Electronic and Photonic Devices, Circuits and Applications
Room Bansal Atrium - Session EP-MoP

Electronic and Photonic Devices, Circuits and Applications Poster Session I

EP-MoP-2 Anisotropy Nature of NiO_x/β-Ga_2O_3 *p-n* Heterojunctions on (-201), (001), and (010) β-Ga_2O_3 Substrates*, Dinusha Herath Mudiyanselage*, *D. Wang, H. Fu,* Arizona State University

Recently, β-Ga_2O_3 has been extensively studied for power, optical, and RF electronics due to its large bandgap of 4.9 eV and high breakdown field of 8 MV/cm. However, most of the demonstrated devices are unipolar due to the lack of *p*-type Ga_2O_3, such as FETs and SBDs. This is primarily attributed to the absence of shallow acceptors in Ga_2O_3. As a solution, other *p*-type materials, such as NiO_x, have been utilized to produce β-Ga_2O_3 based *p-n* heterojunctions. Several NiO_x/β-Ga_2O_3 devices, such as *p-n* diodes and junction barrier Schottky diodes, have been demonstrated with excellent electrical properties. Moreover, due to its highly asymmetric monoclinic crystal structure, β-Ga_2O_3 exhibits anisotropic properties along different crystal orientations. However, the impacts of different β-Ga_2O_3 crystal orientations on NiO_x/β-Ga_2O_3 *p-n* heterojunction are still unclear. In this work, we perform a systematic study of NiO_x/β-Ga_2O_3 *p-n* heterojunctions on (-201), (001), and (010) crystal orientations. The EFG-grown β-Ga_2O_3 substrates were acquired with a similar *n*-type doping concentration and thickness. First, the substrates were cleaned using acetone, IPA, and DI water. The Ti/Au (20/130 nm) back contacts were deposited by E-beam evaporation followed by rapid thermal annealing at 500 °C in N_2. Then, standard photolithography was performed to define patterns for deposition of NiO_x and the anode. 200 nm NiO_x and the anode Ni/Ti/Au (20/15/100 nm) were deposited using E-beam evaporation, followed by a liftoff process to isolate devices. I-V and C-V measurements were performed using a 4200 SCS semiconductor parameter analyzer. All devices show an excellent rectification with on/off ratio $>10^9$. I-V measurements indicate a turn-on voltage of 2.09, 2.22, and 2.50 V, an ideality factor of 1.95, 2.03, and 2.13, and an on-resistance of 2.92, 1.55, and 6.50 mΩ.cm^2 for (-201), (001), and (010) devices, respectively. C-*f* measurements indicated an interface state density of 4.3×10^{10}, 7.4×10^{10}, and 1.6×10^{11} $eV^{-1}cm^{-2}$ for (-201), (001), and (010) plane devices, respectively. Furthermore, the reverse recovery of the diodes shows a slight difference between (-201) [or (001)] and (010) devices due to the anisotropic nature of β-Ga_2O_3. These differences in the electrical properties are attributed to the different atomic configurations, the density of dangling bonds, and conductivity-modulated hole injection into β-Ga_2O_3. Further investigation through temperature-dependent measurements will reveal more information about the anisotropic nature of NiO_x/β-Ga_2O_3 *p-n* heterojunctions.

EP-MoP-3 Ultrathin Films of Amorphous Gallium Oxide for Ultra-Fast Solar-Blind Photodetectors*, Damanpreet Kaur*, *M. Kumar,* Indian Institute of Technology Ropar, India

In addition to stable and meta-stable crystalline phases of Ga_2O_3, its amorphous phase is also being explored for various applications owing to its technological advantage like room temperature and large area growth for next generation solar-blind photodetectors .[1] But being often sub-stoichiometric and replete with oxygen vacancies, performance of amorphous thin film PDs is far below their crystalline counterparts. Hence, novel methods and techniques need to be adopted to improve performance of such devices.[2] Herein, we report one such method where ultra-thin films of amorphous Ga_2O_3 are deposited on nanopatterned SiO_2 coated Si substrate. Controlled nanopatterns or ripple formation is carried out by irradiating SiO_2/Si substrate with 500eV Ar^+ ions for variable times. Morphology of ripples formed on substrate is studied using AFM images to calculate the characteristic wavelength and Power Spectral Density. Amorphous Ga_2O_3 (~5nm) is then sputtered onto these rippled substrates using RF Magnetron Sputtering at room temperature. Uniformity of Ga_2O_3 is confirmed by EDX elemental mapping studies. Reflectance measurements were carried out using UV-Vis spectroscopy and results showed lower reflectance as compared to non-rippled because of the enhanced absorption due to multiple scattering by the substrate and enhanced surface area. FDTD was used to simulate reflectance measurements which are well in agreement with experimental results.

The performance of subsequently fabricated photodetectors showed that conformally coated devices had an enhanced performance as compared to non-rippled “bare” device. The solar-blind PDs show an increase in the responsivity from ~3 mA W^{-1} to 433 mA W^{-1} – an increment of more than 140 times at +5V. For the response times, bare device shows slow rise/fall time of 0.37s /0.39s whereas the conformal devices showed an ultrafast rise time of 896µs and fall time of 710µs, respectively, to 254 nm incident light. The detailed analysis showed that the device performance can be attributed to the incorporation of elemental Si from the substrate below, the presence of which is confirmed by XPS. This study shows how amorphous Ga_2O_3 films can be used to fabricate ultra-fast devices, especially for next-generation solar-blind PD applications.

References:

1. Kaur, D. and M. Kumar, *A Strategic Review on Gallium Oxide Based Deep-Ultraviolet Photodetectors: Recent Progress and Future Prospects.* Advanced Optical Materials, 2021. **9**(9): p. 2002160.
2. Kaur, D., et al., *Surface nanopatterning of amorphous gallium oxide thin film for enhanced solar-blind photodetection.* Nanotechnology, 2022. **33**(37): p. 375302.

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