Uniformity Analysis of Nanowires with Elemental Imaging

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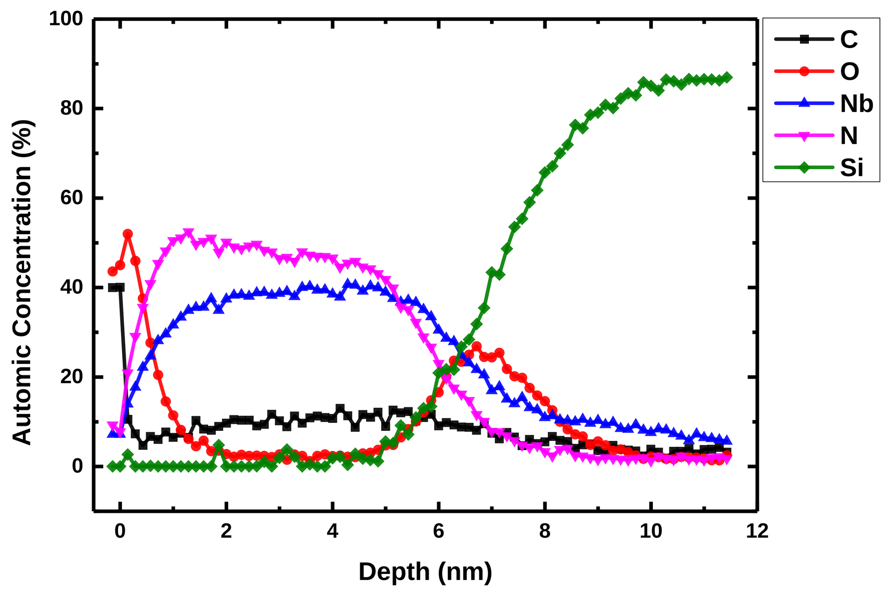
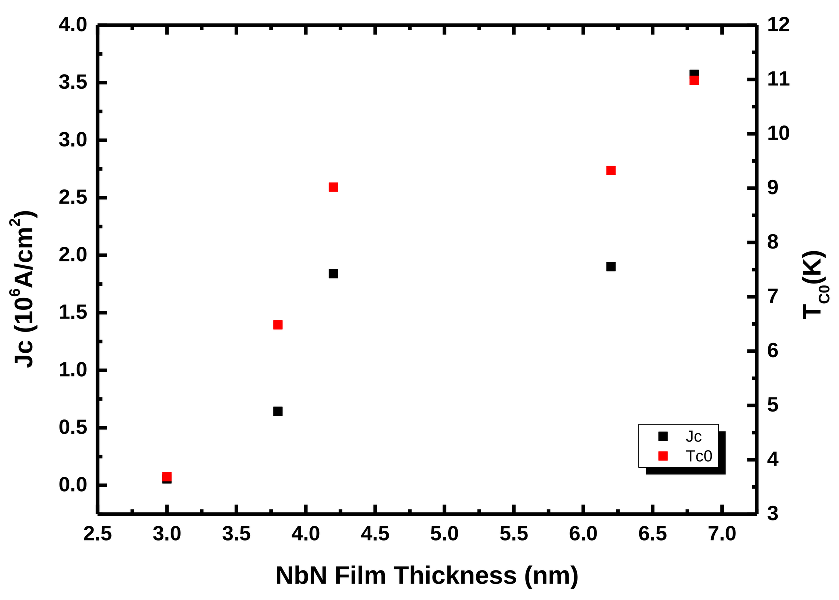
I. Introduction

Superconducting nanowire single photon detector (SNSPD) has the best overall performance among all the single photon detectors so far. The promising performance of SNSPD is based on the preparation of superconducting films and nanowires with high quality and homogeneity. To this end, we have optimized the preparation of plolycrystalline NbN nanofilms mainly by adjusting the substrate temperature and the comparison of properties with WSi films and NbN films prepared at ambient temperature have been made as well. NbN films used in our experiment are fabricated by DC magnetron sputtering on MgO(100) and Si(100) substrates with a 4 inch niobium target. WSi films on Si(100) substrates are prepared in a magnetron co-sputtering system at ambient substrate temperature. The critical temperatures Tc0 of 4nm-thick-film and 6nm-thick-film grown on Si(100) substrates at 600℃ reached 6.6K and 9.4K separately. With the help of Auger Electron Spectroscopy(AES), atomic force microscopy (AFM), transmission electron microscope (TEM), X-ray diffraction (XRD) and other analytical tools, the differences of property and composition of NbN nanofilms obtained at varied substrate temperatures have been observed. Furthermore, we present the elemental imaging of narowires with different widths on both NbN and WSi nanofilms in the interest of distribution uniformity.

