Dualtronics: leveraging both faces of polar semiconductors

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For at least the last forty years, gallium nitride (GaN) has continuously attracted increasing interest from scientists and engineers. This is mainly due to the wide range of applications for GaN and its related ternary alloys (In,Ga)N and (Al,Ga)N, including light emitters covering a wide spectral range from visible to ultraviolet light, as well as high-power transistors and radio-frequency transistors.
An important material property of III-nitrides utilized in heterostructure design is the built-in polarization. Since GaN primarily crystallizes in the wurtzite structure, which breaks inversion symmetry along the c-axis [0001], opposite surfaces along this direction exhibit drastically different physical and electronic properties. This fact can be leveraged for specific applications. However, since polarization is dictated by the substrate polarity, until now, the use of a single wafer implied only one alignment of polarization in the devices grown on top of it.
In this work, we propose leveraging the unique advantages of the GaN material system, its wide range of applications, and the support of high-quality bulk substrates to develop a new method for monolithic integration of electronic and optoelectronic devices on the same wafer. By utilizing consecutive epitaxial growth processes on both polarities of GaN substrates, i.e., the gallium face (0001) and nitrogen face (000-1), it is possible to achieve structures with distinct physical and chemical properties on the same bulk crystal.
We demonstrate the ability to control epitaxial growth on both polarities of GaN by plasma-assisted molecular beam epitaxy, presenting the monolithic integration of a metal-polar light-emitting diode (LED) and a nitrogen-polar high electron mobility transistor (HEMT)[1], as well as a double-sided LED (see Fig. 1.). The obtained integrated structures can pave the way for new device functionalities.

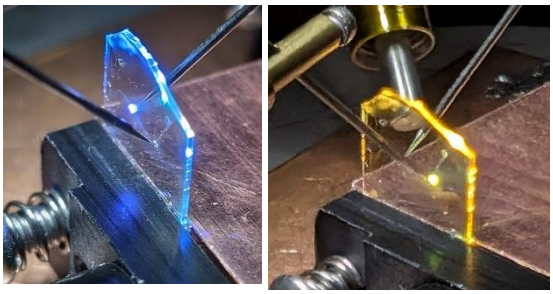

Fig. 1. Real-color electroluminescence images obtained for the double-sided sample with LED structures grown on both sides. The images were captured under positive bias applied to the (a) Ga-polar and (b) N-polar surfaces, each emitting at different wavelengths due to the varying chemical compositions of the grown active regions.

[1] L. van Deurzen, E. Kim, N. Pieczulewski, Z. Zhang, A. Feduniewicz-Zmuda, M. Chlipala, M. Siekacz, D. Muller, H.G. Xing, D. Jena, H. Turski, *Dualtronics: leveraging both faces of polar semiconductors*, in, (2024), pp. **arXiv:2404.03733**.