

Characterization of Defect and Strain Configuration in Langanite Single Crystals Using SWBXT

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Abstract No. Chen7381

Beamline(s): X19C

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). Langanite or LGN ($\text{La}_3\text{Ga}_{5.5}\text{Nb}_{0.5}\text{O}_{14}$), along with Langasite or LGS ($\text{La}_3\text{Ga}_5\text{SiO}_{14}$) and Langatate or LGT ($\text{La}_3\text{Ga}_{5.5}\text{Ta}_{0.5}\text{O}_{14}$), 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 Langanite single crystals, which were obtained by the Czochralsky method. Both plano-convex blanks sliced from as-grown crystals and resonators fabricated from them have been examined using SWBXT. Topographs were recorded under transmission geometry.

Results: Figure 1 is a SWBXT image recorded in transmission geometry ($\mathbf{g}=\bar{1}10$) from a langanite crystal wafer cut perpendicular to the [001] growth axis of the boule. Well-defined sets of striations K can be observed. The concentric striations indicate that the growth interface is either concave or convex, rather than flat. The presence of such striations in Langasite was attributed by Chai et al to the onset of constitutional supercooling in an off-composition melt. It is possible that the growth striations observed in the Langanite crystals have similar origins. Numerous precipitates or inclusions P are distributed uniformly throughout the whole crystal. Several scratches S can also be seen across the crystal.

Figure 2 is a SWBXT image recorded in transmission geometry ($\mathbf{g}=002$) from a Langanite resonator fabricated from a ($1\bar{1}0$) wafer cut parallel to the [001] growth axis of a similar Langanite crystal boule. Well-defined unconcentric set of striations K is shown clearly in the image. Precipitates/inclusions and scratch can also be observed. Strain contrast associated with the edge of the electrode can be observed, superimposed on the striation contrast.

Conclusions: The striation contrast shown in the topograph is indicative of a slight variation in lattice parameter during growth, possibly associated with the onset of constitutional supercooling in an off-composition melt. Growth striation structures observed on topographs recorded from crystal sections cut perpendicular to the growth axis appear as concentric rings, the spacing of which reveals the periodicity of the striations, and the symmetry of which reveals the symmetry of the thermal field inside the growth chamber. Striations observed on topographs recorded from crystal sections cut parallel to the growth axis reveal a cross-sectional view of the melt-solid interface shape. Typically, this is not observed to be flat but rather concave or convex. Clear images of precipitates are also routinely observed, providing further evidence of inhomogeneous constituent element or impurity segregation.

Acknowledgments: Research supported by Army Research Laboratory. SWBXT carried out at the Stony Brook Synchrotron Topography Facility, Beamline X19C at BNL, which is supported by the DOE.

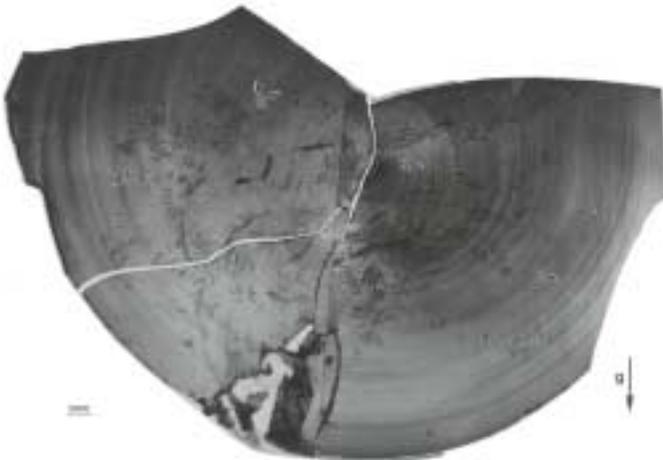


Figure 1. SWBXT image recorded in transmission geometry from a Langanite crystal wafer

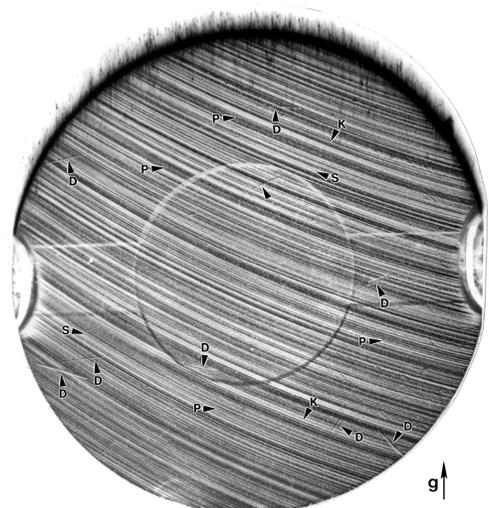


Figure 2. SWBXT image recorded in transmission geometry from a Langanite resonator