The study of high energy particle irradiation effect on Josephson junction trilayers is relevant to applications in space and radioactive environments. It also allows us to investigate the influence of defects and interfacial intermixing on the junction electrical characteristics.

In this work, we studied the influence of 2MeV Helium ion irradiation with doses up to $5.2 \times 10^{16}$ ions/cm$^2$ on the tunneling behavior of Nb/Al/AlOx/Nb Josephson junctions. Structural and analytical TEM characterization, combined with SRIM modeling, indicates that over 4nm of intermixing occurred at the interfaces. EDX analysis after irradiation, suggests that the Al and O compositions from the barrier are collectively distributed together over a few nanometers. Surprisingly, the IV characteristics were largely unchanged. The normal resistance, $R_n$, increased slightly ($<20\%$) after the initial dose of $3.5 \times 10^{15}$ ions/cm$^2$ and remained constant after that. This suggests that tunnel barrier properties are largely unaffected, despite the significant changes in the chemical distribution of the barrier’s Al and O. The onset of quasi-particle current, characteristic of $2\Delta$, dropped systematically from 2.8meV to 2.6meV with increasing dosage. Similarly, the temperature onset of the Josephson current dropped from 9.2K to 9.0K. This suggests that the order parameter at the barrier interface has decreased as a result of a reduced mean free path in the Al proximity layer and a reduction in the Nb electrode transition temperature near the barrier. The dependence of Josephson current on the magnetic field and temperature does not change significantly with irradiation; suggesting that intermixing into the Nb electrode is significantly less than the penetration depth.