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TEM Study of Cu–Ni Core–Shell Nanowires

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Recently, one-pot synthesis of high quality Cu–Ni core–shell nanowires (NWs) with a tunable Ni-shell thickness has been achieved [1-2]. The Cu–Ni NWs with a 10 nm thick Ni shell exhibit the optimal conductivity and oxidation resistance. Its oxidation onset temperature is increased to 270 °C [2]. These Cu-Ni core-shell nanowires may be used to replace expensive Ag nanowires and indium tin oxide (ITO).

Transmission electron microscopy (TEM) techniques, such as selected area electron diffraction (SAED), bright-field (BF) and dark-filed (DF) TEM imaging, high-resolution TEM, STEM, EELS and EDS, have been used to characterize these core-shell nanowires. Here some results are reported, showing how to examine the nanowires using conventional TEM techniques.

Fig. 1 shows the SAED pattern and TEM micrographs of a typical Ni-Cu core-shell nanowire. The SAED pattern (Fig. 1a) indicates that the nanowire contains a single crystal Cu-Ni structure. Cu and Ni crystals have a cubic to cubic orientation relationship, indicating an epitaxial growth of Ni on Cu. Because of the same crystal structure, same orientation, and small lattice parameter difference, the diffraction spots of 200 from Cu and Ni crystals are close to each other, forming elongated spots. The two sets of SEAD patterns are not completely separated till 400 reflections which are enlarged in the inset of Fig. 1a. Fig. 1b is a BF image showing the morphology of the NW. Fig. 1c is a DF image using 400 spots of both Cu and Ni, showing the whole core-shell structure. Ni crystal is revealed in the DF image (Fig. 1d) taken with an objective aperture containing 400 of Ni (red circle showed in the inset of Fig. 1a). Cu core is displayed in the DF image (Fig. 1e) recorded using an objective aperture containing 400 of Cu (orange circle showed in the inset of Fig. 1a). Because NiO-related 400 spot is inside the orange circle, so Fig. 1e also shows NiO, a thin layer outside Ni shell. This NiO layer (Fig. 1f) could be seen more clearly when the objective aperture was moved slightly towards to the direct electron beam (yellow circle showed in the inset of Fig. 1a). NiO related diffraction spots can be revealed using a longer exposure time.

We also observed twins in the Cu core and twin-like relationship between Cu and Ni. The images below show the twins in the Cu core. Fig. 2a is the SEAD pattern of the twins from a nanowire (Fig. 2b). Using the apertures centered at the red and yellow circles (Fig. 2a), we can reveal the twins in different orientations (Fig. 2c and d) separately.

In conclusion, conventional TEM techniques can still play an important role in materials characterization when advanced TEM techniques are available.

References:

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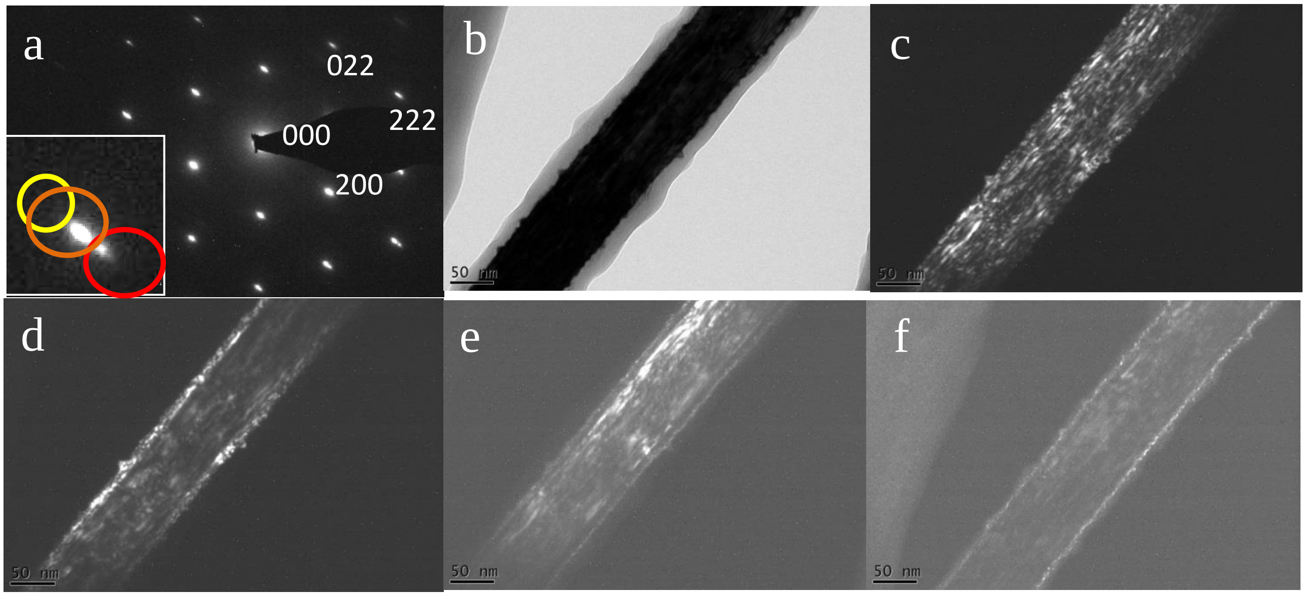

