Epitaxial ultra-thin NbN films grown on sapphire dedicated for superconducting mixers

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Sputtered niobium nitride (NbN) films have been considered as a good candidate for rapid single flux quantum electronics based on Josephson Junctions, for THz mixers based on Hot Electron Bolometric effect or for single photon detection applications (SSPD). Applications would benefit from higher quality films (epitaxial growth) with low concentration of defects, such as grain boundaries or twins, whose nature and concentration depend on the deposition conditions and the substrate.

Efforts devoted to grow NbN aim at improving their critical temperature and critical current density, while keeping their thickness in the 3 to 5 nm range and Tc above 10 K, which insure a large bandwidth and large SNR detection at 4K. Choice of substrate is critical: for applications, MgO wafers and R-plane sapphire are usually considered as best choice. However, growing NbN on either M-plane or A-plane orientations of sapphire wafers, 3 inch in diameter, can help improving the film quality and fabrication yield. NbN thin films were grown by reactive DC magnetron sputtering at about 600°C and passivated by an AlN layer 1.5 nm thick deposited in-situ at room temperature. Growth on M-plane is shown to be better than on other sapphire orientations, including R-plane. NbN layer critical temperature reaches 13.3 K. Their properties are uniform on the 3 inch wafer, for a film thickness of 4.4 nm measured by X-ray reflectivity. We also obtained promising results on NbN growth on silicon wafers by using either an epitaxial YSZ/CeO_2 buffer layer grown ex-situ by PLD or a thin NbMgO buffer sputtered in-situ. Transport properties of NbN grown on those various substrates have been correlated to their crystallographic microstructure, examined by both symmetric and asymmetric X ray diffraction, high resolution transmission electron microscopy (HRTEM), spectroscopical ellipsometry, atomic force microscopy (AFM). These results will be presented in the framework of HEB and SSPD applications. Epitaxial multilayers NbN/MgO/NbN on M-plane sapphire have been also studied. Applications of these tunnel junctions as superconductor-insulator-superconductor (SIS) mixers have been considered.