Evolution of Dislocations in GaAs Wafers Investigated by Means of X-ray Diffraction Imaging

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Gallium arsenide (GaAs) is one of the most important materials for optoelectronics due to its suitable material properties like direct band gap and high electron mobility [1]. However, during industrial fabrication, the presence of crystal defects like dislocations can drastically influence the fabrication yield and the performance of the devices obtained [2]. In particular, thermal treatments as typical for wafer processing can trigger dislocation nucleation at mechanical surface damage sides, followed by slip band formation and propagation into distant regions, where local electronic and mechanical properties are influenced. Therefore, understanding the temporal evolution of such mobile crystalline defects is both a scientific and industrial concern.

Here, 2D and 3D synchrotron X-ray diffraction imaging methods, namely conventional X-ray white beam topography (XWBT) and recently developed X-ray diffraction laminography (XDL) [3] were employed. The non-destructive nature of these techniques allowed time-resolved quasi *in situ* studies with µm resolution also for industrially relevant sample volumes (mm-sized) like typical wafers. To emulate typical industrial manufacturing processes, the investigated GaAs wafers were mechanically micro-indented in a controlled and well-defined way, and they were subsequently annealed at temperatures above the brittle-to-ductile transition. For this, a well-characterized and calibrated double ellipsoidal mirror heater was used to emulate typical conditions expected during device fabrication. The topographic measurements were performed alternating with these thermal treatment steps, thus following the development of dislocations.

The presented study aims on providing a deeper understanding of dislocation generation and development in GaAs wafers with mechanical surface damage exposed to thermally induced stress, see Fig. 1. Our results provide insight into the development of dislocation arrangements on different {111} <110> glide systems, by the systematic variation indentation and heating geometries enabling conclusions on the influence of thermal gradients as well as crystal polarity. Moreover, XDL studies allow us to investigate the expansion of individual dislocations into the crystal bulk, enabling us to propose a general model for the involved 3D movements.

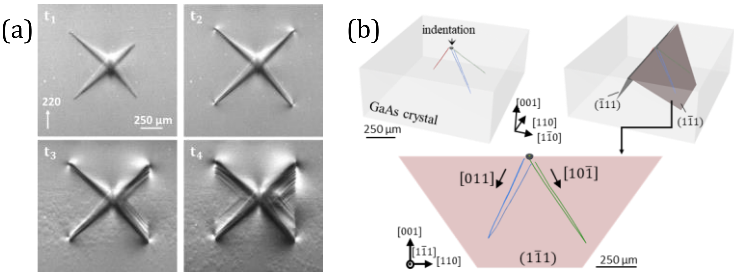

Figure 1: (a) X-ray white beam topographs showing the evolution of dislocations around an indentation during gradual heating, (b) 3D visualization of individual dislocations in the crystal bulk, obtained by X-ray diffraction laminography.

[1] J. Yoon *et al.*, Nature, 465, 219-333 (2010)
[2] P. Möck *et al.*, Material Science and Engineering B80, 91-94 (2001)
[3] D. Hänschke *et al.*, Applied Physics Letters, 101, 244103 (2012)

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