II. Film Preparations

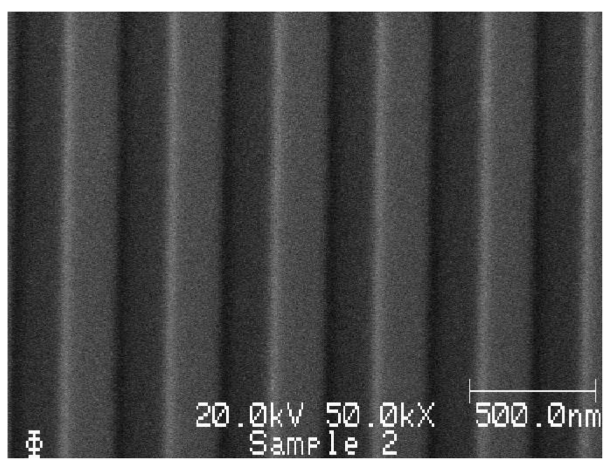


- The auger electron energy spectrometer of 6 nm thick NbN film on Si substrate prepared at 600℃.

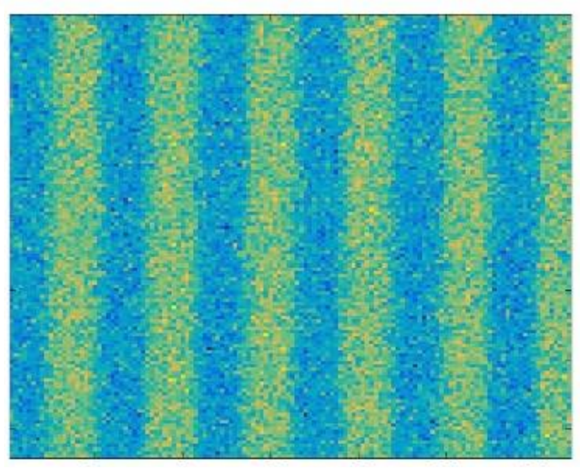


- The zero resistance critical temperature and the critical current density of NbN films on Si substrates prepared at 600 ℃ @ 4. 2 K versus NbN film thickness.

