The use of mechanically hard superconducting materials for making Josephson devices has become of increasing interest since that makes it possible to realize excellent stabilities of the devices for the thermal cyclings and storage. Nb junctions are widely studied from this point of view. However, the surface of Nb films are so active that surface damage layers developed during plasma processes often cause the increase of the subgap conductance which is not suitable for device applications.

Recently, the integration process for NbN based Josephson devices was developed and NbN/Pb junctions were shown to have very small subgap conductances due to the surface stability of NbN films. However, the London penetration depth \( \lambda_L \) of the NbN films are relatively large (\( \approx 5000 \)\( \AA \)) compared with those of the Pb-In alloy or the Nb films, resulting in increasing kinetic inductance. This large kinetic inductance decreases the magnetic sensitivity of the interferometer and increases the propagation delay of the wiring.

In this paper, we propose a new base-electrode structure composed of Nb and NbN double layer. This structure makes it possible not only to decrease the kinetic inductance of the base-electrode due to the small \( \lambda_L \) of Nb film (\( \approx 900 \)\( \AA \)) but also to obtain a good tunneling characteristic of small subgap conductance due to the surface stability of NbN film.

Figure 1 shows an I-V characteristic and a schematic cross-section of a \((\text{NbN},\text{Nb})/\text{Pb}\) Josephson junction. The base-electrode was prepared by sequential sputtering of Nb and NbN films at a substrate temperature of 500\( ^\circ \)C and patterned by a lift-off method using a ZnO film as a resist stencil. The oxide barrier was formed by an rf plasma oxidation method.

Junction quality factors, \( I_cR_{nn} \) and \( V_m=I_cR_{sg} \), are plotted in Fig.2 as a function of the thickness of the surface NbN layer, where \( I_c \) is the maximum Josephson current, \( R_{nn} \) and \( R_{sg} \) are the normal tunneling resistance and subgap tunneling resistance defined as the static resistance at the voltage of 6mV and 2mV, respectively. As shown in this figure, both \( I_cR_{nn} \) and \( V_m \) increase with the thickness of NbN, which indicates that the tunneling characteristics are much improved by the existence of the NbN surface layer. This clearly shows the surface of NbN is more stable than that of Nb against plasma processes.

The \( \lambda_L \) of Nb, \((\text{NbN},\text{Nb})\) and NbN films were estimated from independent meas-
urements of stripline inductance, Fraunhofer characteristics and interferometer characteristics, and plotted in Fig.3. As shown in this figure, the $\lambda_L$ of the double-layered film with about 500Å thick NbN surface layer is about 2000Å, which is much smaller than that of the pure NbN film. From this result, the double-layered electrode is expected to increase the sensitivity of the magnetic field compared with the pure NbN electrode. We have fabricated memory cells by using this double-layered electrode as shown in Fig.4, and observed that the sensitivity is much improved.

In conclusion, we have developed a new fabrication technology with the NbN,Nb double-layered base-electrode, which allows us to make Josephson devices with good tunneling characteristics without losing the magnetic sensitivity.

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References