Examination of Distortions in Cu/Nb Multilayers

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Metallic multilayers have a variety of unique functional and structural properties such as giant magneto-resistance, ultrahigh hardness and new combinations of conductivity/strength. Such new properties depend on the multilayer spacing Λ, nature of the interface structures and perfection of the lattices. On the other hand, as the Λ is decreased, non-equilibrium phases or distorted phases can form in the multilayers or lattices become imperfect. The interfaces may serve as the nucleation sites of dislocations and for formation of both stable and metastable phases with distorted structures, etc., which control the properties of the multilayers. Many drawn or rolled micro- or nano-composites respond to external load in a similar manner to metallic multilayers fabricated by deposition methods. A typical example is the Cu-Nb composite used for high strength conductors [1]. This report summarizes some of our understanding of the multilayers that can be used as a model for high strength high conductivity materials.

In both nano-composites and multilayers made of Cu and Nb, the strength increases with increase of the Λ. However, the crystallographic orientation relationships are found to be the same for the multilayers with different Λs.:

The dominant relationship observed is Kurdjumov-Sachs

$$(111)_{fcc\ Cu}//(110)_{bcc\ Nb} \quad \text{and} \quad [0\bar{1}1]_{fcc\ Cu}//[1\bar{1}1]_{bcc\ Nb}$$

In addition, regions exhibiting the Nishiyama-Wasserman orientation relationship are also found:

$$(111)_{fcc\ Cu}//(110)_{bcc\ Nb}, \text{ and} \quad [\bar{1}01]_{fcc\ Cu}//[001]_{bcc\ Nb}$$

On the other hands, the crystallographic lattice shows more distortions with decrease of the of the Λ. It is also observed that the lattice distortions are spatially non-uniform. Due to this spatial variation, it is not appropriate to try and express the distortions as an average strain in the interfacial region. Rather, we consider examples in which the distortions result in large local elastic strains and those in which well defined crystal defects are observed in the region of the interface and within the copper layers.

The measurement of the average lattice spacing can provide information of the lattice distortion in different components. Therefore, we used the High Resolution Transmission Electron Microscopy (HRTEM) images accompanied by Selected Area Diffraction Pattern (SADP) to assess the lattice distortions. We considered three types of simple lattice distortions. These are tension or compression, shear and bending. The lattice distortions related to tensile or compressive, stresses and shear can be measured from either HRTEM images or SADP. The examples can be found in reference [2]. The lattice bending occurs in various metallic multilayers. Fig. 1 demonstrates the bending of the {111} planes of fcc-Cu in a Cu-Nb multilayer [3]. The stress or strains developed in the multilayers and composites influence the phase transformation, physical properties, such as the electric resistivity and mechanical response of the materials to the external load.

Fig. 1. <110> HRTEM image of a Cu region in a Cu-Nb multilayer showing the lattice bending. The rows of the bright or dark contrast represent rows of Cu atoms that comprise the lattice of the Cu. The row about parallel to the horizontal margins of the image represents the lattice of {111}, that is usually straight in perfect crystals without distortions. In this example, the {111} lattices are shown bending upwards.

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Reference:

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