Controlled Crystallization of Centimeter-Size 4HCB Organic Single Crystalline Semiconductors for Novel Radiation Sensor Applications

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4-hydroxycyanobenzene (C_7H_5NO, 4HCB) organic single crystalline semiconductors (OSCS) have raised significant interest in next-generation radiation detection applications due to their high hydrogen density, tissue equivalence, and excellent charge transport properties [1-3]. However, their performances suffer from the uncontrollable solution growth process, leading to issues such as dense surface defects, serious crystals adhesion and small crystals size [4-6]. To improve the quality of the as-grown 4HCB crystals, the physical origin behind the above issues should be clarified first.

Here, the two-dimensional (2D) nucleation and layer-growth mechanism for solution-grown 4HCB OSCS is clarified by analyzing the 2D anisotropic intermolecular force and characterizing the multiscale surface layer edges. In this mechanism, the small increase of solution supersaturation leads to a dense crystallization nucleus, resulting in the growth issues mentioned above. Then, the controlled crystallization method in terms of the solution supersaturation (by adjusting growth temperature) and the nucleation position (by adjusting the anti-solvent) is utilized to optimize growth of 4HCB OSCS, with obtaining 4HCB OSCS in the dimension of $18\times15\times1.2$ mm^3, high bulk resistivity of $(1.12\pm0.05)\times10^{12}$ $\Omega\cdot$cm, and excellent charge mobility of 3.40 ± 0.10 cm$^2\cdot$s$^{-1}\cdot$V^{-1}.

As the result, high-performance sensors are fabricated based on the as-grown 4HCB OSCS, achieving direct detection of low-dose X-rays [7], solar-blind UV lights [8], and fast neutrons [9] with superior performances, fast response and low-cost.

References

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