Solid oxide fuel cell produces electricity directly from chemical reactions between a fuel and an oxidant with high efficiency, fuel flexibility and low emissions. Ni/yttria stabilized zirconia (Ni/YSZ) cermet is now the main anode material for commercial products. Ni/YSZ interface and Ni/YSZ/pore triple-phase boundary (TPB) play important roles in SOFC. For specially designed boundaries, the crystallographic orientation relationship between Ni and YSZ has been investigated by transmission electron microscopy (TEM), and scanning TEM (STEM). The orientation relationships are found to be easy and contact surfaces are low index, such as Ni[1-10]/YSZ[1-10], Ni(111)/YSZ(111) and Ni[1-10]/YSZ[001], Ni(111)/YSZ(100). For conventional cells, little is known on the orientation relationship, which is quite important for the performance. In this study, we used a conventional Ni/YSZ anode of a button cell and focused on the TEM and STEM investigations at the boundaries.

Ni/YSZ cell was prepared by conventional screen-printing/sintering/reduction procedures. The TEM specimen was lifted out in a focused ion beam & scanning electron microscopy (FIB-SEM, FEI Quanta 200i 3D). An advanced mill machine (Fischione NanoMill 1040) was used for the post-FIB processing to remove damage layers. Microstructure observations were done using two machines: JEOL JEM3200FSK and ARM200F. Elementary mappings were used to identify the phases. High resolution TEM (HRTEM) and atomic resolution STEM images were taken at different Ni/YSZ interfaces or TPBs.

As an example, Fig. 1 shows the diffraction patterns of YSZ(a), Ni(b) and interface(c), respectively. Fig. 2a is the bright-field image of region of interest while Fig. 2b shows the elemental mapping of Ni. These two images agree well with each other and the boundary of Ni and YSZ is at the center line. The STEM image in Fig. 2c shows the boundary clearly. By evaluating Fig. 1 and Fig. 2c, the facets like (111) and (113) of YSZ could be indexed easily. Meanwhile, Ni is very close to [-112] direction. Its lattices could also be indexed with the help of IFFT (Inverse Fast Fourier Transform). The orientation relationship is Ni[-112]~//YSZ[1-10], Ni(220)~//YSZ(113), Ni(311)//YSZ(111). Step contact surfaces were expected. The misfit between three layers of Ni(1-11) and two layers of YSZ(-1-11) is only 2.8% while it is 3.2% between three layers of Ni(311) and one layer of YSZ(111). So Ni and YSZ match well.

Other cases will be presented. Compared with specially designed boundaries, the orientation relationship between Ni and YSZ in a conventional cell was found to be much more complicated. Misorientation could be frequently found.

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Fig. 1: Diffraction patterns of YSZ (a), Ni (b) and interface (c) along YSZ zone axis.

Fig. 2: Ni/YSZ boundary: left is Ni and right is YSZ. (a) bright-field (BF) image; (b) elemental mapping of Ni; (c) atomic resolution STEM image, inset is the IFFT image of Ni.