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Fabrication of Niobium Weak Links by means of Electron Beam Lithography and Ion Implantation

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Josephson junctions are high speed and low power devices and there has been an increasing interest in applications for electronic devices such as radiation detectors and lozic elements.

There are many types of josephson junctions. Among these, bridge-type junctions seem to be stable for thermal cycling and easy to integrate. For bridge types, it is crucial to have a short bridge length and to control a superconducting transition temperature Tc, in order to produce junctions with desired characteristics.

We have been studying fabrications of bridges by using electron beam lithography and ion implantation. 500A thick Nb films (Tc ≈ 9K) were evaporated on Si wafer and was patterned by photoresist techniques to produce a stripe 4 μm wide by 3 mm long with contact tabs at the ends. After the patterning, about 3000A thick PMMA resist was spun onto the surface and a 0.4 μm wide channel with vertical walls was formed by electron beam lithography. Weak links were formed by reducing Tc at a bridge region by implanting 70 keV N_2^+ molecular ions in Nb films through the channel.

Fig. 1 shows a typical current-voltage characteristic of a bridge fabricated by an implantation at a dose $1 \times 10^{16}/cm^2$. The junction width is about 4 μm. At a temperature (a), the current-voltage characteristics exhibited a large hysteresis and the transition of a zero-voltage to a voltage state was very rapid. The hysteris became small and the transition became slow as temperature increased (b~d). The normal resistance of the bridge R_N was about 0.8 Ω.

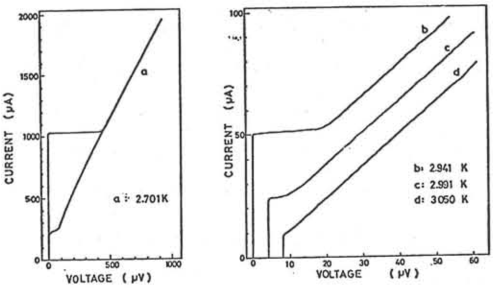

Fig. 1 Voltage-current characteristics of a bridge fabricated by an implantation of 70 keV N_2^+ at a dose of $1 \times 10^{16}/cm^2$.

Temperature dependence of the maximum zero-voltage current Ic is shown in Fig. 2. At low temperature (arround a region marked a) Ic followed the equation $Ic = Ico(1 - \frac{T}{Tc'})^{\frac{3}{2}}$, and Ic decreased monotonously with increasing an applied magnetic field as shown by the curve a in Fig. 3. This indicates that at this temperature range, the junction behaves bulk-like and Ic is determined by depairing prediction. At high temperature Ic exhibited an exponential tail.

Fig. 3 shows Ic as a function of an applied magnetic field. The letters besides the curve indicate the same temperature with those in Fig. 2. At the tail region in Fig. 2 (b,c and d), we observed a periodic dependence of Ic on an applied magnetic field. This indicates that the junction exhibit josephson behavior at this temperature range.

The dose dependence of the junction parameters (Tc' and R_N) is shown in Fig. 4. Normal junction resistance increases and Tc' decreases with increasing a dose. This is probably caused by defects produced by an implantation. We observed by He ion channeling techniques that high density of defects remained after the implantation.

The present results indicate that we can tailor junction characteristics such as a normal junction resistance and a working temperature by changing implantation dose and that the present techniques provides flexible means for fabrications of Josephson bridge-type junctions.

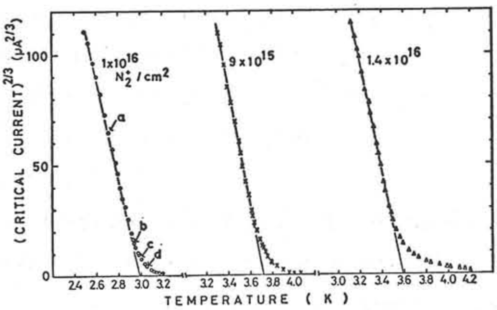

Fig. 2 Critical current as a function of temperature for three bridges implanted at different doses.

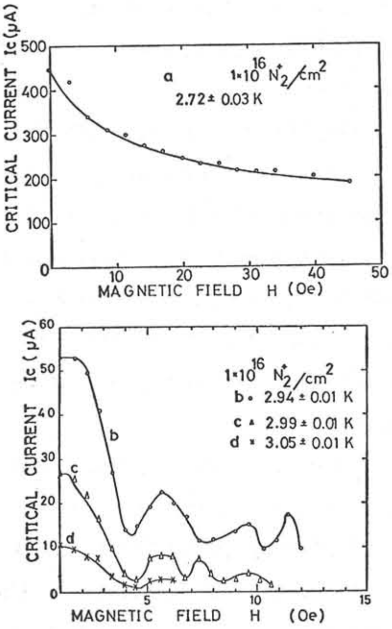

Fig. 3 Critical current as a function of an applied magnetic field.

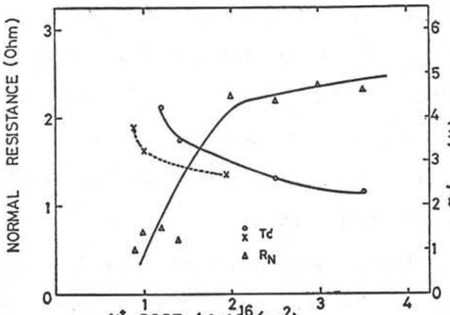

Fig. 4 R_N and Tc' as a function of a dose.