EFFECTS OF PEENING ON SUPERCONDUCTING TRANSITION PROPERTIES

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INTRODUCTION

A peening generates lattice defects and a compressive stress without a large quantity of deformation (1). Tc often changes the lattice constant which is varied by the defects, such as a constitutional vacancy, and a solute concentration of A-15 phases (2 - 3). Since the constant is dominated by the defects and the stress, the peening may be a good tool to increase Tc. However, it is difficult to peen most of A-15 chemical compounds because of their fragility. Besides high superconducting transition temperatures (2, 4), the liquid-quenched Nb-Al alloys (mixture of A-15 + bcc) show ductility. The purpose of the present work is to investigate the effects of the peening on Tc of Nb_3Al crystalline alloys prepared by the liquid-quenching.

Experimental procedure

The alloy was prepared by melting commercially pure metals, niobium (99.8%) and aluminum (99.99%) in an argon arc furnace. This alloy was remelted in this furnace attached to a twin piston-anvil type apparatus. This apparatus was constructed to rapidly quench the molten sample in an argon atmosphere (2, 5, 6). The speed of the piston was about 0.12 m/s. The cooling rate R was varied by controlling the sample thickness D (7 - 8). The logarithmic R is inversely proportional to the logarithmic D.
The peening is performed by an apparatus (9). The nozzle diameter is 2.8 mm. The flow rate is 10^{-3} m^3/s. The distance between the nozzle and specimen is 3 mm. The steel balls were made of SuJ 2 steel (HRc = 64). The mean diameter and weight of the balls are 0.4 ± 0.1 mm and 0.68 mg. The supplied number per second is 3070 s^{-1}.
The superconducting transition temperature Tc (current density = 1 mA/mm^2) and superconducting critical current Jc were determined by the use of a standard 4-probe technique. The structure was measured with an X-ray diffraction and Vickers' hardness test.

Results and Discussion

Electric resistivities are measured for the liquid-quenched Nb_3Al alloy specimens at low temperature. Figure 1 shows the resistivity change with temperature of the specimen (0.85 mm in thickness) peened for 750 s. The superconducting transition temperatures Tc, Ta and Tb are defined to be the temperatures at a midpoint, at a start point and at a finish point of the transition, respectively.

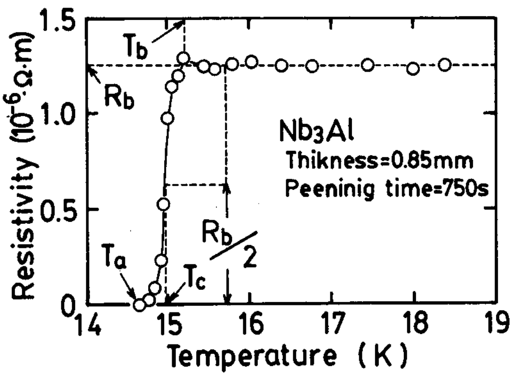

Fig. 1: Change in electric resistivity with temperature of Nb_3Al alloy specimen peened for 750 s.

Figure 2 show changes in superconducting transition temperatures (Tc and Ta) and reduced temperature (Tc/Tc^o and Ta/Ta^o) with the peening time (t), respectively. Here, Tc^o and Ta^o are for as quenched specimens before the peening. These temperatures increase with t. The maximum temperatures are obtained at the peening time from 500 s to 1000 s. The excess peening time over 1000 s decays these temperatures.

