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SAND2018-12269C

SNS Josephson junctions with tunable Ta_xN barriers

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Motivation:

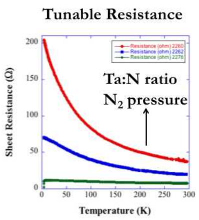
- Can Ta_XN offer advantages over AlO_X barriers?
- Thermal stability – can use optimized dielectric, potential for 3D scaling
- Barrier properties can be tuned – self shunting, may be less susceptible to electronic defects

➢ Explore Nb/Ta_xN/Nb SNS JJs grown at ambient temperature on SiO_2/Si substrates (for future scaling)

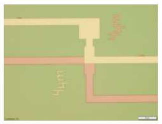
➢ Demonstrate avenue for ambient temperature, tunable, scalable process to address a variety of applications

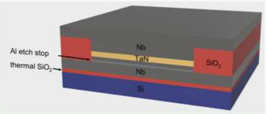
Approach:

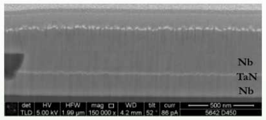
- High quality films and JJs previously demonstrated on crystalline substrates and/or with high temperature growth
- Single Ta_XN films on SiO_2/Si substrates are smooth, single phase and have tunable electronic properties



- Process has been developed for 150 mm sized wafers, leading to uniform thin film and junction properties across the wafer



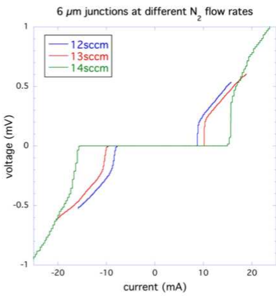


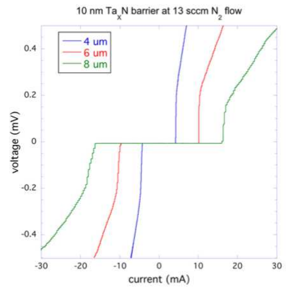


- Junctions with dimensions of 4 to 14 µm in diameter can be successfully fabricated, N_2 flow rates of 10-14 sccm during Ta_xN barrier growth with barrier thicknesses of 10-20 nm have been investigated

Low T Junction Properties:

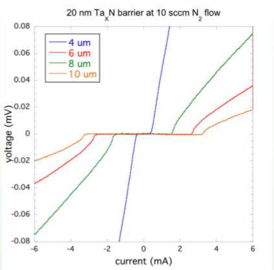
- Critical current I_c of junctions is evidently dependent on junction size
- Critical currents of 20 mA and more can be achieved
- Resistance increases with lower junction size

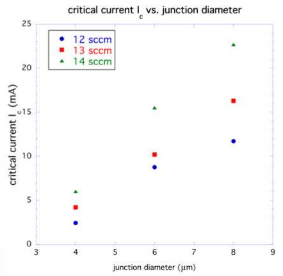




- I_c, as well as the resistance, are also significantly dependent on the N_2 flow rate
- Junctions exhibit critical current densities of 6kA/cm² for low N_2 flow rate samples to 12kA/cm² for high flow rate samples

- Nearly linear increase in I_c noticeable for various junctions sizes and employed N_2 flow rates
- I_cR_n products of on average 450 mV and up to 960 mV have been observed

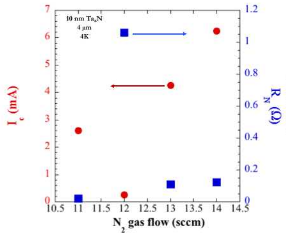


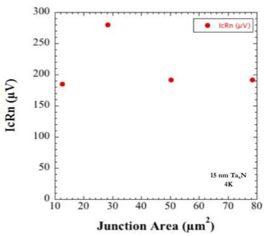


- I_c not only changes with N_2 flow rate and junction size, but also with barrier thickness
- Outliers occur on occasion as more statistical data is being collected (8 µm IV curve in left figure)

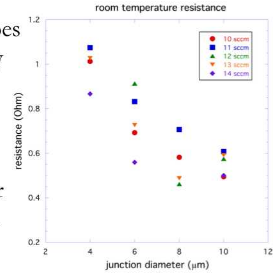
Future Directions:

- Overlap in properties between junctions with different N_2 flow rates and barrier thicknesses, as well as outliers, underlines issue in the ongoing study

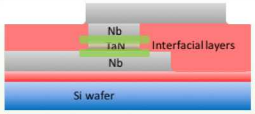




- Junction resistance does not scale monotonically with N content
- Room temperature resistance, an indicator for N content in barrier shows overlap between junctions



- This suggests interfacial layers through the removal of N from the Ta_xN barrier and the formation of the more stable NbN
- This uncontrolled process would result in the addition of a random series resistance in the Nb/Ta_xN/Nb stack



- Analysis of N distribution near interface using STEM/EDS cross-sectional imaging and SIMS depth profiling of possible interfacial layers is underway

This research is supported by the LDRD program at Sandia and the Office of the Director of National Intelligence (ODNI), Intelligence Advanced Research Projects Activity (IARPA). The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the ODNI, IARPA, or the U.S. Government.
The authors thank M. Manheimer and D. S. Holmes for their support.

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