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Biogas to Syngas: flexible on-cell micro reformer and NiSn bimetallic nanoparticles implanted solid oxide fuel cells for efficient energy conversion

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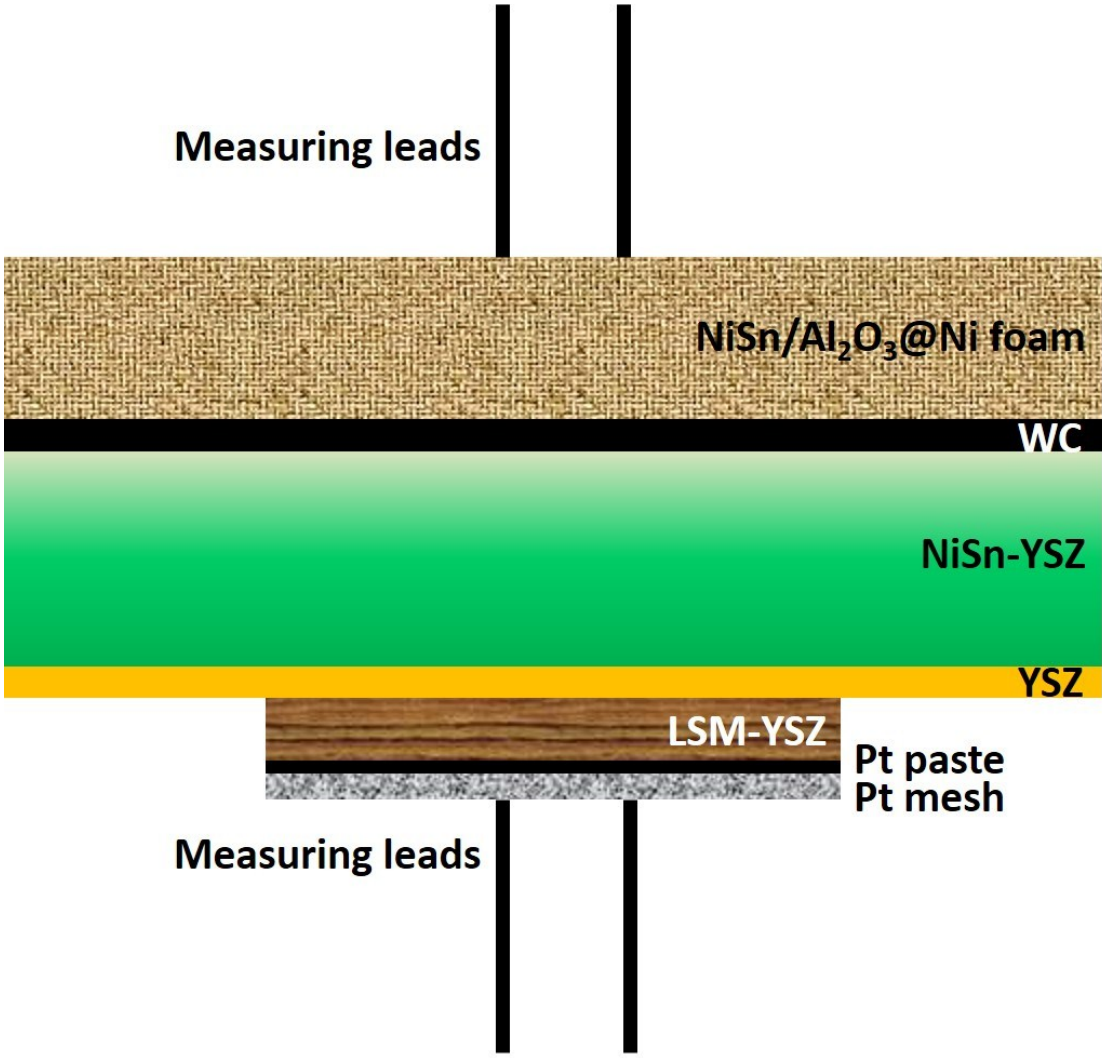
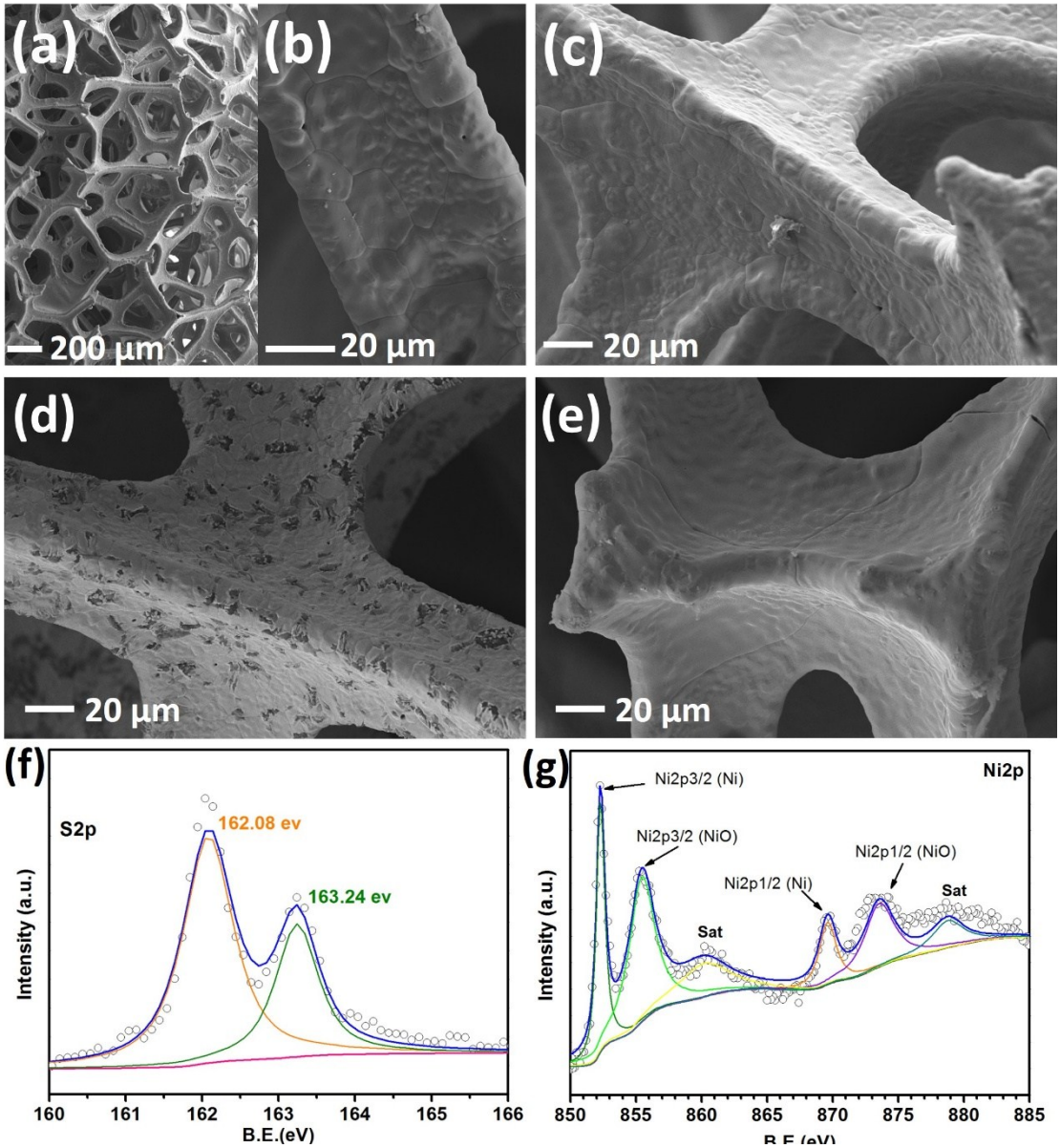
Scheme S1



