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SWBXT Characterization of Bulk AlN Crystals Grown by the Sublimation-Recondensation Technique

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Beamline(s): X19C

Introduction: Aluminum nitride (AlN) is increasingly attracting interest as a substrate for electronic and opto-electronic devices based on III-nitride compound semiconductors due to its excellent properties and the feasibility of producing large bulk single crystals.

Methods and Materials: AlN boules were grown by the sublimation-recondensation technique, first developed by Slack and McNelly [1,2]. In this method, a thermal gradient drives the sublimation of polycrystalline AlN starting material and recondensation occurs at the colder part of the crucible as a single crystal. A relative movement between the thermal gradient and the crucible sets the driving rate (0.9mm/hr used here). Since no seed is used, several nuclei form during the first stage of the growth process on the crucible walls and these nuclei compete as the growth run proceeds. Wafers cut from AlN boules and polished by CMP were characterized by synchrotron white beam x-ray topography (SWBXT) using a combination of back reflection and transmission geometries. Results from one particular AlN wafer are presented here.

Results: Figure 1(a) shows an optical photograph of a polished AlN wafer. An x-ray diffraction pattern recorded from the wafer shown in Figure 1(b) indicates the presence of three single crystal grains labeled 1, 2 and 3 and a polycrystalline region labeled 4. Area of polycrystalline region decreases down the length of the boule. This behavior is advantageous to growing self-seeded crystals. X-ray topographs recorded from the three grains indicate a high degree of structural perfection. A high magnification topograph from the largest grain, shown in Fig. 2, reveals groups of dislocations with a local density of around 10^3-10^4 cm^{-2}. Regions in between those indicated by G have dislocation densities that are lower by at least two orders of magnitude. The original nucleation source for the dislocations, from which the multiplication occurs, appears to be closely associated with the region of high deformation observed in the topograph. The dislocation configurations are clearly the result of plastic deformation processes [3,4] which must occur away from the growth interface and, therefore, after the growth process. Largest stresses are expected during post-growth cooling, most probably due to thermal expansion mismatch between crucible and the boule, as indicated by the high deformation areas (D) in the periphery of the crystal.

Conclusions: Self-seeded sublimation-recondensation technique has been used successfully to grow 15mm diameter AlN boules containing large single crystal grains and SWBXT studies reveal that an average density of dislocations of the order of 10^3-10^4/cm^2 can be achieved using this growth technique.

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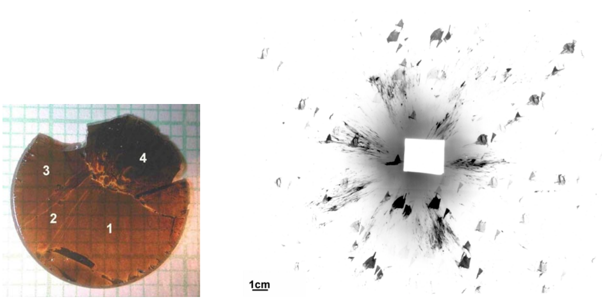

(a) (b)

Figure 1. (a) Optical photograph of AlN wafer and (b) Transmission x-ray diffraction pattern showing orientation contrast between different regions.

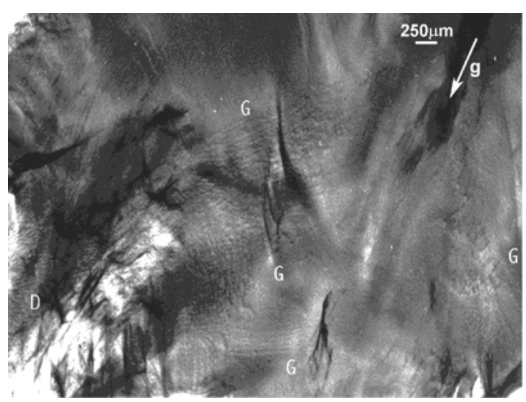

Figure 2. High magnification transmission x-ray topograph from grain **1** showing groups of dislocations G nucleated from highly deformed region D.