Materials Science & Engineering Doctoral Defense

Hafnium Oxide as an Alternative Barrier to Aluminum Oxide For Thermally Stable Niobium Tunnel Junctions

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abstract

In this thesis, our goal was to fabricate Josephson junction that can be stably processed at 300°C or higher. With the purpose of integrating Josephson junction fabrication with current semiconductor circuit fabrication process, back-end process temperature (>350 °C) will be a key for producing large scale junction arrays reliably, which requires the junction to be more thermally stable than current Nb/Al-AlO_x/Nb junctions.

From theory of thermodynamics, Hf was chosen to produce thermally stable Nb/Hf-HfO_x/Nb superconductor tunnel Josephson junctions that can be grown or processed at elevated temperatures. Also elevated synthesis temperatures will improve the structural and electrical properties of Nb electrode layers in the junction that could potentially improve junction device performance. The refractory nature of Hf, HfO_2 and Nb allow for the formation of flat, abrupt and thermally-stable interfaces. But the current Al-based barrier will have problem when using with high-temperature grown and high-quality Nb. So our work is aimed at using Nb grown at elevated temperatures to fabricate thermally stable Josephson tunnel junctions.

As a junction barrier metal, Hf was studied and compared with traditional Al-barrier. We have proved that Hf-HfO_x is a good barrier candidate for high-temperature synthesized Josephson junction. Hf deposited at 500 °C on Nb forms flat and chemically abrupt interfaces. Nb/Hf-HfO_x/Nb Josephson junctions were synthesized, fabricated and characterized with different oxidizing conditions. The results of materials characterization and junction electrical measurements are reported and analyzed. We have improved the annealing stability of Nb junctions and also used high-quality Nb grown at 500 °C as the bottom electrodes successfully. Adding buffer layer or multiple oxidation steps improves annealing stability of Josephson junctions. We also have attempted to use Atomic Layer Deposition (ALD) method for Hf oxide growth as junction barrier and got tunneling results.

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