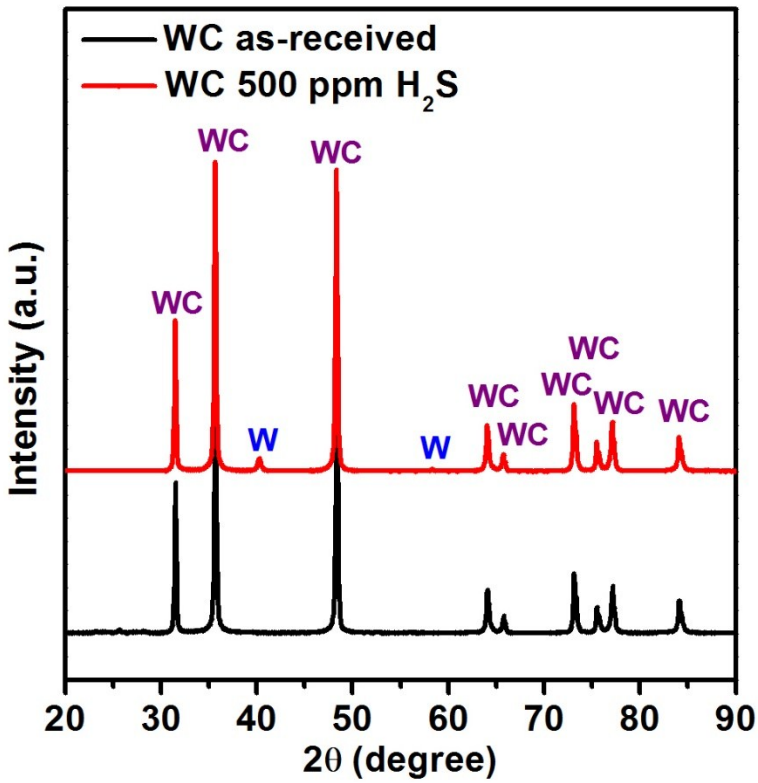
Schematically showing the profiles of the biogas reactor.

