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Electronic Transport and Breakdown Phenomena
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Electronic Transport and Breakdown Phenomena Poster Session

ET-MoP-2 Electric Field Mapping in β-Ga_2O_3 by Photocurrent Spectroscopy, ***Darpan Verma**, M. Adnan, S. Dhara,* Ohio State University*; C. Sturm,* Universitat Leipzig, Germany*; S. Rajan, R. Myers,* Ohio State University

Power electronics devices suffer from unexpected field non-uniformity, and high field often degrades these devices by limiting their lifetime. Electric-field mapping could aid in the design of device features non-destructively by identifying breakdown regions. We will discuss progress in developing an E-field mapping technique that can spatially map out the E-field maxima in β-Ga_2O_3 space charge regions and could identify E-field hotspots at which the breakdown is likely. Previously, we showed that the Exciton Franz-Keldysh (XFK) effect can be used to estimate the local E-field maximum in (010) β-Ga_2O_3 Schottky diodes based on the redshift of the photocurrent spectral peak.[1] In that study, we implemented an XFK model using an analytical approximation for the XFK effect based on the modified Wannier-Mott model. Here, we extend these measurements to higher photon energies (< 5.6 eV) in (001) β-Ga_2O_3 Schottky diodes, and observe a total of three absorption peaks whose intensity varies with the angle of the linear polarization of the monochromatic UV light incident on the device. The three peaks at 4.9 eV, 5.2 eV and at 5.5 eV, match quasi-particle-DFT transitions as well as measurements in β-Ga_2O_3 from previous studies[2,3]. Peaks at 4.9 eV and 5.2 eV correspond to excitons polarized within the a-c plane, and the peak at 5.5 eV corresponds to exciton along the b axes. These peaks red shift with bias and can be calibrated to serve as an E-field sensors. A well-calibrated vertical Schottky barrier diode was fabricated on a 10um thick HVPE grown (001) β-Ga_2O_3 epitaxial layer (N_D=1.5E16/cm^3). For the top Schottky contact, a circular Pt (5nm) layer was deposited by E-beam evaporation. Further, leaving the center of the Pt layer exposed for light illumination, a circular ring (overlapping the thin Pt layer) with a contact pad was fabricated using Pt/Au (30/70nm). Afterward, an ohmic back contact of Ti/Au (30/70nm) was blanket deposited. At this structure, the parallel-plate electric field can be theoretically estimated to calibrate the redshift of the photocurrent peaks to E-field values and convert the spatially-resolved photocurrent spectra into mapped E-field values across the whole device active region.

References:

[1] M.M.R. Adnan, D. Verma, Z. Xia, N.K. Kalarickal, S. Rajan, and R.C. Myers, Phys. Rev. Appl. **16**, 1 (2021).

[2] J. Furthmüller and F. Bechstedt, Phys. Rev. B **93**, 1 (2016).

[3] C. Sturm, R. Schmidt-Grund, C. Kranert, J. Furthmüller, F. Bechstedt, and M. Grundmann, Phys. Rev. B **94**, 1 (2016).

ET-MoP-3 Activation of Si, Ge, and Sn Donors in High-Resistivity Halide Vapor Phase Epitaxial β-Ga_2O_3:N, ***Joseph Spencer**,* Naval Research Laboratory/ Virginia Tech CPES*; M. Tadjer, A. Jacobs, M. Mastro, J. Gallagher, J. Freitas, Jr,* Naval Research Laboratory*; T. Tu, A. Kuramata, K. Sasaki,* Novel Crystal, Japan*; Y. Zhang,* Virginia Tech (CPES)*; T. Anderson, K. Hobart,* Naval Research Laboratory

With an ultra-wide bandgap (4.8eV), high critical field (6-8MV/cm) and melt-growth capability, the popularity of Gallium oxide (GO) has surged within the material growth and electronic device fields. Even with an UWBG, dopants such as Si and Sn have been shown to be shallow donors (30 and 60meV, respectively) [1-2]. It has also been demonstrated that the addition of nitrogen acceptors allows for the UID level to fall as low as $10^{14}cm^{-3}$, extending the doping range of GO by over an order of magnitude [3,4]. The inclusion of N also results in a highly resistive current blocking layer (CBL) in GO due to the deep acceptor state formed by the N dopants. In this work we demonstrate how implanted donors can overcompensate the highly resistive GO:N CBL, resulting in highly conductive films while the unimplanted regions remain highly resistive.

Halide vapor phase epitaxial (HVPE) films were grown on semi-insulating (001) GO:Fe substrates. Prior works [5] characterized the films using Secondary ion mass spectroscopy (SIMS) to confirm the presence of the N acceptor and 9.2 µm thickness. C-V measurements showed a net free carrier concentration below the detectable limit of 10^{14} cm^{-3} (N_D-N_A). Lateral Schottky diodes showed breakdown voltages that surpassed 2kV for the resistive films [5].

Linear/circular transfer length method (LTLM/CTLM) and van der Pauw (VdP) structures were patterned for donor implantation. Si, Ge, and Sn donors were implanted with a box profile of 100nm at a dose of $3.3^{14}cm^{-2}$. Implanted donors were activated with a rapid thermal anneal (RTA) at 925C for 30min in N2. The LTLM/CTLM and VdP structures were isolated using an 800W BCl_3 reactive ion etcher for a 150nm etch. Ti/Au ohmic contacts were deposited followed by a contact anneal.

A contact resistance (R_c) of 1.2 Ωmm and 2.3 Ωmm for the Si and Sn implanted samples, respectively was measured from LTLM/CTLMs. Temperature dependent Hall effect measurements (15-300K) gave the sheet carrier concentration (n_s), sheet resistance (R_{sh}), and mobility (µ). Hall structures that did not receive implantation of the active region between the ohmic contacts could not be measured due to excessive resistance demonstrating retention of N doped film resistivity. Full implanted VdP structures were highly conductive and measurable. At 300K, the Si, Ge, and Sn doped samples achieved mobilities, sheet resistances, and sheet electron densities of 86, 71, and 59 cm2/Vs, 324, 941, and 1750 Ω/sq, and 2.25e14, 9.3e13, and 6.0e13 cm^{-2} respectively. The implant activation efficiency was found to be 66%, 28%, and 18% for Si, Ge, and Sn, respectively. See supplemental page for references.

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