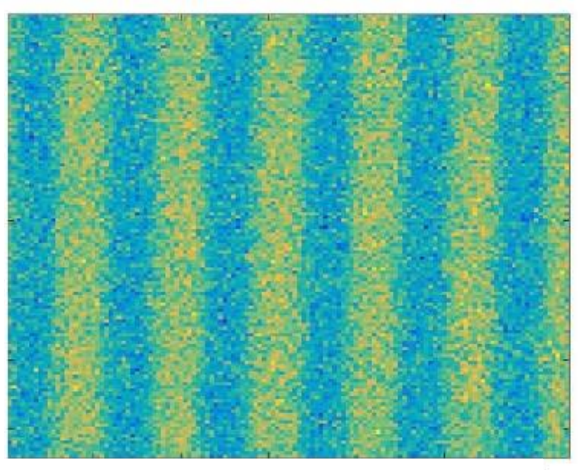
III. AES Imaging



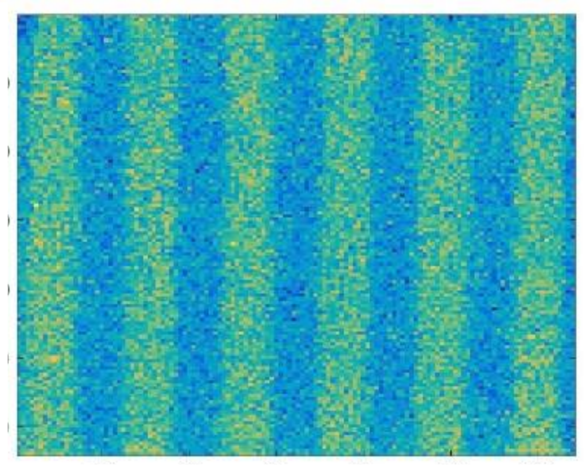
SEM



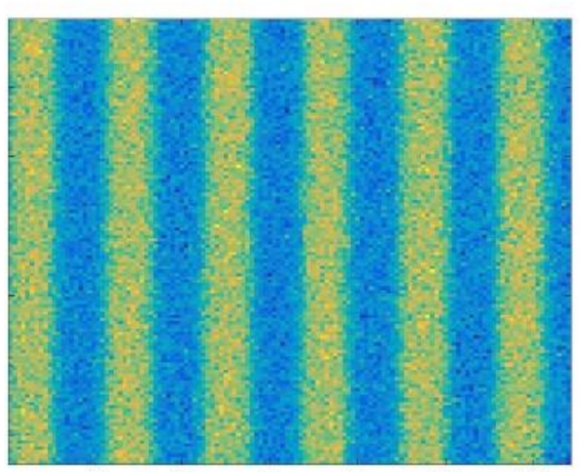
N



Nb



Si



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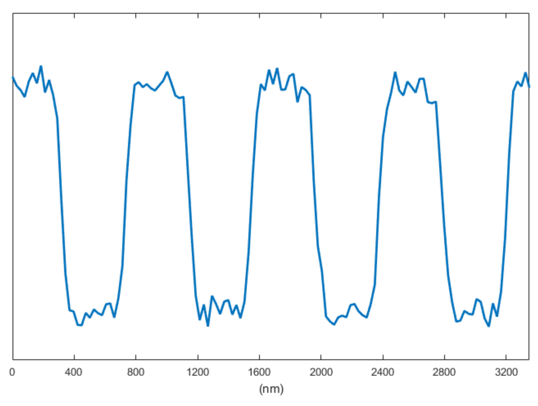
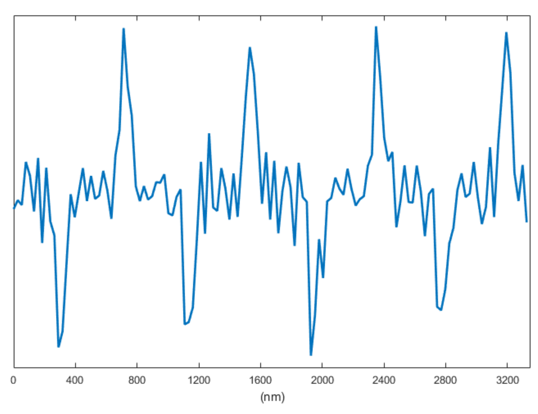
- The AES mapping has been done on NbN nanowires having thickness of 6 nm and width of 100, 200, 400 and 600 nm. The SEM picture shown here is of 200 nm wide.
- Scanning AES maps of elements N, Nb, O, Si of the selected area have been obtained for further analysis.