Figure S1



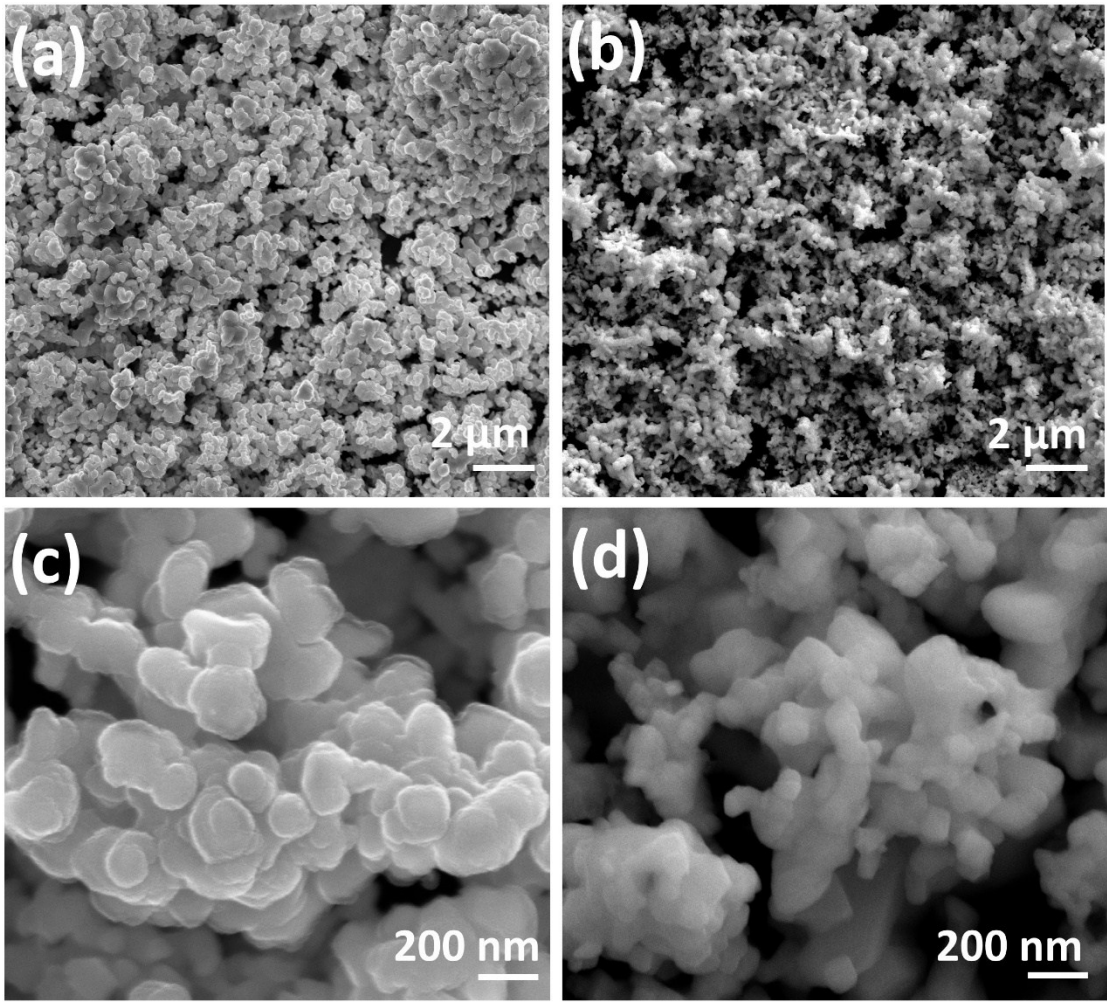
(a) and (b) as received Ni foam; (c) Ni foam treated in H_2-500 ppm H_2S at 850 °C for 5h, showing no visible physical change; (d) Ni foam treated in CH_4-CO_2 at 850 °C for 5h, and damage was observed on the Ni surface; (e) Ni foam treated in H_2-500 ppm H_2S at 850 °C for 5h, and then treated in CH_4-CO_2-200 ppm H_2S at 850 °C for 24h, showing that the carbon deposition resistance of the Ni foam was enhanced via contaminating in H_2S; (f) and (g) XPS spectrum of the (e): (f) Sulfur species were detected on the Ni foam, which should be responsible for the enhanced carbon deposition resistance; (g) No Ni-S compounds were observed.

