**Introduction**

In pursuit of higher acceleration gradients, beyond the material limits of bulk Nb, research has turned to superconductor–insulator-superconductor (SIS) layers [1]. When the superconducting layer is thinner than its superconducting London penetration depth, the structure can shield the underlying superconductor from magnetic flux. Then the accessible cavity can withstand higher gradients thus fewer expensive cavities are needed to reach the energy specifications for accelerator machines. NbTiN/AlN is promising materials for these SIS structures. NbTiN has a superconducting Tc of 13.2 K for bulk-like films. AlN has a lattice parameter close to NbTiN which favors growth of the 5–phase with the desired Tc. This contribution discusses the properties of NbTiN monolayers and NbTiN/AlN/Nb SIS structures deposited by reactive DC magnetron sputtering. To assess the first flux penetration $\Phi_{c}^{3}$ of the structures a 3rd–harmonic magnetometer is under development in collaboration with CEA-Saclay.

**Deposition**

The structures in this work are deposited by reactive DC magnetron sputtering (DCMS). During depositions the working gas is Ar and the reactive gas is N. The films are deposited in a UHV system with a base pressure of $10^{-9}$ Torr. The system is equipped with multiple DCMS guns with rotatable substrates. Two of the sputtering guns are used for SIS structures, one with a 70/30% at. wt. NbTi target and another with a pure Al target. The sample holder rotates in front of the sputtering guns insuring similar in-situ conditions during film growth.

The substrates used are NbO, Nb and NbN ceramic. The NbO (100) lattice parameter (4.36 Å) closely matches NbTiN (4.34 Å) leading to the best NbTiN films. Nb is used as the substrate for SIS structure since it is the desired high $T_{c}$ phase with the 5–phase. This phase can be stabilized in the Nb substrate by the addition of a layer of Nb on the Nb substrate. The NbTiN films are produced at 600°C, for SIS structures the substrate is heated only to 450°C in order to limit Al diffusion into Nb and NbTiN [2].

**Monolayer and Multilayer Films**

The samples have been prepared for 3rd harmonic measurements with a NbTiN layer of 250 nm and AlN layers from 22 nm down to 5.6 nm. NbTiN monolayers have been prepared on MgO from bulk like thickness (~1.5 um) to 52 nm. The substrates of the monolayer films are the different orientations of MgO and electropolished Nb. The films are deposited simultaneously on NbTiN/TiN on Nb (EP) substrates. The films deposited on buffered chemical polished (BCP) Nb, show better crystallinity. Multilayer films show the same trend, EP substrates show less crystallinity than BCP substrates. BCP substrates provide better film growth is unexpeceted. The EP gives a smoother surface with less features (similar to AlN) which should improve deposition.

The roughness of the substrate directly affects the films roughness. Increasing roughness is undesirable because of the increased migration of magnetic fields from surface features. TEM cross sections of multilayer NbTiN and AlN shows that the layers are smooth. Also, the figure on the bottom right shows that the roughness does not increase until the films reach bulk like thickness.

**Magnetometry**

Magnetometry is used to evaluate first flux penetration $\Phi_{c}^{3}$ of films and SIS structures. Superconducting quantum interference device (SQUID) magnetometry applies a magnetic field to both sides of a sample. This is undesirable because it is dissimilar from the field inside of a cavity and induces edge effects. 3rd–harmonic magnetometry applies a magnetic field to only one side of the sample, producing less edge effects.

3rd–harmonic magnetometer systems have three components, a coil, a sample holder and a cold reservoir. The coil is used to generate a magnetic field parallel to a superconducting sample (see figure on the left). The sample holder establishes a gap of 10–50 microns between the sample and coil. This proximity is necessary to detect the 3rd harmonic signal but the heat generated from the coil can warm the sample. The cold reservoir is assembled to remove heat from the coil.

A coil of Cu wire is used to both apply the magnetic field and act as a pickup to measure the 3rd harmonic induced voltage. The output of the pickup is conditioned in the induced voltage, directly provides $H_{c}$. Also, the coherence length of the Meissner transition can be observed over a wide range of fields and temperatures. The film producing coil is 5 mm in diameter so the edge effects for a 24.5 mm diameter sample’s will be minimized, and minimized further with a sample diameter of 50.8 mm.

**Conclusion**

These films for measurement by 3rd harmonic magnetometer have been prepared, they will be used to investigate the effect of thickness of the insulator on the $T_{c}$ in a SIS of NbTiN and AlN. $H_{c}$ enhancement has been observed for NbTiN/AlN/Nb SIS structures. NbTiN monolayers have been prepared on MgO from bulk like thickness (~1.5 um) to 52 nm. The substrates of the monolayer films are the different orientations of MgO and AlN. The films are deposited simultaneously on NbTiN/TiN on Nb (EP) substrates. The NbTiN films are produced at 600°C, for SIS structures the substrate is heated only to 450°C in order to limit Al diffusion into Nb and NbTiN [2].

**Future Work**

- Completing the 3rd–harmonic magnetometer.
- Measure the above films with the magnetometer.
- Improved materials for coils. Annealed Cu wire and highly thermally conductive coating for the coil.

**References**