



Focused Electron Beam Induced Etching of Superconducting and Semiconducting Materials and Devices

Philip D. Rack,^{*a} Kyle Sprecker,^a Spencer Gellerup^b, Steven Randolph^b

^a *University of Tennessee, Department of Materials Science and Engineering, Knoxville TN, USA;*

^b *Oak Ridge National Laboratory, Oak Ridge, TN, USA*

Niobium has the highest superconducting transition temperature ($T_c \sim 9\text{K}$) of all the elements and NbN has even higher T_c of $\sim 15\text{K}$. In this work, we explore focused electron beam induced etching (FEBIE) of Nb/NbN thin films with the XeF₂ precursor as a facile route to fabricate superconducting and quantum devices. To this end, we have studied the effect that current, dwell time, beam energy and XeF₂ flux have on the etching efficiency and rate. We perform detailed calculations to rationalize the synergistic effects of the XeF₂ mass transport (adsorption from gas phase), the electron beam induced reaction rate (dissociation and subsequent fluorination), and desorption (spontaneous and electron stimulated) and elucidate which mechanisms are rate limiting in the various processing regimes [1]. Finally, we optimize the line etch resolution and show that 17 nm line widths are possible. In addition, we study the Nb_xTi_{1-x}N system via a combinatorial thin film sputtering technique. Here, in addition to the scanning parameters, we measure the FEBIE etching rate as a function of chemical composition. Subsequent to the detailed mechanistic studies we fabricate superconducting devices and measure the relevant transport properties. We demonstrate Nb lateral Josephson junctions and variable resistance devices [2] and Nb_xTi_{1-x}N single photon detectors.

Additionally, we have investigated FEBIE of MoS₂ [3] and WS₂ [4] multilayer and single layer semiconducting materials. We have studied the etching efficiency and resolution as a function of the beam and gas parameters. We have also fabricated field effect transistors and edited the channel widths via FEBIE. We show that peripheral etching affects the devices and elucidate important electron-solid-precursor gas dynamics that affect the process.

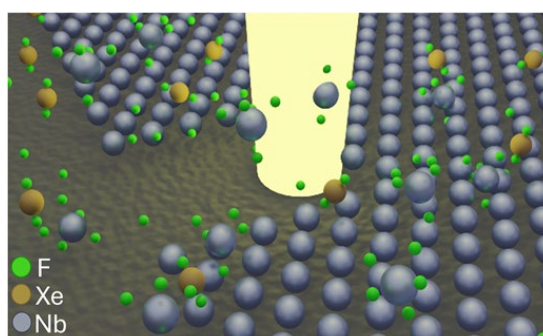


Figure 1. Schematic illustrating the FEBIE of Nb superconducting films [1].

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* Corresponding author: prack@utk.edu; phone | 865 974-5344;