Impact of Interface Density and Internal Stress on Properties of Cu-Nb Conductors

Han, K. (MagLab); Deng,L.(MagLab, Fuzhou University); Hartwig, K.T.(Texas A&M University); Siegrist, T.M.; (FAMU-FSU, Department of Chemical Engineering, MagLab); Dong, L. (Chongqing University, CQU); Sun, Z.; Yang, X.; Liu, Q. (CQU)

Introduction

We studied evolution of microstructure, hardness, and electrical conductivity of high strength Cu-Nb microcomposites as a function of drawing strain (η) [1]. The goal was to develop new Cu-Nb conductors for future high-field magnets. Both interface area-density and lattice-distortion were taken into account for analyzing hardness and electrical resistivity at different levels of strain.

Experimental

Cu–Nb microcomposite was cold-drawn to different η values and subjected to intermediate heat-treatments. The microstructure of the wires was investigated on cross-section specimens. Lattice constants were measured by X-ray diffractometers. Both microstructure and X-Ray studies were undertaken with facilities hosted in MagLab.

Results and Discussion

Comparison of microstructure in Cu–Nb composites indicated that, as η increased, the morphology of Nb filaments/ribbons changed and spacing between them decreased. With η at 4.3, Nb filaments were rod-shaped. At η=5.5, Nb filaments were ribbon-shaped and curled to various degrees, as shown in Fig. 1. Certain thinly curled Nb ribbons are indicated by white arrows in Fig. 1. At η = 7.8, almost all Nb ribbons were curled or kinked. This suggests that Nb does not curl or kink until its thickness reaches a critical value. Both changes in curl and spacing produced change in interface area (S_V) changes. Fig. 2 shows hardness values as a function of S_V. The trend-line indicates that hardness increases with increasing S_V. XRD results showed that, with increasing η, the lattice constant of Cu increased while that of Nb decreased. Fig. 3 shows that the ratio of interplanar spacing of $(110)_{Nb}$ over $(111)_{Cu}$ declines as η.increases. The ideal ratio for Cu and Nb in prefect equilibrium condition is 1.12, the ratios estimated from our experimental values were always below that ideal point. The difference between the ideal ratio and the actual ratios indicates that internal stresses are under compression in $[110]_{Nb}$ and under tension in $[111]_{Cu}$. Our results suggest that interface area density and internal stress have significant impacts on both hardness and electrical resistivity [1, 2]. The model we developed can predict hardness, and therefore mechanical strength, by consideration of the internal stress that is related to solid solution hardening as well as the interface density and the curling level of the Nb ribbon-like phase.

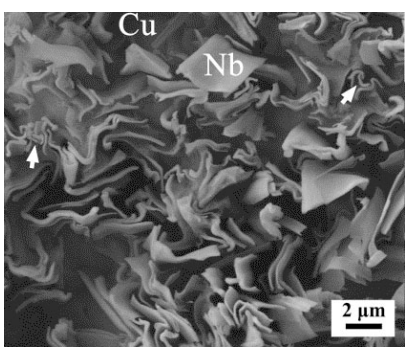

Fig. 1. Microstructure features of Cu-Nb composites

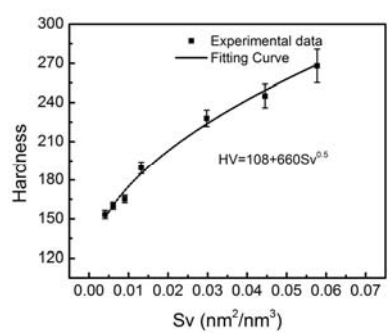

Fig. 2. Hardness (HV; kg/mm^2) of Cu–Nb composites as a function of S_v.

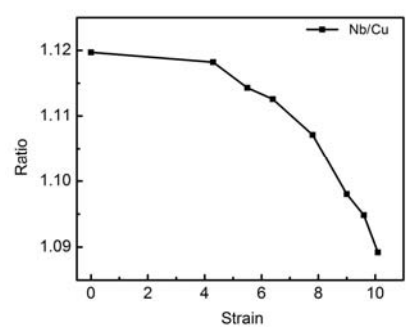

Fig. 3. Interplanar-spacing ratio of $(111)_{Cu}$ over $(110)_{Nb}$ at different strains

Acknowledgements

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References

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[2] Deng, L.P.; *et al*., Acta Metallurgica Sinica, 50 (2), 231-237 (2014)