Figure 1. a) SAED pattern and b-f) TEM micrographs of a typical Ni-Cu core-shell nanowire, showing the Ni shell (d) covered with NiO thin layer (e), and the Cu core (f).

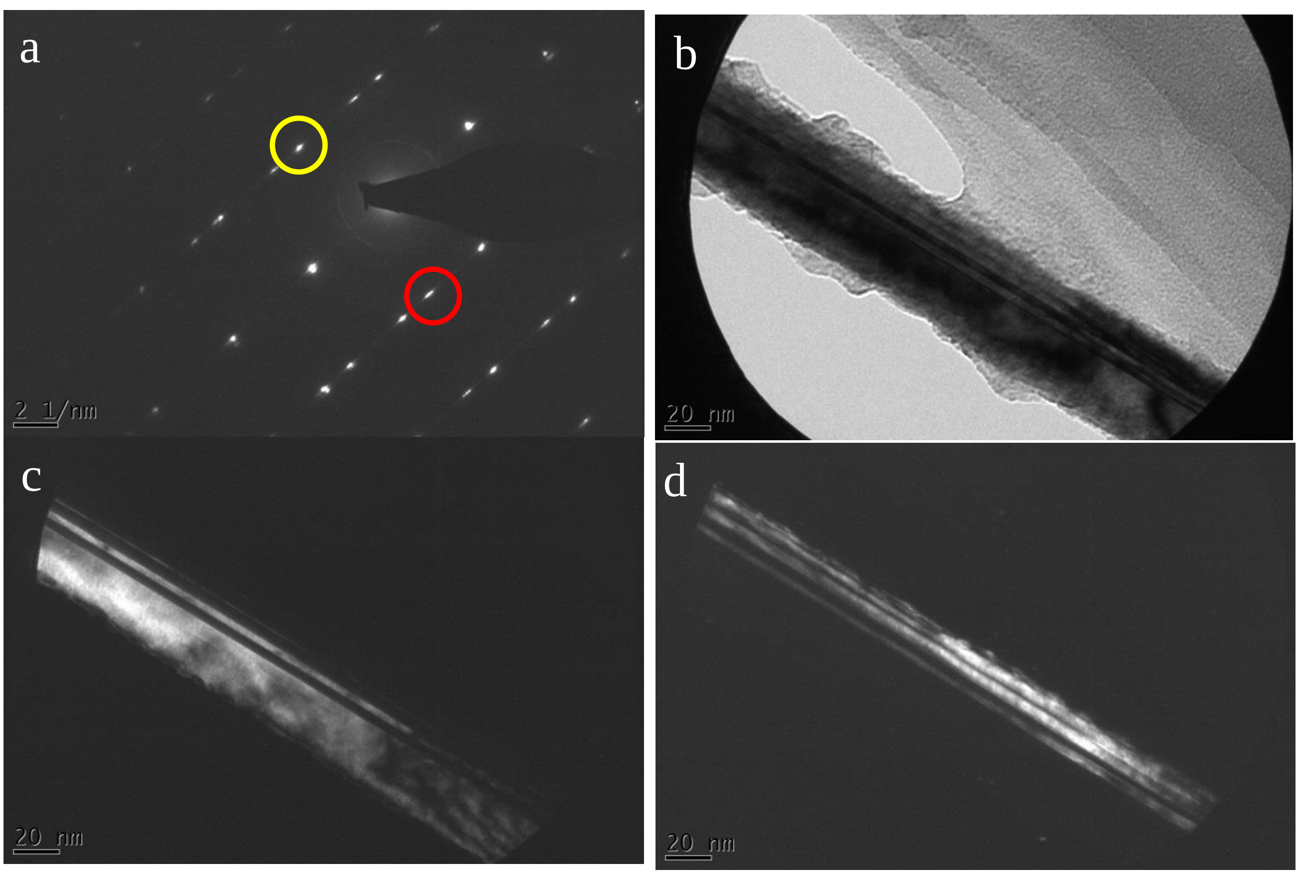

Figure 2. a) SAED pattern and b-d) TEM micrographs of a Ni-Cu core-shell nanowire containing with twinned core. b) morphology of the nanowire, c) twin in one orientation d) twin in another orientation

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