Figure S2



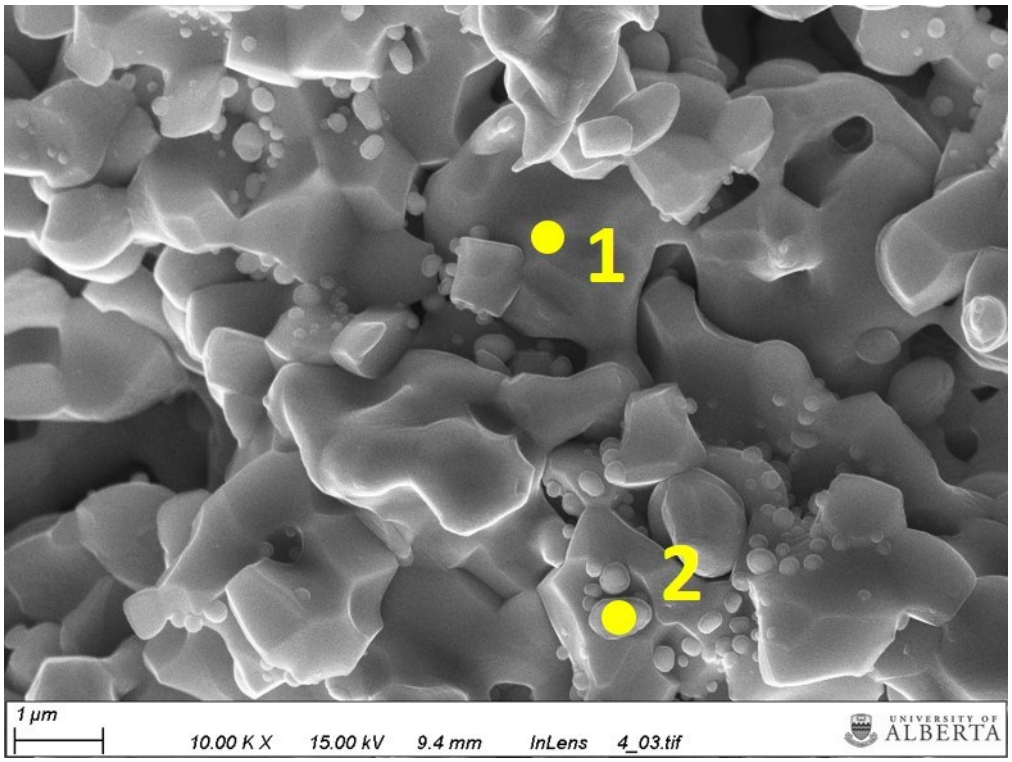
WC before and after contaminated in H_2-500 ppm H_2S (850 °C 24 h). It is seen that no S-containing species have been detected in the WC sample (e.g., absorbed S and W-S compounds), but a small part of WC was reduced to metallic W.

Figure S3



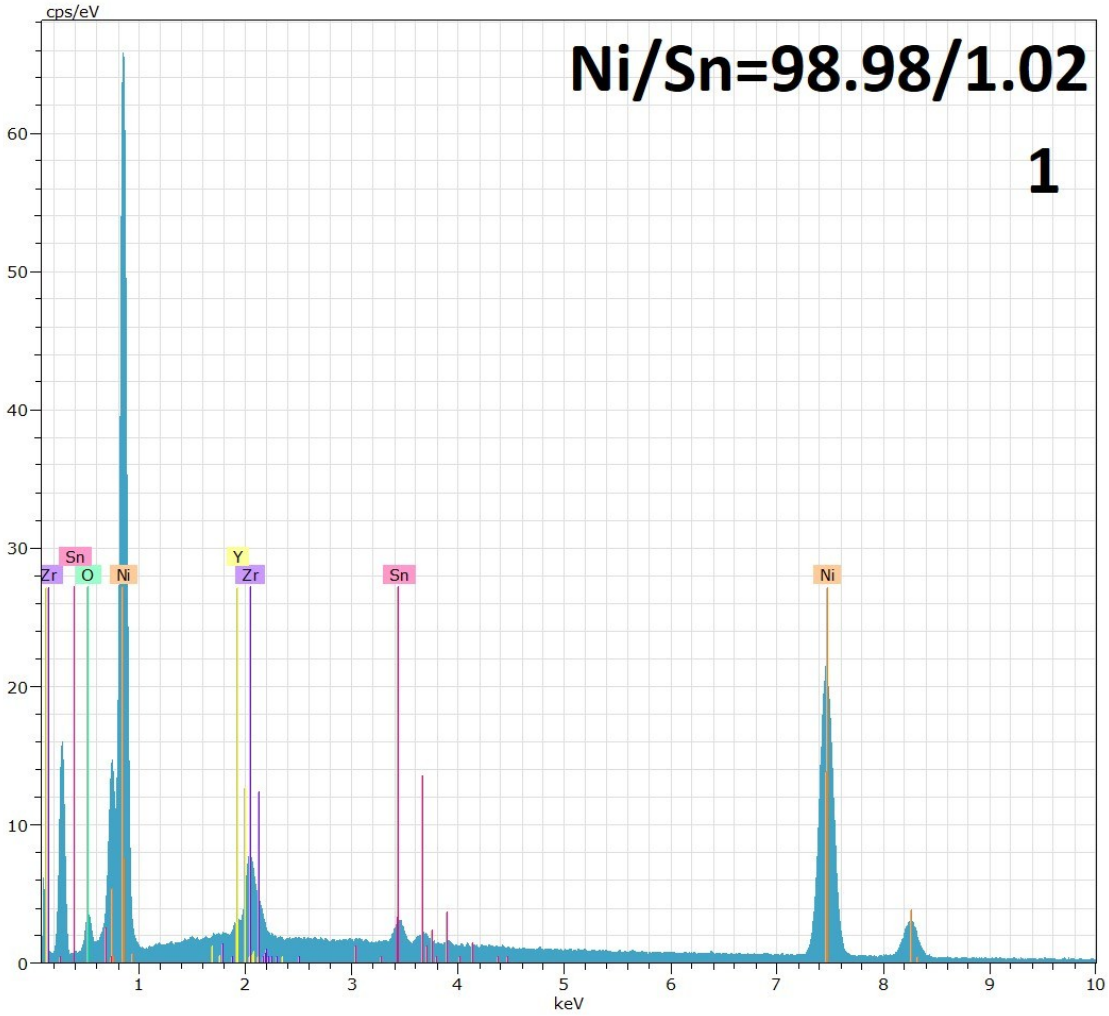
WC before (a and c) and after (b and d) contaminated in H_2-500 ppm H_2S. No agglomeration was absorbed, which ensures a good durability of the WC current collector.