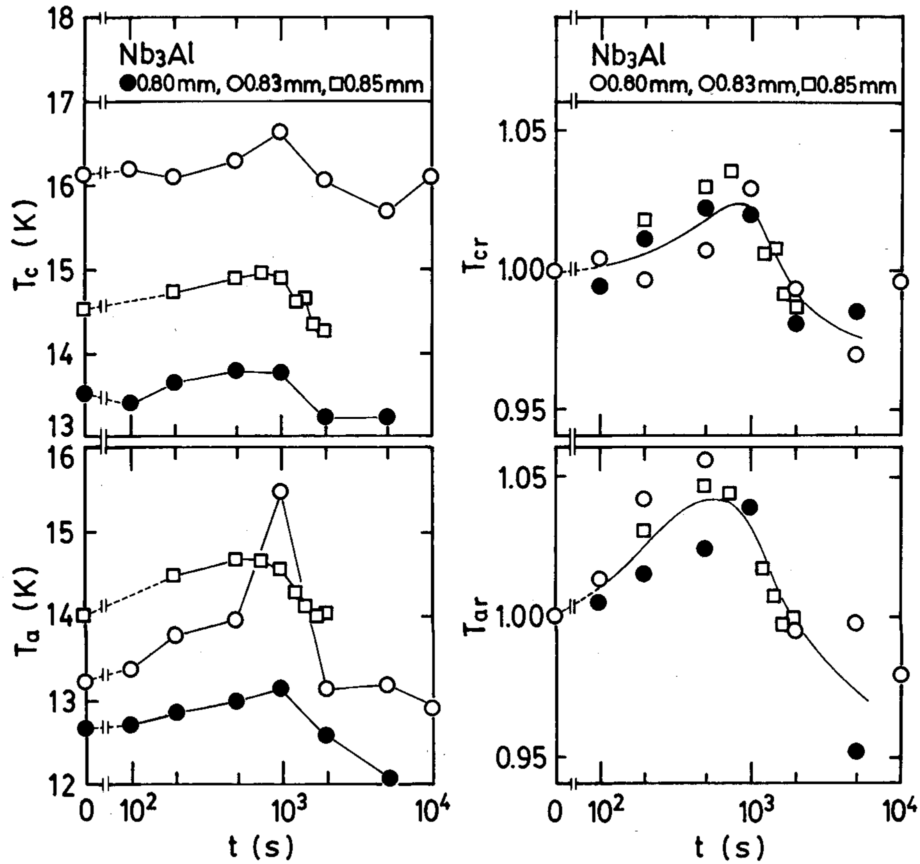

Fig. 2: Changes in superconducting transition temperatures (Tc and Ta) and reduced superconducting transition temperatures (Tcr and Tar) with peening time (t) of Nb_3Al alloy specimens. Tc and Ta are temperatures at midpoint of the transition and just below the transition, respectively. Tcr and Tar are Tc/Tc^o and Ta/Ta^o, where Tc^o and Ta^o are temperatures before peening.

The peening may increase the compressive stress. The stress increases T_c (10). Figure 3 shows micro-hardness configurations with peening time. The hardness change with depth and the experimental scatter of the hardness value are small of the liquid-quenched specimen of 0.85 mm in thickness. The peening enhances the hardness. The peening is seemed to affect the hardness of the peened specimen of about 0.4 mm in depth, though the experimental scatter is large. The scatter is probably caused by the differences of the work-hardening. The high hardness predicts the high density of lattice defects and the large compressive stress. Thus, the peening increases T_c.

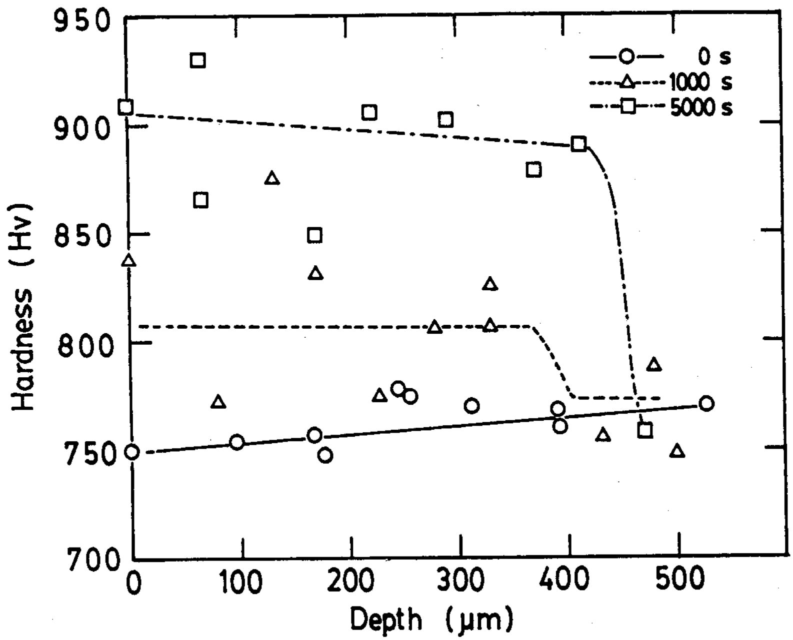

Fig. 3: Changes in hardness with depth of the specimen peened for 0, 1000 and 5000 s.

On the other hand, the thermal energy is generated by the peening. The energy homogenizes and reorders atom distribution. The atom distribution may be close to the higher Tc phase of the A-15 chemical compound. Figure 4 shows Rb against t. Above the superconducting transition below about 30 K, the electric resistivity is indepent of the temperature and is equal to Rb (see Fig. 1). Although Tc increases with Rb increase for V_3Si alloy (5), this changes, on the contrary, are inversely correlated with Tc and Ta. Namely, the lower the Rb, the higher the Tc and Ta become. Before 1000 s, Rb decreases with t because of the solute homogenization. On the other hand, the peening after 1000 s generates an excess defects which disorders the A-15 crystal lattice. Thus, low Tc and Ta are found after 1000 s.

