Andreev Reflection Spectroscopy Study of Single-Crystal Bi$_2$Se$_3$ and Bi$_2$Te$_3$ Topological Insulators

C. R. GRANSTROM, I. FRIDMAN, University of Toronto, H.-C. LEI, C. PETROVIC, Brookhaven National Laboratory, J. Y. T. WEI, University of Toronto, Canadian Institute for Advanced Research —

To understand the superconducting proximity effect that occurs across the c-axis of non-ideal three-dimensional topological insulators, we perform point-contact Andreev reflection (AR) spectroscopy on Bi$_2$X$_3$ (X=Se,Te) single crystals with Nb tips at 4.2 K. Robust AR spectra are observed, and analyzed with the Blonder-Tinkham-Klapwijk (BTK) theory. Non-BTK behavior is seen at low junction impedance and can be attributed to tip-induced Rashba spin-orbit coupling. However, the subgap enhancement seen in all the spectra is not consistent with the Fermi-surface mismatch between Nb and the topological surface states of Bi$_2$X$_3$. Rather, bulk band states with substantial $k_z$-dispersion are needed to explain the AR data, consistent with the Fermi level lying outside the bulk band gap as seen by scanning tunneling spectroscopy. We discuss the implications of our results on c-axis proximity effect experiments.

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