Figure S4-1



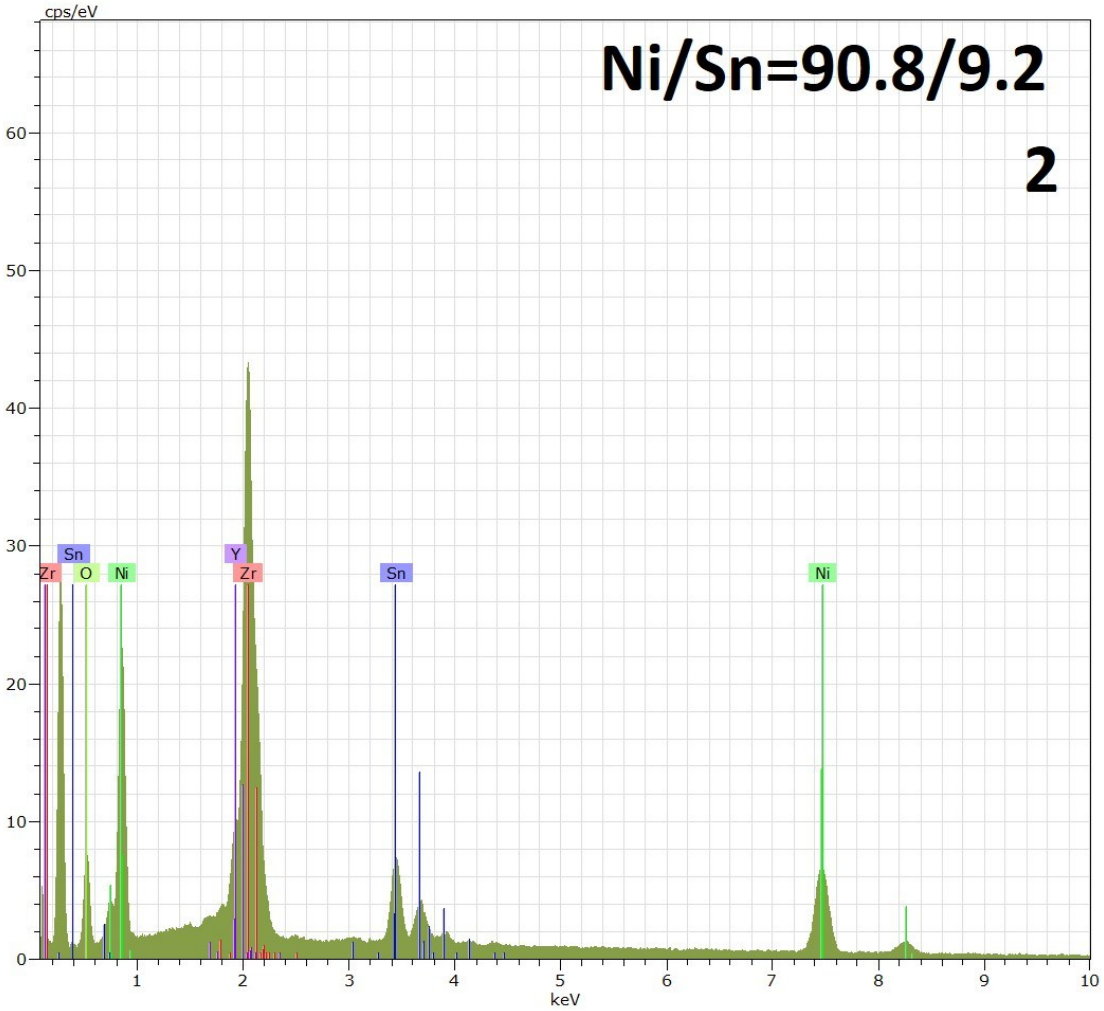
Cross-sectional microstructure of the NiSn-YSZ anode, showing the NiSn nanoparticles and the regions (spots 1 and 2) for EDX analysis.

