1350 °C for 5 h to densify the SDC membrane (~ 8 μm).The cathode slurry was then painted on SDC electrolyte film and sintered at 950 °C for 3 h in air to form the single cell of NiO-SDC/SDC/PBCO. The corresponding thicknesses of the resulting anode/electrolyte/cathode assembly are ~760 μm/~8 μm/~20 μm respectively. The platinum coated carbon black ink was sprayed on the cathode surface as the current collector. As a comparison, the conventional current collector was also prepared by painting the Pt paste on the cathode surface and sintered at 1000°C for 1 hour to burn out the organic solvent. Further the two most widely used perovskite cathode materials $Ba_{0.5}Sr_{0.5}Co_{0.2}Fe_{0.8}O_{3-\delta}$ (BSCF) and $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$ (LSCF) were also employed to fabricate the anode-supported cells NiO-SDC/SDC/BSCF and NiO-SDC/SDC/LSCF. The platinum nanowire current collectors and conventional Pt paste collectors were also applied for the cells respectively. The button cells were tested under the temperatures of 500-650 °C. The humid hydrogen (~3% H_2O) was used as the fuel while the static air was used as the oxidant. The flow rate of the fuel was controlled at 30 ml min^{-1} using a precision flow meter (APEX). The current-voltage curves were recorded by Scribner 890ZV at the scanning rate of 30 mV s^{-1} and the EIS were measured in open-circuit condition over the frequency range of 0.01 Hz to 10^5 Hz.

2. Results

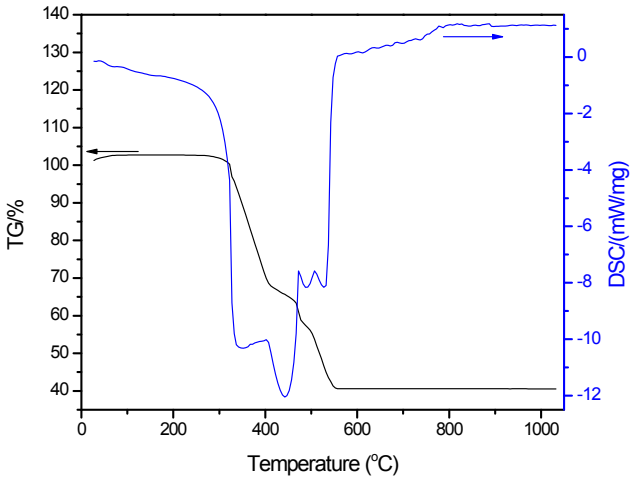

Figure S1: The TGA and DSC curves of platinum coated carbon black powders from room temperature to 1030 °C with heating rate of 10 °C min^{-1}.

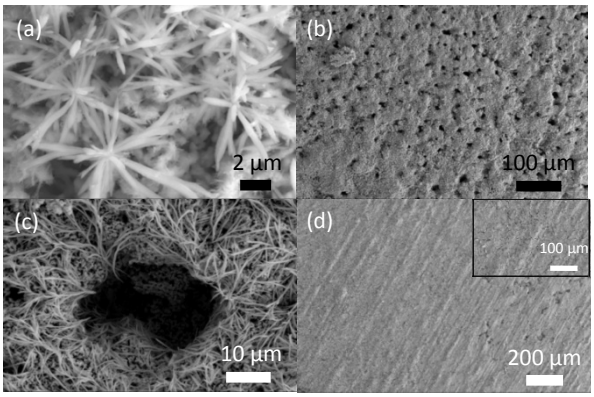

***Figure S2*:** Morphology of current collector surface: (a) Tree-branch like platinum nanowire network covered on the cathode surface; (b) The open pores uniformly distributed on the cathode surface with the platinum nanowire network current collector; (c) The cathode surface with platinumnano-wire network reaching the internal surface of open pores; (d) The cathode surface view of conventional platinum current collector fabricated by painting the Pt paste (the magnified FESEM is inserted).

