

Characterization of Defect and Strain Configurations in Langatate Single Crystals Using SWBXT

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Introduction: The recent progress of electronic technology towards higher frequencies and larger baud rates had led to the interest of finding new piezoelectric materials which realize filters with larger pass band widths and oscillators with larger shifts or larger frequency stability. For designing such devices, it is necessary to discover new piezoelectric crystals having intermediate properties between those of quartz and lithium tantalate (LiTaO_3). Langatate or LGT ($\text{La}_3\text{Ga}_{5.5}\text{Ta}_{0.5}\text{O}_{14}$), along with Langasite or LGS ($\text{La}_3\text{Ga}_5\text{SiO}_{14}$) and Langanite or LGTN ($\text{La}_3\text{Ga}_{5.5}\text{Nb}_{0.5}\text{O}_{14}$), is of current interest for application to above-mentioned devices with high piezoelectric coupling, low acoustic loss (high Q) and temperature compensation. It's also generally accepted that crystal defects, such as dislocations and striations can influence mode shapes in such single crystal resonators.

Methods and Materials: Synchrotron White Beam X-ray Topography (SWBXT) has been used to characterize defect and strain configurations in Langatate single crystals, which were obtained by the Czochralsky method. Wafers sliced from as-grown crystals have been examined using SWBXT. Topographs were recorded under transmission geometry.

Results: Figure 1 is a SWBXT image recorded in transmission geometry ($\mathbf{g}=002$) from set 2 Langatate wafer. Well-defined set of concentric striation rings can be observed in wafers from set 2. The striation contrast visible on these wafers is much clearer than that visible on set 1 wafers. Several bands marked as B are visible running across the middle section of the sample (shown in Fig. 2); these could possibly be dislocation slip bands. Interface breakdown and irregularity of interface shape is clearly revealed in the core region (shown in Fig. 3). Numerous band-like nearly white contrast segments D, likely to be dislocations running through the wafer from bottom to top (shown in Fig. 4) are observed. Numerous precipitates or inclusions are also observed.

Conclusions: The concentric striations indicate and prove that the growth interface of the crystal is either concave or convex, rather than flat, and indicate the presence of slight lattice parameter fluctuations during the crystal growth process. The spacing of the concentric striation rings reveals the periodicity of the striations, which indicates the periodicity of fluctuations during growth. The concentric striation rings are not quite symmetric which reveals an asymmetry in the thermal field inside the growth chamber. Irregular striation rings in the center of the crystal indicate uneven growth near the core of the crystal; possible interface breakdown close to the crystal core is also observed. The asymmetry of the interface shape in the central region is apparently propagated throughout the crystal, which indicates the uneven growth throughout the whole crystal growth process. This central region is invariably surrounded by slip bands and generally is the region with highest dislocation density, further emphasizing the lower crystal quality in this region. These slip bands are possibly generated by the thermal stresses, which accompany the irregular interface shape and growth in this region. Precipitates or inclusions can be observed in every sample. These are mainly distributed around the core area, providing the further evidence of inhomogeneous growth in this region.

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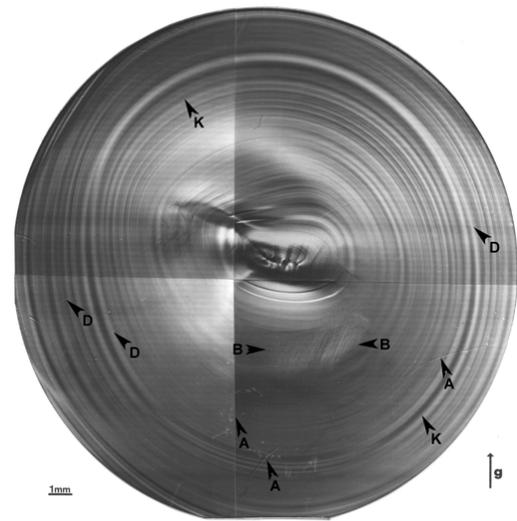


Figure 1. SWBXT image recorded in transmission geometry from a Langatate wafer

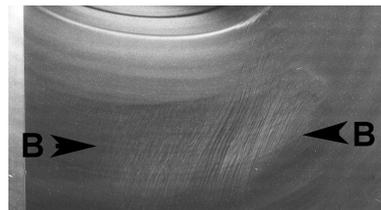


Figure 2. Slip bands contrast



Figure 3. Core region contrast

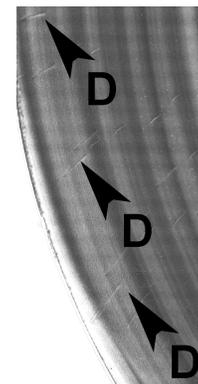


Figure 4. Dislocation contrast