Figure S4-2



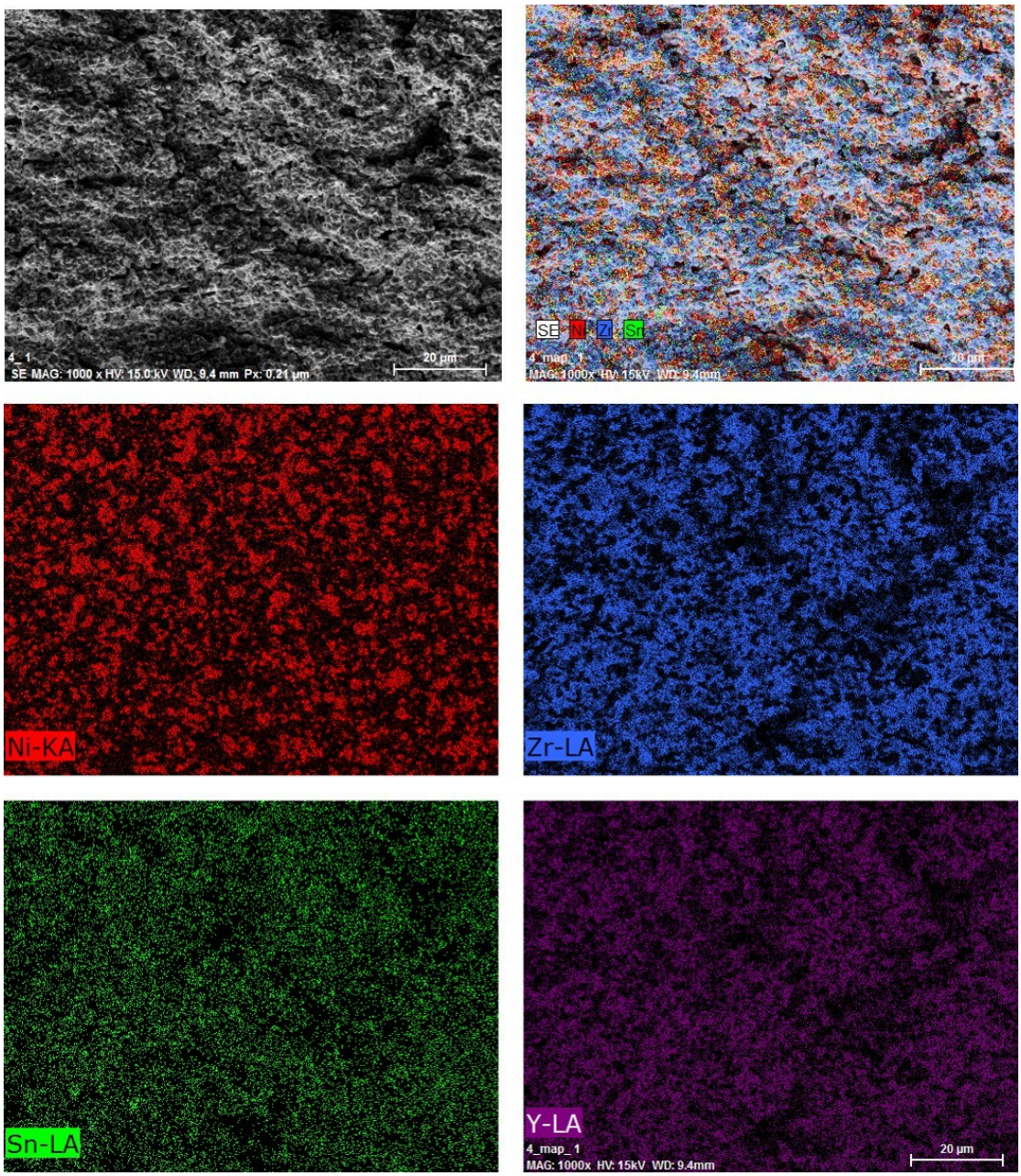
It is shown that the surface of the bulk Ni (spot 1) is alloyed with Sn.

