Josephson current suppression due to the spin Hall effect in InAs two-dimensional electron systems

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InAs is a narrow gap semiconductor, which provides a low interfacial resistance suitable for the investigation of superconductor/semiconductor junctions [1]. In addition, Rashba type strong spin-orbit coupling (SOC) is expected in two-dimensional electron systems (2DESs) at spatially asymmetric structures of InAs quantum well [2]. Such a strong SOC causes a variety of spin phenomena: spin filtering [3], spin Hall effect [4] etc. SOC does not seem to modify transport property in superconducting junctions so drastically since Cooper pair has no spins and SOC conserves time-reversal symmetry. However, the spin mixing due to SOC changes the superconducting symmetry and furthermore the spin Hall effect induced by currents in the 2DESs affects the characteristics of the superconducting junctions, e.g. Andreev bound states.

In this work, we fabricated Nb/InAs/Nb junctions using InAs modulation doped 2DESs. Figure 1 illustrates a schematic of our junctions. Two Nb electrodes are attached to the 2DES and we can apply a longitudinal current and a transverse current along the Nb/InAs/Nb junction independently and simultaneously. In order to avoid the current leak from Nb electrodes to 2DES electrodes, the Nb-InAs crossing point as kept to the ground level during the measurements by applying positive and negative voltages symmetrically. Figure 2 shows the voltage dependence of the longitudinal conductance with applying several transverse currents. Below 0.3 mV the conductance is enhanced due to the Andreev reflections at the Nb/InAs interfaces and has a peak structure at the zero bias. This sharp zero-bias peak is attributable to Josephson current carried by the Andreev bound states in InAs. With increasing transverse currents, the Andreev reflection keeps the same amplitude, but the zero-bias peak is suppressed, that is, only formation of the Andreev bound states are disturbed by the spin Hall effect.

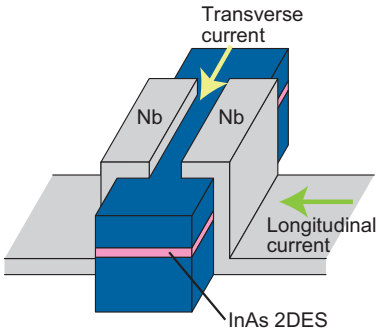

Fig.1. A schematic of Nb/InAs/Nb junctions. The width of the InAs 2DES is 300 nm to 4500 nm.

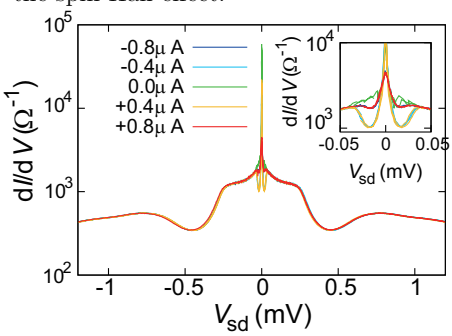

Figure 2. Bias voltage dependence of the differential conductance of a Nb/InAs/Nb junction with a variety of the transverse currents.

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