

# Study of plastic deformation and fracture of polar and nonpolar GaN single crystals: A multiscale approach

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Quasi-static nano-indentation and static micro-indentation techniques were utilized to induce localized deformation on polar  $c$ -plane (0001) and nonpolar  $m$ -plane ( $\bar{1}010$ ) surfaces of GaN single crystals. Both samples were studied for two orientations of Berkovich and Vickers indenter tips, in order to study the effect of crystal anisotropy on the plastic and elastic behaviour. It was found that fracture behaviour is more sensitive to the orientation of the indenter tip, compared to plastic behaviour. The indentation-induced plastic deformation was studied by cathodoluminescence imaging (Figure 1, left). Polar GaN was harder than  $m$ -plane GaN at the nano-scale, while marginally harder at the micro-scale. Pop-in discontinuities were narrower at  $c$ -plane than  $m$ -plane GaN (Figure 1, right), following an analogous behaviour compared to polar and nonpolar GaN thin films [1]. Dislocation arrangements were more isotropic at the  $c$ -plane than the nonpolar  $m$ -plane orientation, since dislocations propagate along the basal plane alone, at both cases. Polar GaN was more susceptible to crack initiation compared to  $m$ -plane, when indented with a Vickers indenter. Nano-indentation did not produce cracking at both samples and indenter orientations. Micro-indentation fostered radial and lateral crack formation at both indenter orientations at polar GaN. Lateral cracks did not reach the surface, i.e. they did not produce surface flaking as in the case of heavily damaged GaN thin films [2].

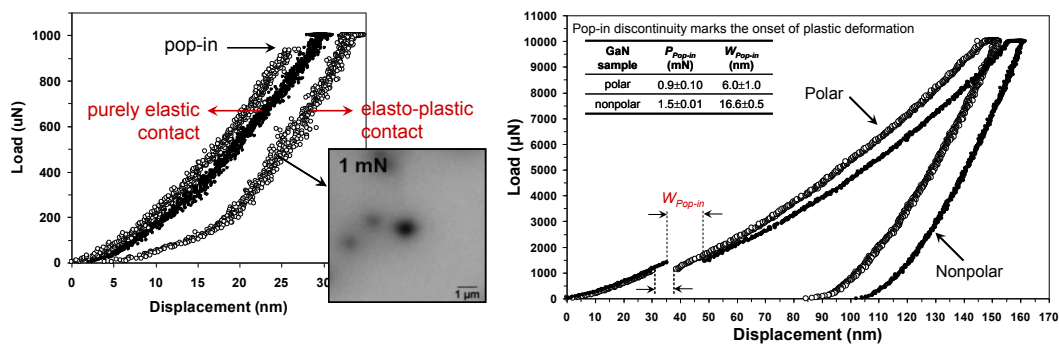


Figure 1: (Left) Load-displacement curves for polar GaN sample at  $0^\circ$  tip orientation for maximum load of  $10^{-3}$  N. Solid circles correspond to purely elastic contact. Open circles correspond to elasto-plastic contact. The inset contains the indentation print left by the elasto-plastic indentation as recorded by CL imaging. (Right) Load-displacement curves for polar and nonpolar GaN samples at  $0^\circ$  tip orientation for maximum load of  $10^{-2}$  N.

## References

- [1] Kavouras *et al.*, Phys. Stat. Sol. A **210**, 213 (2013).
- [2] Kavouras *et al.*, Thin Solid Films **515**, 3011 (2007).

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