Figure S4-3



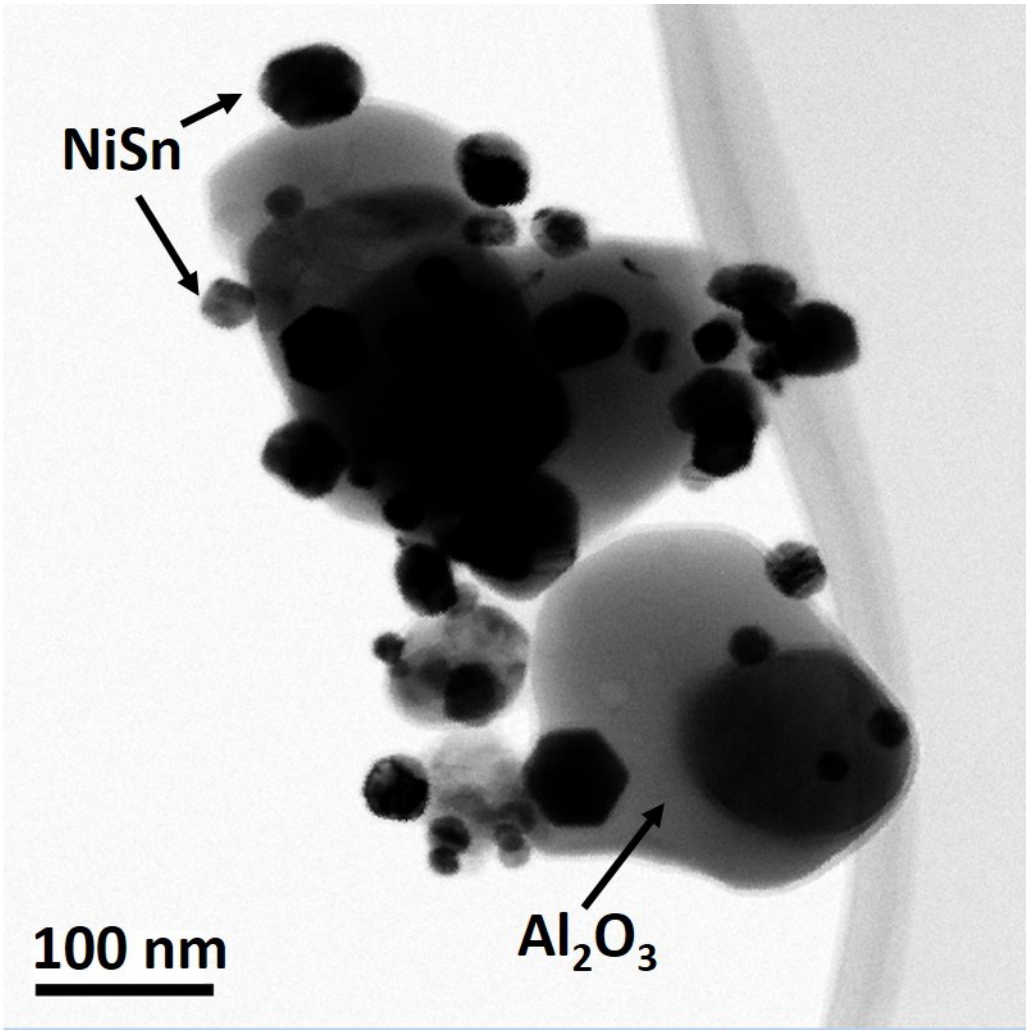
The composition of the infiltrated nanoparticles is close to that of Ni/Sn=9/1 (spot 2).

Figure S5



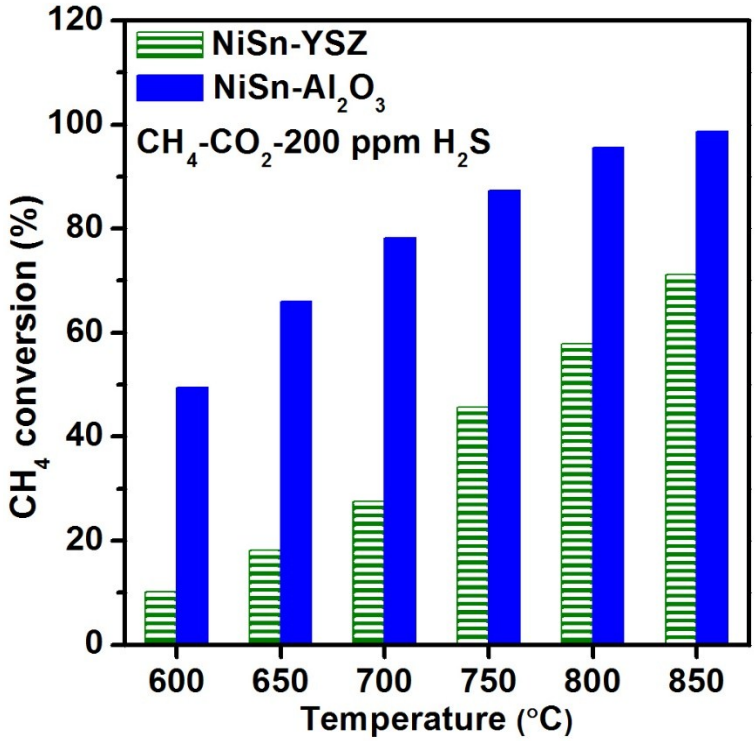
EDX mapping shows the Sn element was well distributed.

Figure S6



The NiSn nanoparticles are well distributed over the Al_2O_3 supports after treated in CH_4-CO_2-200 ppm H_2S at 850 °C for 24 h, no surface absorbed S and C contaminations were detected.

