Heterogeneous Material Integration
Room Bansal Atrium - Session HM-MoP

Heterogeneous Material Integration Poster Session I

HM-MoP-1 Characterization of Sputtered P-Type Nickel Oxide for Ga_2O_3 Devices*, Joseph Spencer,* Naval Research Laboratory*; Y. Ma, B. Wang, M. Xiao,* Virginia Tech*; A. Jacobs, J. Hajzus,* Naval Research Laboratory*; A. Mock,* Weber State University*; T. Anderson, K. Hobart,* Naval Research Laboratory*; Y. Zhang,* Virginia Tech*; M. Tadjer,* Naval Research Laboratory

β-Ga_2O_3 is a promising UWBG (E_G = 4.8 eV) material in the field of power electronics. However, the flat valence band of β-Ga_2O_3 has prevented the realization of p-Ga_2O_3. Without shallow acceptor dopants and p-type conductivity in β-Ga_2O_3, the ability to fabricate high power homojunction devices (PN and JBS diodes) with appropriate field mitigation (guard rings, JTE) is not possible. While other WBG materials such as SiC and GaN can be doped to form p-type conductivity, Ga_2O_3 must rely on a heterojunction. A heterojunction device often exhibits interface traps that negatively impact device performance.

Nickel Oxide (NiO) is a cubic WBG (3.7 eV) p-type semiconductor [1] that is stable at room temperature and forms a favorable band offset to Ga_2O_3 [2]. Reactive ion sputtering is often used to deposit NiO thin films on Ga_2O_3; in our case, a NiO target was utilized to sputter at room temperature. Small changes in sputtering conditions and parameters such as deposition power and pressure, results in widely varying electrical and material properties of the NiO thin films, making characterization challenging. While accurate and repeatable values of N-$_A$ can be challenging, a better understand is crucial for device fabrication.

In this work we characterized room-temperature sputtered NiO thin films using electrical methods, ellipsometry, and X-ray photoelectron spectroscopy (XPS) in an attempt to understand the properties of the films. Variations in sputtering power, pressure, and oxygen partial pressure resulted in wide ranging electrical parameters. Most deposition conditions (Table I) result in low mobility (~1 $cm^2/(V{\cdot}s)$ and high sheet resistance (kΩ/sq – MΩ/sq) making Hall effect characterization difficult. Instead, we used Hg probe CV measurements to estimate free hole concentration ($p=N_A$), a critical parameter for device design (Fig 1). MOS capacitance structures and Hg probe CV show N_A values ranging over two order of magnitude (10^{17}-10^{19} cm^{-3}) stemming from variations in the oxygen partial pressure. As more oxygen is forced into the NiO, the amount of nickel vacancies (Ni^{3+}); the source of p-type conductivity, increases (Table 1). Other methods of NiO film characterization include ellipsometry and XPS. Ellipsometry is critical for investigating film quality, thickness, and band gap; while XPS has been used to observe the content of the Ni vacancies. We have also investigated ohmic contacts to NiO such as Ni, Pt, and PtOx (Fig. 2, Table 2), all of which produce Schottky contacts to Ga_2O_3. While p-type Ga_2O_3 remains unrealized, continued material research into NiO is critical for the advancement of Ga_2O_3 devices.

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