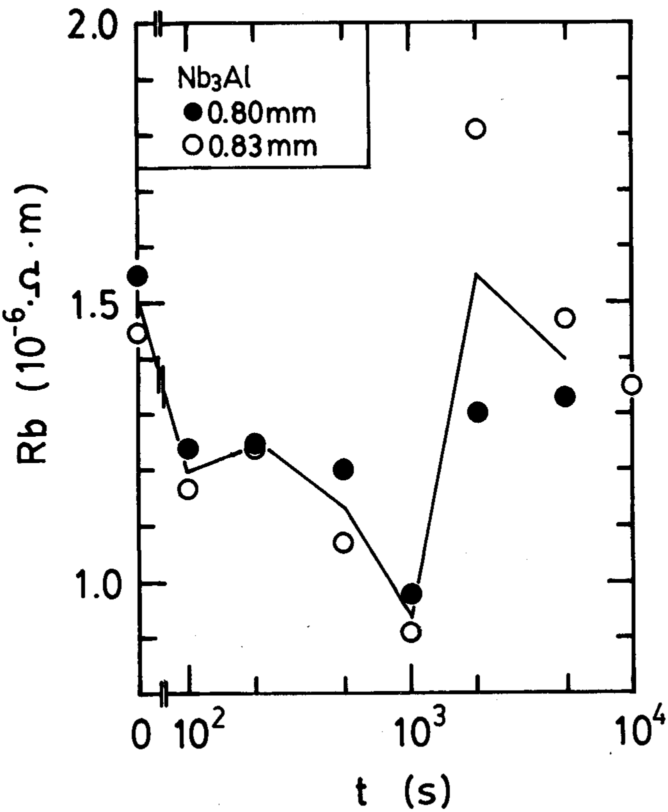

Fig. 4: Changes in electric resistivity (R_b) with peening time (t) of Nb_3Al alloy specimens.

Figure 5 shows the change in the superconducting critical current Jc (at 4.2 K) with the peening time (t). The Jc increases with the peening time for 500 s and then decreases. Namely, the time to the maximum Jc is as same as that to the maximum Tc. The Jc increase is partly explained by the high density of the lattice defects (Refs. 6, 11) introduced by the peening. Since the defects is driving a superconducting phase into the normal state, it acts as an additional pinning site (6). An additional flux pinning sites enhances Jc. On the other hand, the decay of Jc may be caused by the excess lattice defects. Since the large amounts of defects derive a high Tc phase into a low Tc phase below 4.2 K, the volume of the high Tc phase decreases with t. Thus, the low Jc is found after 1000 s.

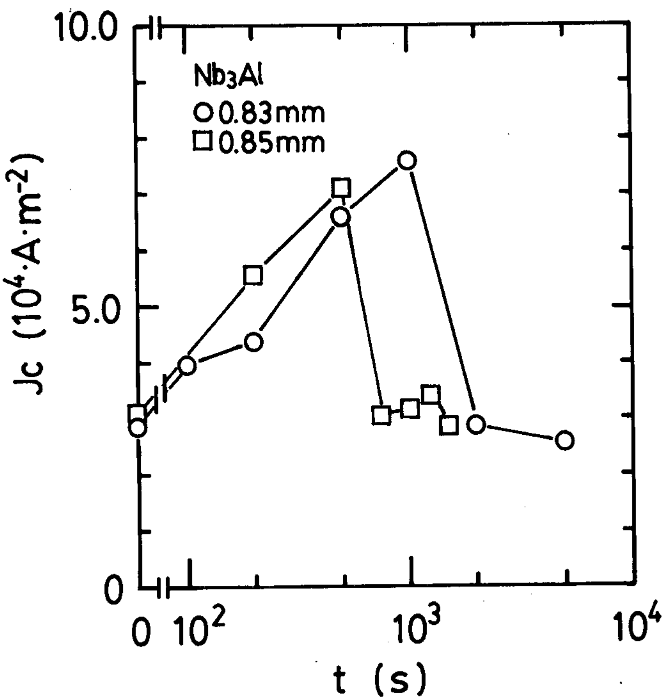

Fig. 5: Changes in superconducting critical current (J_c) with peening time (t) of Nb_3Al alloy specimens.

Conclusion

The effect of peening on Tc and Jc are investigated in the liquid-quenched Nb_3Al alloy. The Tc and Jc increase with peening time for 500 s. Taking into the electric resistivity and the resistance to micro-plastic deformation, it is concluded that the peening homogenizes the solute distribution and increases the compressive stress in A-15 phase, resulting in higher Tc.

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