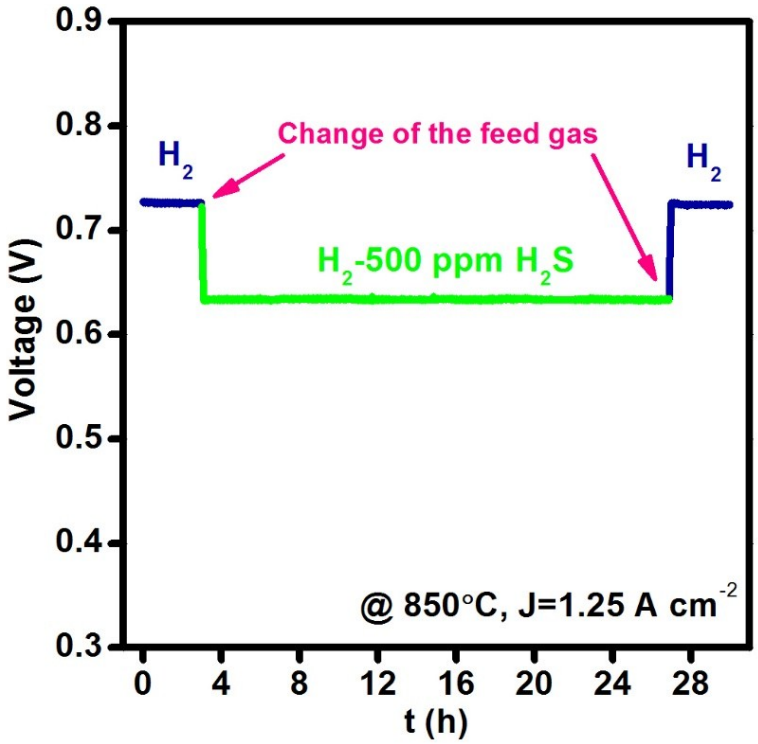
Figure S7



The catalytic activities of NiSn-YSZ [Ni-YSZ (57-43) is pre-sintered at 1390 ºC, and then is infiltrated with NiSn bimetallic NPs] and NiSn-Al_2O_3 were compared. Catalytic activity measurements for dry reforming of biogas reaction were performed at atmospheric pressure using a compound of 0.2 g catalysts and 0.4 g catalytically inactive quartz powder, which was sieved to the particle sizes ranging from 30 to 60 mesh and packed on a bed of quartz tube. The gas mixtures of CH_4-CO_2 were fed into the reactor at the flow rate of 20 ml min^{-1} (gas hourly space velocity at ~2000 h^{-1}). Compositional analysis of the effluent gases was performed with a gas chromatography (GC, Hewlett Packard Series two). The catalytic reactions took place at the temperatures ranging from 700 to 800 ºC. The percentages of CH_4 conversion were calculated according to:

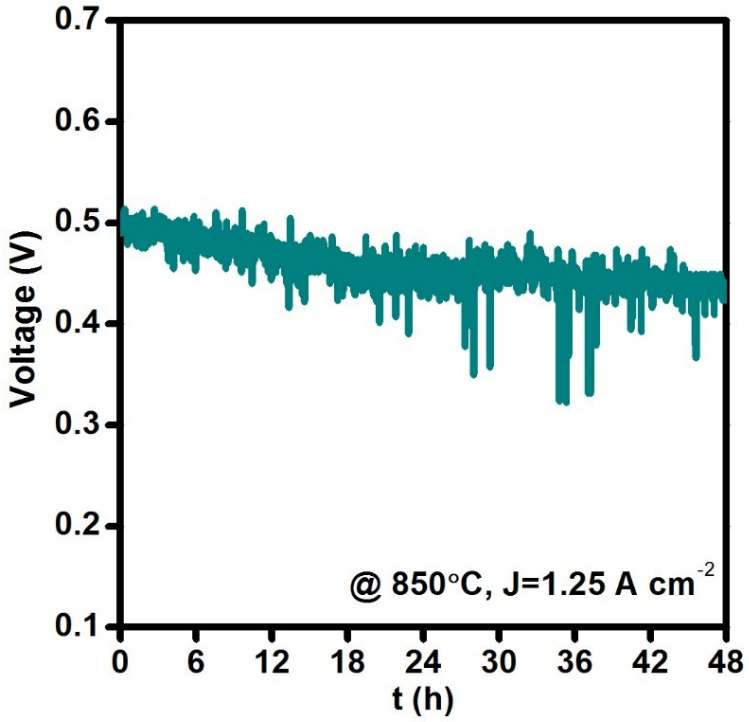
$$CH_4\ conversion = \frac{1/2[CO]}{1/2[CO] + [CH_4]} \times 100\%$$

Figure S8



Voltages as a function of time for the NiSn-YSZ anode which operated in H_2 and H_2-500 ppm H_2S at a constant current density of 1250 mA cm^{-2} and 850 °C, showing the H_2S poisoning on the NiSn-YSZ anode is reversible.

Figure S9



Voltage as a function of time during dry reforming of biogas in a single cell with Ni-YSZ anode under 1.25 A cm^{-2} and at 850 °C. The feeding stream during the long term test is equal amount of CH_4 and CO_2 balanced with 200 ppm H_2S in a total flow rate of 20 ml min^{-1}.