IV. Elements Distribution Analysis



Sum Along Lines

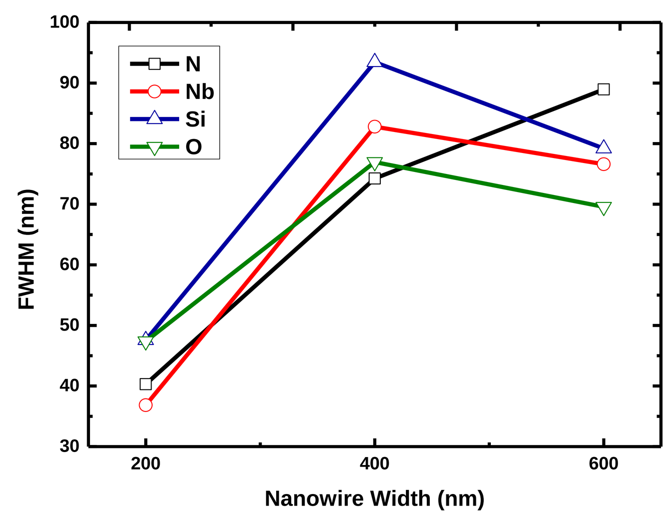


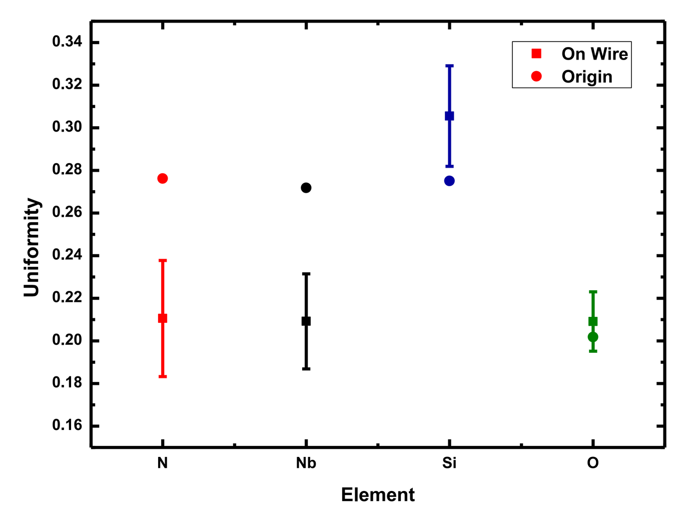
Derivative Curves

- Scanning AES maps show the relative elemental distributions (peak intensity) as a function of pixel position; that is, the greater the intensity, the brighter the pixel value.
- We use FWHM (Full Wave at Half Maximum) to represent the line edge roughness. Based on the mapping data, we calculate the derivatives of pixel values along the direction perpendicular to the nanowires. By calculating the FWHM values of the derivative curves, we can evaluate the edge roughness.

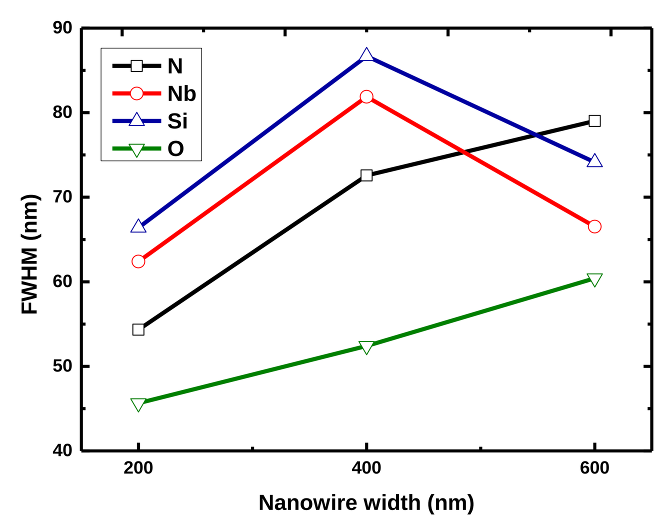
- $\text{Uniformity} = \dfrac{\text{Standard Deviation of the Pixel Values}}{\text{Mean of the Pixel Values}}$
- We use the ratio of STD and MEAN value to represent the uniformity of different elements on the nanowires and on the origin films.

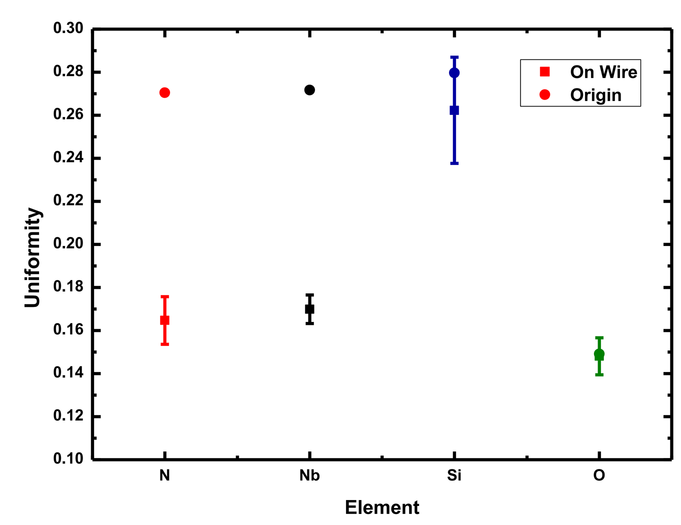
Nanowires of Ambient NbN Films





Nanowires of Heated NbN Films





V. Conculsion

- We optimized the fabrication process and obtained 6 nm NbN thin films with high quality (T_{c0}: 9.2 K) on heated Si substrate at 600 ℃. The analysis has been carried out on ambient NbN films and heated NbN films.
- With the AES imaging, we propose a new method to evaluate the line edge roughness and uniformity of nanowires in different scales with statistical data. The results show that the actual width of nanowires are smaller than that we designed or measured with SEM. The uniformity is also affected by the fabrication process.

References

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