CUPID Crystal Validation Run: A Systematic Framework for LMO Crystal Performance and Radiopurity Assessment

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CUPID (CUORE Upgrade with Particle IDentification) is a next-generation experiment aiming to search for $0\nu\beta\beta$ decay of ^{100}Mo and to probe the inverted-hierarchy region of neutrino masses. CUPID is designed to minimize background for $0\nu\beta\beta$ decay by exploiting the high Q-value of ^{100}Mo, which sets the region of interest above almost the entirety of the natural β/γ background, and by implementing particle identification via a dual readout of heat and scintillation light to suppress the α background. In particular, CUPID will operate 1596 $Li_2^{enr}MoO_4$ scintillating crystals (LMO), each coupled with a pair of Ge light detectors (LDs). Both the calorimetric and scintillating properties of LMO crystals, as well as their ultra-high surface and bulk radiopurity, are crucial for achieving the target sensitivity of CUPID. The task of growing, cutting and polishing of LMO crystals has been assigned to the Shanghai Institute for Ceramic Materials (SICCAS). However, the lack of industrial-scale expertise in the production of LMO has required SICCAS to develop a robust and reliable production process, starting from the synthesis of LMO powder up to the final polishing of the crystal surfaces. To monitor the crystal quality during the R&D and the upcoming mass-production phase, the CUPID collaboration has developed an extensive multi-technique protocol for crystal-quality assessment, at the heart of which lie the CUPID Crystal Validation Runs (CCVRs). The latter are cryogenic measurements of various crystals produced by SICCAS, performed by operating LMOs and LDs as bolometers in a standardized detector assembly to assess their performance and radioactive contamination levels. In comparison to other techniques implemented for radiopurity assessment of CUPID materials (γ-spectroscopy, ICP-MS, and NAA), the bolometric measurement is the only technique capable of combining both sensitivity to every portion of the natural radioactive chains, despite possible secular-equilibrium breaking, and the possibility of working with reduced array sizes for the samples or limited measurement times, making it the cornerstone of the low-radioactivity assay developed to reach the ultra-low contamination targets of CUPID. This talk will present the results of the CCVRs performed during the R&D phase of LMO crystal growth, together with the optimization work already completed and still ongoing to enable the transition to the mass-production phase of the CUPID experiment.