# The role of defects in ion induced $\beta$-$Ga_2O_3$ to $\gamma$-$Ga_2O_3$ conversion

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Gallium oxide ($Ga_2O_3$) is a highly versatile material with applications in power electronics, optoelectronics, and battery technologies. Among its polymorphs, monoclinic $\beta$-$Ga_2O_3$ is the most chemically and thermally stable phase. However, controlling the metastable polymorph phases remains challenging, and fabrication technologies for nanoscale structures are still under development. This study aims to enhance the understanding of polymorph conversion mechanisms and to establish novel fabrication techniques for single-phase polymorph films, buried layers, multilayers, and various nanostructures of $Ga_2O_3$.

We investigate $\beta$-$Ga_2O_3$ samples irradiated with different ions and fluences, as well as $\alpha$- and $\kappa$-$Ga_2O_3$ thin films. Broad beam (BB) ion irradiation was employed to induce phase transformations in the near-surface region. The irradiated samples were characterized using transmission electron microscopy (TEM) and X-ray diffraction (XRD) to analyze structural changes. Complementary experiments using Positron Annihilation Lifetime Spectroscopy (PALS) and Doppler Broadening Variable Energy Positron Annihilation Spectroscopy (DB-VEPAS) provided insights into defect types and concentrations.

Our results reveal the evolution of defect types and densities based on DB-VEPAS and positron lifetime measurements. During the phase transition from $\beta$- to $\gamma$-$Ga_2O_3$, a significant reduction in positron trapping sites is observed, indicating a decrease in defect density in the newly formed $\gamma$-$Ga_2O_3$ layer compared to the highly irradiated $\beta$ material. This observation aligns with previously reported high radiation hardness of $Ga_2O_3$ [1].

Additionally, we employed Neon-based helium ion microscopy to investigate the minimal achievable polymorph feature size, exploring the feasibility of

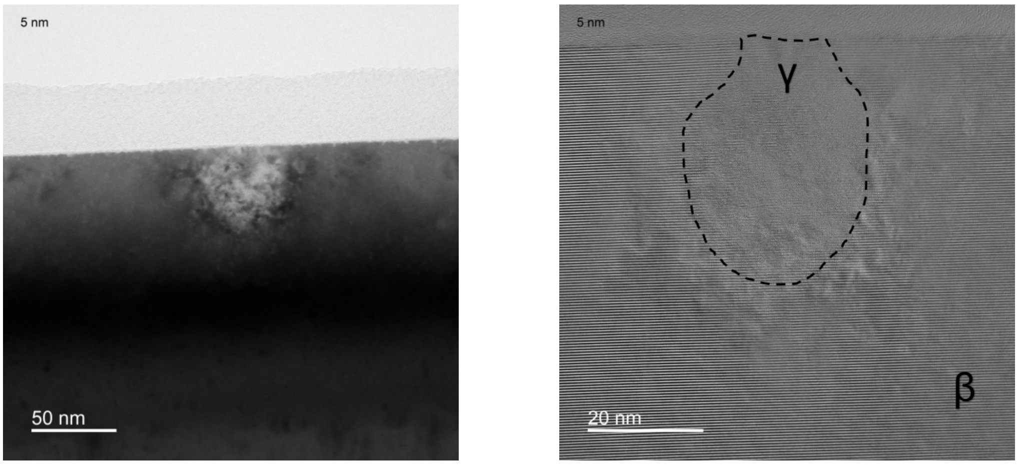


Figure 1: Dark field and high-resolution TEM images of a $20\,\mathrm{nm}$ wide $\gamma$-$Ga_2O_3$ line embedded in $\beta$-$Ga_2O_3$. The line was created using a $25\,\mathrm{keV}$ focused Neon beam from a gas field ion source (GFIS).

future polymorph-based devices (see Figure 1).

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# References

[1] A. Azarov, J. G. Fernández, J. Zhao, F. Djurabekova, H. He, R. He, Ø. Prytz, L. Vines, U. Bektas, P. Chekhonin, N. Klingner, G. Hlawacek, and A. Kuznetsov, Nature Communications **14**, 4855 (2023), arXiv:2303.13114 [cond-mat.mtrl-sci] .