Two-dimensional electron (2DEG) and hole (2DHG) gases onto β-Ga_2O_3

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A new generation of UWBG semiconductors will open new territories for higher power rated power electronics and solar-blind deeper ultraviolet optoelectronics. Gallium oxide - Ga2O3 (4.5-4.9 eV), has recently emerged pushing the limits set by more conventional WBG (~3 eV) materials such as SiC & GaN as well as for transparent conducting oxides (TCO) like In2O3, ZnO and SnO2 to name a few.

While there are several *n*-type transparent semiconductor oxides (TSO) for optoelectronic applications their required *p*-type counterpart oxides are known to be more challenging. We have demonstrated that Ga2O3 is also the intrinsic (or native) *p*-type TSO. [1]

In 2019, we first reported [2] a two-dimensional electron gas (2DEG) onto beta-Ga_2O_3, a solid that is a pure insulator in its bulk but has a metallic conductive termination presenting a two-dimensional conductive channel at its surface. β-Ga_2O_3 thin films exhibited degenerate semiconductor conduction with a room temperature $n = 8\times10^{18}$ cm^{-3} electron concentrations and $\mu = 19$ cm^2/Vs Hall electron mobility. Under the Thomas-Fermi approximation, the sheet charge concentration of the 2DEG is $n_s \sim 2\times10^{14}$ cm^{-2}. This 2DEG was found to be resistant to high dose proton irradiation (2 MeV, $5 \times 10^{15} cm^{-2}$ dose) and was largely invariant (metallic) over the phenomenal temperature range of 2 K -850 K. In 2023, we first reported [3] a two-dimensional hole gas (2DHG) onto beta-Ga_2O_3. Although two-dimensional electron gases have been realized in a number of semiconductor surfaces, examples of two-dimensional hole gases (2DHG) - the counterpart to 2DEG - are still very limited. In this work, we report what appears to be an exceptional *p*-type 2DHG surface on a Si-doped monoclinic (010) β-Ga_2O_3 epitaxial films which are *n*-type in the bulk. The majority of the free carries at the surface have been determined to be holes with a sheet concentration of $p \sim 8.7\times10^{13}$ cm^{-2} and a puzzlingly high mobility value of $\mu_h \sim 80$ $cm^2/(V\cdot s)$ at room *T*.

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2. E. Chikoidze, D. J. Rogers, F. H. Teherani, C. Rubio, G. Sauthier, H. J. Von Bardeleben, T. Tchelidze, C. Ton-That, A. Fellous, P. Bove, É. V Sandana, Y. Dumont, A. Perez-Tomas, Materials Today Physics, 8, 10 (2019).
3. E. Chikoidze, J. Leach, Z. Chi, J. von Bardeleben, B. Ballesteros, A.-M. Gonçalves, T. Tchelidze, Y. Dumont, A. Pérez-Tomás, Journal of Alloys and Compounds, 271, 172713 (2024).