INTERNAL STRESSES IN COLD-DEFORMED CU-AG AND CU-NB WIRES

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The co-deformation of Cu-Ag or Cu-Nb composite wires used for high-field magnets have a number of important microstructural consequences, including the production of very fine-scale structures, the development of very high internal surface-area to volume ratios during the drawing, and the storage of defects at interphase interfaces. In addition, the fabrication and co-deformation of the Cu with Ag or Nb, which differ in crystal structure, thermal expansion, elastic modulus and lattice parameter, lead to the development of short-wavelength internal stresses in both composites. We have characterized these internal stresses as a function of the imposed drawing strain using neutron diffraction and transmission electron microscopy [1]. The radial internal strains (and therefore the internal stress) in Cu-Nb measured by neutron diffraction are significant, as shown in figure 1a. The internal strains are different in different orientations in both Cu and Nb phases. The radial internal strain patterns in Cu-Nb are very complicated. Nevertheless, it can be seen that in [110]Nb, the internal stresses are in tension and in [220]Cu, the internal stresses are in compression. For comparison, samples with drawing strain $\varepsilon_d = 0.71$ were machined to different diameters. Sample sizes have no significant effects on the measured internal strains in different orientations. Therefore, short periodicity internal stresses are dominant. Similar conclusions were drawn in Cu-24wt%Ag composites. The radial internal strains measured by neutron diffraction in Cu-24wt%Ag with different drawing strains are shown in figure 1b and are smaller than those in the Cu-12.5wt%Nb. The internal strains are different in different orientations in both phases. Figure 1b also shows that the radial residual strains in Cu and Ag are in compression and tension, respectively.

Figure 1. Radial internal strains of (a) Cu and Nb in Cu-12.5wt%Nb and (b) Cu and Ag in Cu-24wt%Ag at different drawing strains.

The internal stresses lead to important changes in the elastic-plastic response, which is related to both magnet design and service life. We use the second derivative of the stresses $\sigma$ with respect to strain ($\partial^2 \sigma / \partial \varepsilon^2$) to describe the low strain anelasticity of the composites. The internal stresses in Cu-Nb are higher than in Cu-Ag, and consequently, the absolute values of ($\partial^2 \sigma / \partial \varepsilon^2$)$_{\text{Cu-Nb}}$ are higher than those of ($\partial^2 \sigma / \partial \varepsilon^2$)$_{\text{Cu-Ag}}$ at low strain. The detailed descriptions of the correlation between ($\partial^2 \sigma / \partial \varepsilon^2$) and internal stresses are reported in reference [1].

References