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NIS tunneling junction fabricated by superconducting Boron-doped diamond

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1. Introduction

Diamond is electrochemically stable and mechanically tough. Therefore, Normal conductor – Insulator – Superconductor (NIS) tunneling junction fabricated by heavily boron doped diamond has a potential to be a promising X-ray detector[1] or a part of superconducting base transistor[2]. The characteristic of junction depends on the particular energy gap of superconductor called superconducting gap. The Fermi energy of superconductor corresponds to that of normal conductor, but the superconducting gap (Vgap) arises a few meV above and below the Fermi energy under critical temperature (Tc). So the tunnel current cannot flow like under T > Tc. The Vgap can be clearly observed in the current-voltage characteristics when the NIS tunneling junction fabricated on the smooth surface.

In this research, NIS tunneling junction operates with heavily boron doped diamond layer as superconductor and aluminum oxide (Al_2O_3) layer as insulator and gold (Au) as normal conductor. Boron doped diamond's Tc of zero resistance is around 9K[3], so the Vgap at 0K is expected nearly 1.35mV which is calculated from the empiric formular $2\Delta(0) = 3.52k_BTc$.

2. NIS tunneling junction fabrication process

Structure of NIS tunneling junction is shown in Fig.1.

Boron doped diamond films were deposited using the microwave plasma assisted chemical vapor deposition (MPCVD) method. The thickness of superconductor layer is 200nm. The HPHT Ib single crystal diamond was used for substrate, and superconducting thin film with Tc=8.9K was deposited.

Subsequently, Al was deposited on half of the superconducting layer and oxidized in the atmosphere to make Al_2O_3 layer for insulator. The thickness of Al_2O_3 is nearly 1 nm. It is an important factor to settle on tunnel current can flow or not through the junction. Au was deposited on Al_2O_3 layer as normal conductor. The thickness is 100 nm. In this way, the three layer structure vertical style NIS tunneling junction was fabricated on diamond substrate.

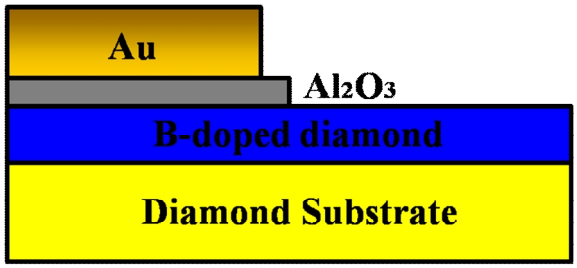

Fig.1 the structure of NIS tunneling junction
This junction made up of three parts. B-doped diamond layer as superconductor (S), aluminum oxide layer as Insulator (I), and gold layer as normal conductor.

3. Measurement

3.1 Current-voltage characteristics

The current - voltage characteristics at 2.0K and its temperature dependence are shown in Fig.2 . The typical current-voltage curve of NIS tunneling junction is observed at 2.0K. The gradient of characteristic changed around 1.3mV which represents the existence of the superconducting gap that in agreement with the theoretical value.
Additionally, current-voltage curve become sharp with increase in temperature (Fig.2). Superconducting gaps are decreased with temperature increase, so the characteristic became linear like that of normal conductor – insulator – normal conductor (NIN) tunneling junction.

3.2 Conductance–voltage characteristics

The conductance-voltage (dI/dV-V) characteristics at 2.0K and its temperature dependence are shown in Fig.3 and Fig.4. The typical dI/dV -V characteristics were observed. The result shows that the gap of superconducting was clearly observed. It begins to drop to a lower value at the Vgap. The Vgap is 1.3mV at 2.0K.

Vgap became unclear with temperature increase. Additionally, as temperatures rise, carriers can surpass the superconducting gap due to the heat energy. The superconducting gap became unclear shown in Fig.4.

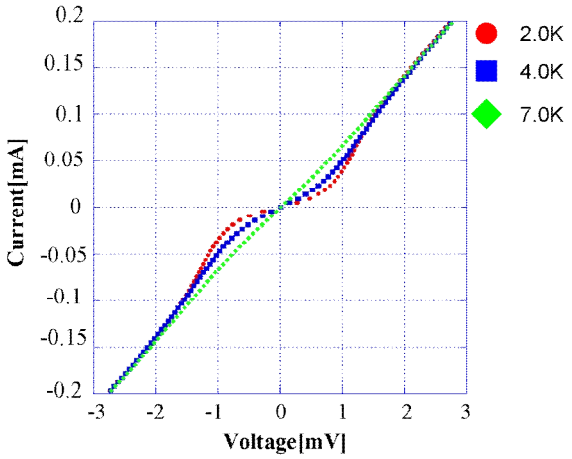

Fig.2 the current-voltage characteristics at 2.0K and the temperature dependence of current-voltage characteristics. The characteristics become line shape with temperature increase.

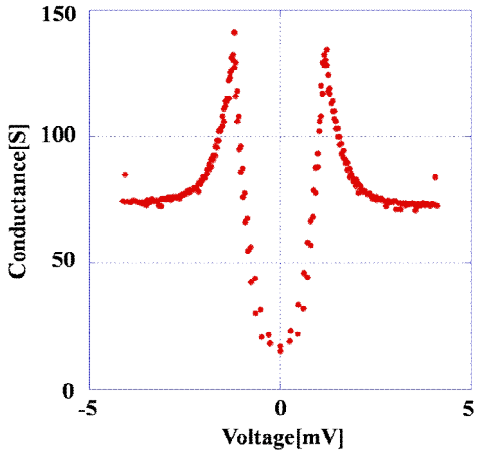

Fig.3 conductance – voltage characteristic at 2.0K. Superconducting gap arises symmetrically above and below of Fermi energy, so the dI/dV -V curve is symmetrically centering around zero voltage. The Vgap is near the voltage when the conductance is the maximum value.

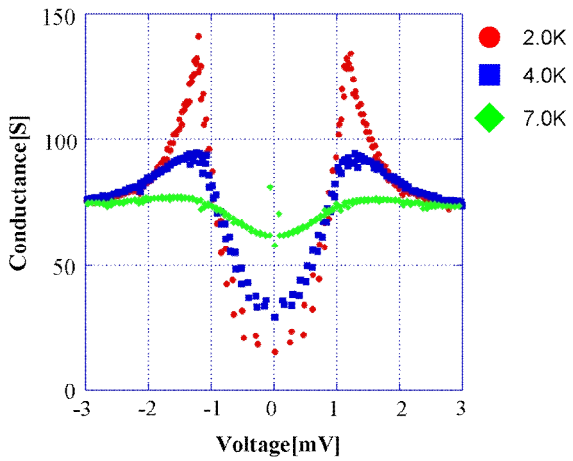

Fig.4 the temperature dependence of conductance-voltage characteristics. The dI/dV - V curves become moderate with temperature increase.

4. Conclusion

In the present work, NIS tunneling junction was fabricated by heavily boron doped diamond as superconductor. The characteristics of current – voltage and conductance – voltage were both similar to theoretical characteristics. We first observed the superconducting gap of diamond from current-voltage characteristics. The Vgap was 1.3mV at 2.0K, it is close to the theoretical value 1.35mV from the critical temperture of superconducting diamond. While the Vgap of diamond was measured by other methods (ex.scanning tunneling microscopy/spectroscopy (STM)[4], Laser-Excited Photoemission Spectroscopy (PES)[5]) carried out in low Tc samples[4], the Vgap is observed in NIS tunneling junction fabricated by higher Tc of superconducting diamond in this research. The most reliable Vgap has been obtained by homogeneously boron-doped diamond films.

5. Acknowledgement

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6. Reference

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