Cesium Lead Bromide Crystal Growth: An investigation guided by lessons learned from the family of heavy metal compounds for radiation detection

Gilad Orr[1*], Liviu Matei[2], Assaf Zuck[3], Michael Zinigrad[1],Elsa Ariesanti[2], Rastgo Hawrami[2] & Arnold Burger[2]

*lead presenter: gilad.orr@ariel.ac.il

1 Department of Physics & Chemical Engineering, Ariel University, Ariel 40700, Israel

2 Department of Life and Physical Sciences, Fisk University, Nashville, TN 37208, USA

3 Department of Physical Chemistry, Israel Institute for Biological Research, Israel

Cesium Lead Bromide crystals are usually grown using the Bridgman method [1], and in this paper from low temperature HBr solution for radiation detection applications. HBr acts as the solution for $PbBr_2$ as it is hardly soluble in water $(9.7\,g/l@20^{\circ}C\,;44.\,g/l@100^{\circ}C)$ compared to $CsBr$ $(1380\,g/l@35^{O}C)$. Low temperature growth ($<88^{\circ}C$) was tested using different ratios of $CsBr:PbBr_2$ up to a ratio of 2:1. Using both mentioned methods, single phase $CsPbBr_2$ crystals were confirmed using XRD and EDS measurements. In order to asses the $CsPbBr_3$ crystal system it is compared with the HgI_2 crystal which possesses a similar bandgap (2.10eV [2], compared to 2.3eV [1]). In order to improve the crystal quality, the important physical properties we have to examine, are the resistivity and the dark current. While for HgI_2 they are respectively $\rho\approx 10^{12}\Omega\cdot cm$ [3], and $J_{Darkcurrent}\approx 10\,pA/cm^2$ with reported values of $\rho\approx 10^{9}\Omega\cdot cm$ and $J_{Darkcurrent}=10\,nA/cm^2$ for $CsPbBr_3$. This disparity between the theoretical values and the experimental values reported so far (including the current work) shows that the theoretically achievable properties are yet to be demonstrated for optimal device performance. X-ray diffraction (XRD) studies [4], indicated that $CsPbBr_3$ had two successive phase transitions at around $88^{\circ}C$ and $130^{\circ}C$, corresponding to the crystal structure transforming upon heating from room temperature orthorhombic to tetragonal and then to cubic, respectively. Although there are reports that crystal grown from the melt result in orthorhombic structure crystals, we have decided in this study to investigate the properties of crystals grown from solution, below $88^{\circ}C$ and compare them with those reported for the melt grown crystals. The results indicate that the phase transitions encountered during the cooldown of the melt growth are not as destructive as the orthorhombic to tetragonal phase transition at $127^{\circ}C$ reported [3,5], for HgI_2 which restricted the growth on nuclear detector grade material by physical vapor transport, below this phase transition. Initial results of a comparative study of crystals grown by both methods indicates that an improved annealing program in the case of the Bridgman case can result in improved detector performance. Our preliminary results show that HBr low temperature solution growth holds much promise in growing high quality detectors which can help in benchmarking the material.

References

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