Superconducting Thin Film Growth and Post Laser Annealing

CNF Project Number: 2779-19

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Primary Source(s) of Research Funding: National Science Foundation under Grant No. PHY-1549132

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Primary CNF Tools Used: Oxford FlexAL atomic layer deposition system, Arradiance Gemstar-6 atomic layer deposition system, Woollam spectroscopic ellipsometer, Zygo optical profilometer, P10 profilometer.

Abstract:

Superconducting radio frequency (SRF) cavities are important in accelerating charged particle beams in broad applications such as colliders, neutron sources, and light sources. Niobium tin and magnesium diboride superconductors are the most promising candidates for the next generation SRF cavities. However, their thin film growth is still challenging due to grain boundaries, defects generation, surface roughness, and surface oxidation. Thus, this project investigates the growth mechanisms of superconducting films and explores post processing techniques, such as laser annealing and surface passivation, to mitigate the crystal defects, surface roughness, and oxidation.

Summary of Research:

This report is based on the work done since April 1st, 2019 when Zeming became a user of Cornell NanoScale Science and Technology Facility.

The project has focused on (1) reduction of surface roughness for niobium substrates, (2) deposition and optimization of titanium nitride film as a laser absorber, and (3) deposition of aluminum nitride film for passivating magnesium diboride surface.

(1) Reducing surface roughness of starting niobium substrates is critical for the following deposition of superconducting films since the roughness could negatively affect the nucleation process. Mechanical polishing was exploited, and Zygo optical profilometer was used to monitor the roughness. As shown in Figure 1, the final roughness of niobium substrates are reduced to R_a = 72 nm.

(2) Laser annealing technique has been explored to enable the epitaxial growth of niobium tin grains and also reduce the film surface roughness. Preliminary results showed that niobium tin surface failed to absorb sufficient laser energy using a 120 W, 1064 nm wavelength CO_2 laser and a 250 W, 980 nm wavelength diode laser. In order to enhance the laser light absorption, a titanium nitride film was deposited using thermal atomic layer deposition system. The film thickness and refractive index are important for achieving the anti-reflection. Both parameters were determined by the ellipsometer as shown in Figure 2 and 3.

(3) Magnesium diboride superconducting thin film is easily oxidized in air which hinders its wider application. An aluminum nitride film is deposited on the magnesium diboride film using plasma-enhanced atomic layer deposition. This dielectric film is expected to passivate the magnesium diboride film surface. Further investigations are ongoing.

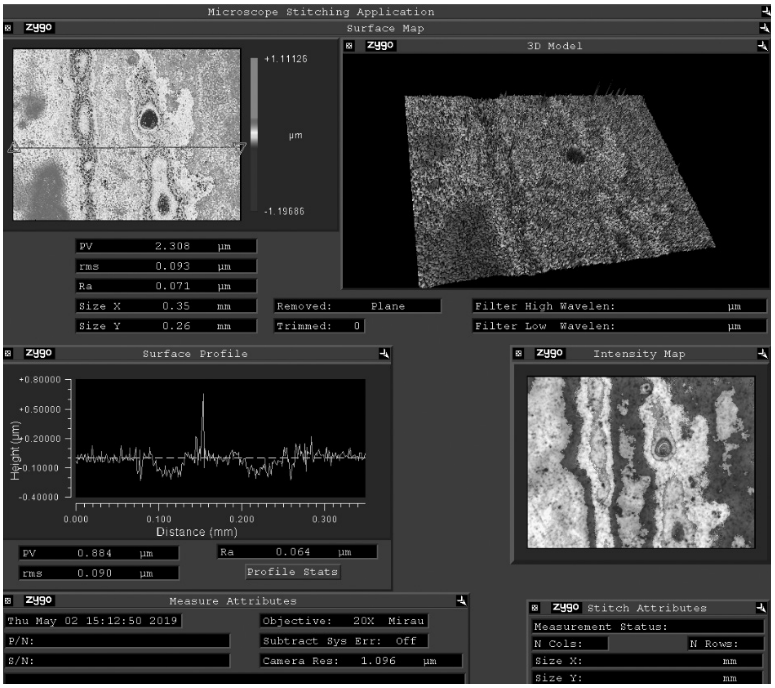

Figure 1: Surface roughness of niobium substrate after mechanical polishing. (Find full color on pages xiv-xv.)

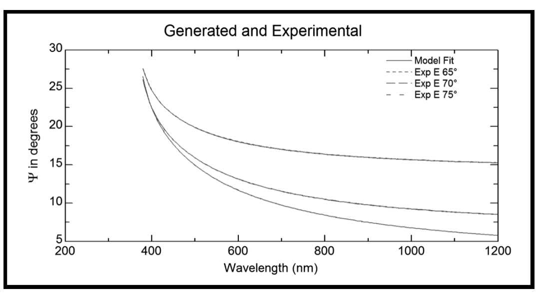

Figure 2: Ellipsometry modeling for determining the thickness of titanium nitride deposited by thermal atomic layer deposition.

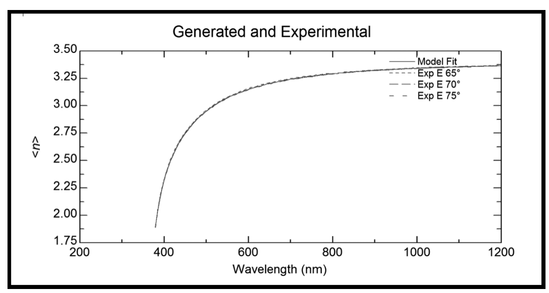

Figure 3: Refractive index of atomic layer deposited titanium nitride film.