Effect of 31.2T High Magnetic Field on an Ag-45.8wt%Ni Alloy

L. Zhang (Northeastern University, China), K. Han (FSU, NHMFL), E.G. Wang (Northeastern University, China), and X.W. Zuo (Northeastern University, China)

Introduction

Ag-Ni alloys have good electrical and mechanical properties. Ag-Ni magnetic and noble nonmagnetic multilayers also have pronounced giant magnetoresistance. The Ag–Ni binary equilibrium diagram exhibits a large miscibility gap in both solid and liquid states. Therefore, Ag-Ni is hard to fabricate via conventional solidification methods. In our experiment, Ag/Ni multilayers were successfully fabricated with the layer thickness of about 50 nm by accumulative roll bonding (ARB) directly from a macroscopic stack of pure metal Ag/Ni foils. During the fabrication, it is necessary to anneal the samples to reduce the internal stress. However, annealing may render the coarsening of the layer and therefore reduce the hardness of the materials. The effect of a 31.2T magnetic field on the annealing processes of Ag/Ni multilayers is investigated in our research to understand if the high magnetic field can reduce the coarsening.

Experiment

The total thickness reduction in ARB is about 99.995%. To study the influence of high magnetic field on the structural coarsening, the annealing of the final ARB foils is performed for 2 hours in a 31.2T magnetic field at 450℃, 500℃, and 550℃.

Results and Discussion

Figure 1 shows the hardness of the Ag-Ni multilayers as a function of annealing temperatures. The hardness decreases as the annealing temperature increased. The sample annealed with a high magnetic field perpendicular to the foil surface has a largest hardness than the rests, and the sample annealed without magnetic field has the lowest hardness. The results indicate that a high magnetic field reduces the coarsening of the microstructure. Our microstructure examinations confirm above conclusion.

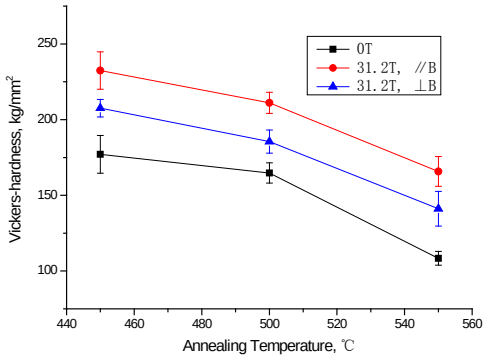

Figure 1. Vickers hardness of Ag-Ni multilayers annealed at different temperature.

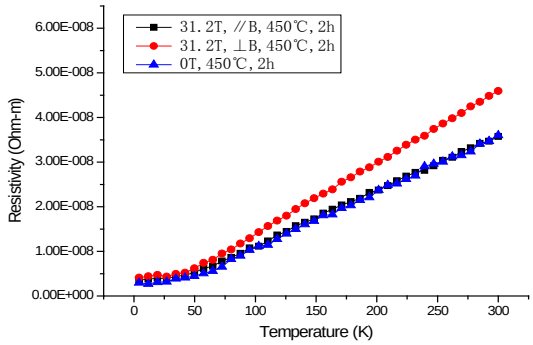

Figure 2. Hysteresis loops of Ag-Ni samples annealed at 450℃ for 2 h with or without magnetic field.

Figure 2 shows the resistivity values from 4.2K to 300K of Ag-Ni multilayers annealed at 450°C. The sample annealed at a 31.2T perpendicular high magnetic field has the largest resistivity. In our composite, the electrical current in Ag-Ni is essentially carried by the Ag phase. However, the resistivity of the Ag is affected by the Ni layers. Large deformation strain leads to a reduction of the average layer thickness. When the thickness of Ag layer between two Ni layers is of the order of the mean free path (50nm at room temperature) of a conduction electron in the Ag layer, a drop in conductivity is expected. In about half locations, the Ag thickness is smaller than 50 nm so the interface scattering contributes to the resistivity. A decrease in the electron mean-free path due to the small layer thickness may give an additional contribution to the resistivity. Annealing without high magnetic field results in coarsening of the structure and reduces the electrical resistivity significantly. This is consistent with our microstructure examination and hardness results.