Structural and electronic properties of NbN and III-N/NbN heterostructure grown by molecular beam epitaxy

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Abstract: We have investigated the growth of NbN thin films and the incorporation of NbN into III-N semiconductor heterostructures using nitrogen plasma-assisted molecular beam epitaxy. We demonstrate how the structural and electronic properties of NbN vary as a function of the growth parameters including the substrate material, the substrate temperature, the nitrogen plasma conditions, and the Nb flux. NbN thin films possess a metallic state resistivity of around 100μΩ-cm and transition to the superconducting state below 17K. We demonstrate that atomically smooth epitaxial NbN thin films can be grown on both 6H-SiC and GaN. We have also investigated the epitaxial growth of GaN and AlN on NbN films with the goal of integrating NbN into heteroepitaxial III-N devices, creating new opportunities to utilize both the metallic and superconducting properties of NbN in III-N electronic devices.

We observe 2D layer-by-layer growth of NbN for over 100 monolayers on 6H-SiC substrate as evidenced by RHEED intensity oscillations during growth, yielding atomically smooth epitaxial NbN films with monolayer step heights. We show that when grown on GaN, NbN will grow in a layer-by-layer mode only below a critical thickness of between 6nm and 9nm, at which point the growth transitions to a 3D growth mode. When GaN films are grown on NbN using the metal rich growth conditions typically used in MBE growth of GaN it is observed that GaN will not form a continuous film but rather segregates into islands on the NbN surface. Our effort to optimize the growth of III-N thin films on NbN is ongoing.

We use X-ray characterization to assess the structure of NbN films and NbN/III-N heterostructures. We characterize the crystalline quality of the films using the rocking curve measurement technique, finding full width at half maximum of NbN on 6H-SiC of 0.05^{o}. We also investigate variation in the measured out of plane lattice parameter of NbN over a large range, from 2.50Å to 2.56Å, a difference of 2.37%, depending on the MBE growth process.

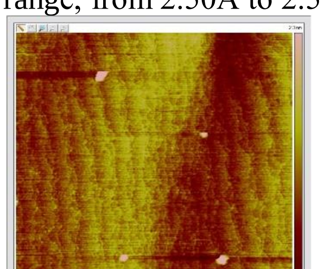

Figure 1: AFM surface height map of a $1\mu m^2$ area of a 3nm NbN film grown by PAMBE on GaN surface shows atomic steps on the NbN surface

Figure 2: Intensity of RHEED specular point during nucleation and growth of a 30nm NbN film on 6H-SiC substrate showing oscillations that correspond in period to the growth of a NbN monolayer, demonstrating that NbN is grown in a 2D layer-by-layer growth mode.

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