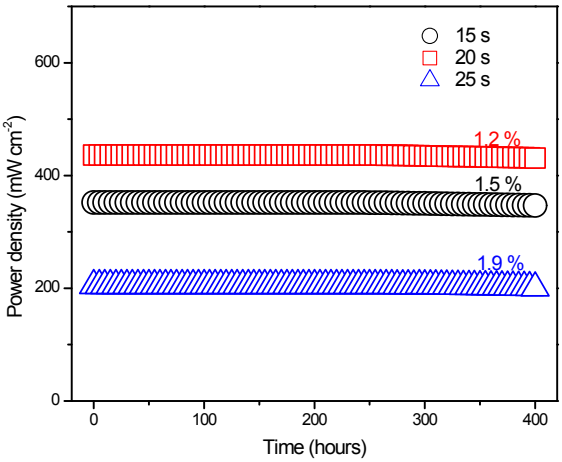

***Figure S4*:** The long-term stability of the button cell Ni-SDC/SDC/PBCO with different loadings of platinum nanowire network as the cathode current collectors at 600 °C for 400 h.

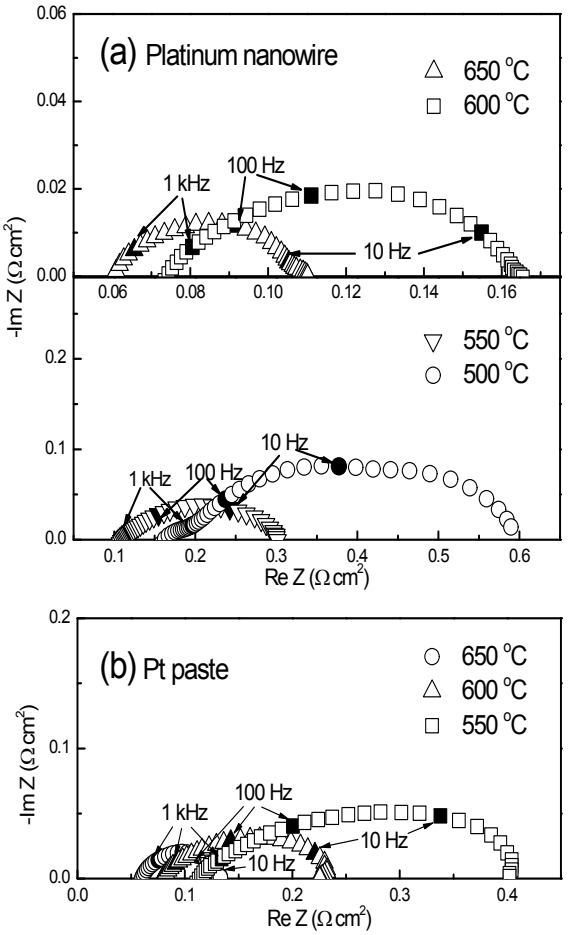

***Figure S3*:** Impedance spectra measured under open-circuit conditions with different current collectors: (a) platinum nanowire network; (b) conventional Pt paste.

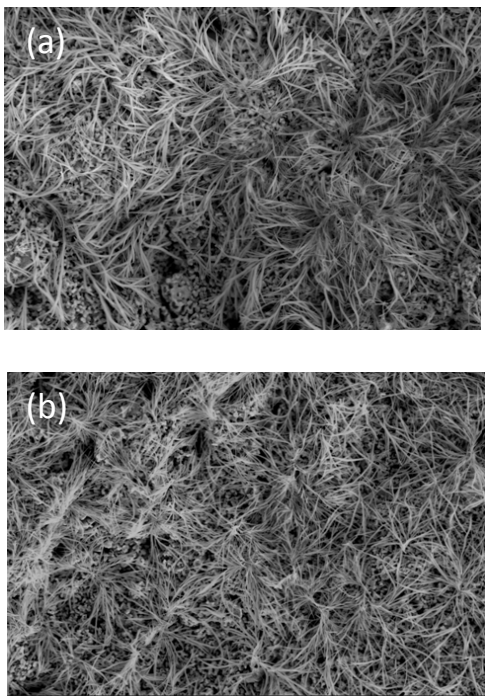

***Figure S5*:** The surface morphology of platinum nanowire network current collector in post-test cells: (a) 100 h; (b) 400 h.