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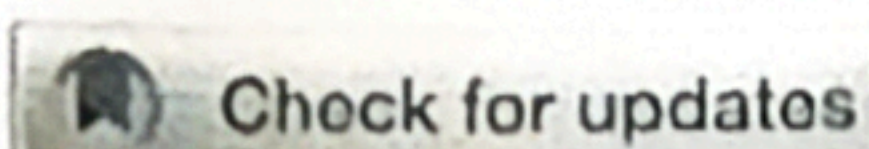
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Melt processed perovskite glass-ceramic films for large-area X-ray detection and imaging

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Metal halide perovskites are promising semiconducting materials for sensitive X-ray detection and imaging. However, their incompatibility with thin-film transistor (TFT) backplanes has posed a major challenge to the commercial deployment of perovskite devices. Here, we report perovskite glass-ceramic films comprising (4-EAMP)₂Pb₃Br₁₀ glass (4-EAMP = 4-(ethylaminomethyl)pyridine) and CsPbBr₃ crystals that can be fabricated via a melt-pressing procedure. We found that the glassy phase fills the crystal grain boundaries, which reduces interface defects and suppresses ion migration along the boundaries. These improvements thus enable the composite film to achieve a remarkable mobility-lifetime ($\mu\tau$) product of $1.13 \times 10^{-4} \text{ cm}^2 \text{ V}^{-1}$, a high sensitivity of $9.8 \times 10^4 \text{ } \mu\text{C Gy}_{\text{air}}^{-1} \text{ cm}^{-2}$, and a low detection limit of $197 \text{ nGy}_{\text{air}} \text{ s}^{-1}$. Compared to pressed perovskite wafers, the adhesive and meltable nature of the glass phase enables seamless integration of the detector with substrates, leading to high-performance X-ray imaging via TFT backplane integration. The demonstrated perovskite glass-ceramic system represents a new kind of semiconductive composite with both excellent processability and optoelectronic properties for integrated optoelectronics.

Introduction

X-ray detection plays a vital role across multiple fields, including structural analysis, medical diagnostics, and industrial non-destructive testing. The development of detector materials that simultaneously exhibit high sensitivity and low detection limits is of paramount importance. Metal halide perovskites have attracted considerable research interest owing to their strong X-ray attenuation, tuneable bandgaps, high carrier mobility lifetime ($\mu\tau$) products, remarkable radiation tolerance, and cost-effective processability.^{1–5} In recent years, a variety of solution-processed perovskite single-crystal materials have been synthesized, demonstrating detection sensitivities that significantly surpass those of conventional commercial X-ray detectors.^{6–10} However, the controllable morphology and scalable growth of single crystals remain challenging. Meanwhile, polycrystalline films fabricated by hot-pressing or blade-coating contain voids, grain boundaries, and defects that act as carrier recombination traps, hindering charge transport and degrading optoelectronic

performance.^{11–18} These issues collectively hinder the commercialization of perovskite materials.

The recent emergence of perovskite glasses, such as [TPrA]₃[M(dca)₃] (TPrA = tetrapropylammonium, M = Mn²⁺, Fe²⁺, Co²⁺, dca = dicyanamide) and (S-NEA)₂PbBr₄ (S-NEA = S-(–)-1-(1-naphthyl)ethylammonium), has garnered significant research interest.^{19–22} These materials undergo a solid-to-liquid transition near their melting points, which produces a melt with excellent fluidity and adhesion that enables integration with diverse substrates. Quenching this melt yields a glassy material while retaining the semiconducting properties of the original crystalline phase.^{23–26} For example, the (4-EAMP)₂Pb₃Br₁₀ (4-EAMP = 4-(ethylaminomethyl)pyridinium) glass we previously developed exhibits exceptional glass-forming ability and a broad processing window, enabling outstanding melt-processability. It also maintains X-ray detection performance in its glassy state, making it a superior semiconductor material.²⁴ We propose that a composite strategy, which leverages the superior processability of perovskite glass and the exceptional X-ray detection capability of crystalline materials, can overcome the intrinsic limitations of both single crystals and polycrystalline films.

In this work, we developed a strategy of combining (4-EAMP)₂Pb₃Br₁₀ glass with CsPbBr₃ crystals. The role of the glass phase in this strategy shifts from providing optical transparency to acting as a stabilizing host matrix that enhances detection sensitivity and operational stability, thereby shifting the functional paradigm. During the hot-pressing process, the molten

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