Czochralski growth, behavior and mechanical properties of massive Li_2MoO_4 crystals for scintillating bolometers

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Abstract: Understanding the origin of neutrino mass and the direct detection of dark matter in our universe are among the most exciting scientific drivers in astrophysics today. Crucial experiments in these fields require the detection of extremely rare events, such as neutrinoless double beta decay ($2\beta0\nu$). Among the most powerful detectors of this decay are the scintillating bolometers that simultaneously generate a nuclear event and record it in the same crystal that constitutes the heart of these bolometers. One of the most promising crystals is lithium molybdate Li_2MoO_4 (LMO).

In the framework of this thesis work, we succeeded, using the Czochralski (CZ) method, in growing several massive LMO crystals (up to 1 Kg) of good crystal quality, one of which was used to realize a scintillating bolometer in the CSNSM laboratory in Orsay.

One of the crystals that we developed fractured during its drawing, another had previously cracked during the machining for the realization of a bolometer. This led us to focus on the mechanical properties of LMO crystals, never studied before, in order to understand the mechanical behavior of the crystals during their growth.

In order to obtain the elastic coefficients of LMO at different temperatures, which are indispensable for the calculation of the thermomechanical stresses in the crystal during its pulling by the Czochralski method, we performed Brillouin scattering experiments at ambient and high temperatures on samples of different crystal orientations. Uniaxial compression tests on oriented single-crystal LMO samples were performed at high temperatures, which allowed us to study the plastic behavior and fracture of the material.

Always in the logic of estimating the risk of LMO cracking, we have developed a finite element calculation model of the temperature fields and thermomechanical stresses in the crystal during the Czochralski pull and during the subsequent cooling.

In conclusion, this work discusses the mechanical stresses related to the risk of cracking of LMO crystals during the Czochralski pull.