Effect of current annealing on magnetic and mechanical properties of Co-based amorphous glass-coated microwires

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Co-based amorphous microwires with glass coating have been widely studied since the giant magnetoimpedance (GMI) firstly discovered in the 1990s[1], which is a greatly promising technology for sensor application[2]. A larger GMI exists in Co-based glass-coated amorphous microwires, compared with other GMI materials for the high conductivity and permeability, small hysteresis and vanishing magnetostriction, especially the peculiar domain. While most applications of the microwires is focus on development of sensors, Qin's studies[3-5] show microwires can act as multifunctional phase inserted in composite for its tunability and good mechanical properties.

On account of the disparity in thermal expansion coefficients of the glass coating and metallic core, there are internal stresses concentrated on the contact surface between the outer coating and inner core when preparation, which are detrimental to magnetic and mechanical properties. At present, direct current annealing is a more effective method to relieve internal stress than conventional annealing [6], leading to a substantial improvement in magnetic and mechanical properties[7]. In fact, current annealing is widely used in amorphous wires. Additionally, the toroidal magnetic field generated by the direct current can result in some interesting magnetic behaviors, responding to the rotation of domains in the field.

In this work, amorphous glass-coated microwires with a nominal composition Fe4Co68.7Ni1B13S11Mo2.3 were prepared by glass-coated melt spinning method. The diameters of the metallic core and the wire are 20.53μm and 29.59μm, with a length of 10cm. For current annealing, the glass coating on ends of the wires were removed by mechanical method. When annealing, the electrodes of DC power were clamped with the microwires ends. The annealing currents (I_a) were 10mA, 20mA, 25mA, 30mA, 40mA, 50mA and 60mA,respectively, in a constant annealing duration,10min. A group of untreated samples served as control group. The magnetic measurements were performed using PPMS 9T from Quantum Design from -200Oe-200Oe at 300 K.

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The tensile properties of microwires were measured by an Instron tensile tester (5943).

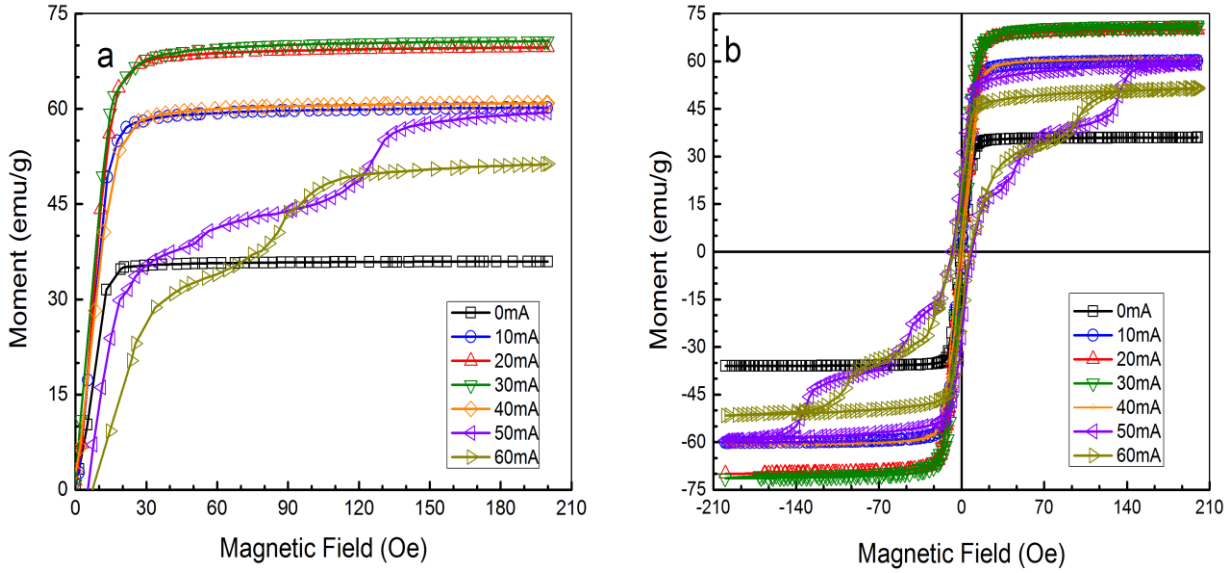

Fig.1. Initial magnetization curves and hysteresis loops of the samples at different currents

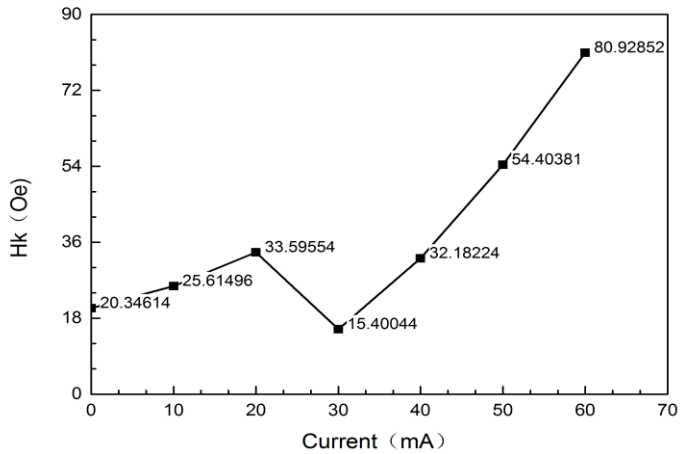

Fig.2. The dependence of effective anisotropy field H_K on the annealing current.

As per Fig.1 the as-cast amorphous glass-coated microwires have rather small coercivity. Current annealing greatly improves the saturation magnetization (Ms) of the samples up to 70emu/g. But with the current increasing over 30mA, M_s becomes smaller gradually and the hysteresis loops transform into a asymmetrical shape, indicating the current is deleterious at such amplitude to the soft magnetic properties. The asymmetry may result from the uniform composition, because of mass transfer effect when the microwires are overheated. The anisotropy field is defined by $H_k = M_s/\chi_i$, where χ_i represents the initial permeability calculated from the initial magnetization curves. Figure 2

demonstrates that the value of H_k at 30mA is the lowest of all studied samples, which accords with the former observation, denoting that 30mA appears to be most suitable amplitude for the current annealing of the samples to obtain good soft magnetic properties.

The effect of current on tensile properties is displayed in Fig.3, which is a complex dependeny. The tensile strength reaches its maximum at 50mA. When current is over 50mA, a sharp decline appears. The phenomenon maybe respond to the transmission from amorphous phase to crystal phase.

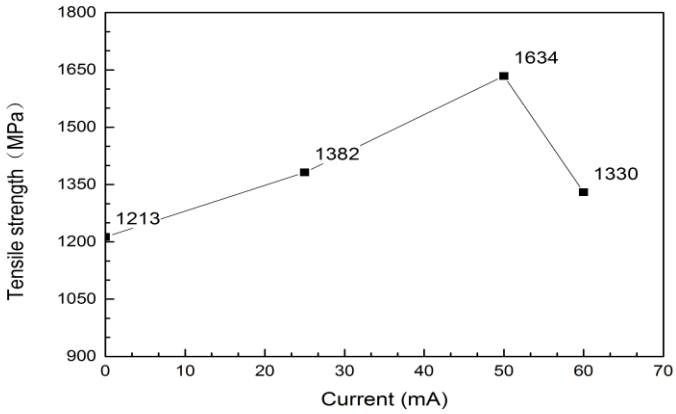

Fig.3. The dependence of tensile strength on the annealing current

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