$CsPbBr_3$ Nanocrystals based Plastic Scintillator for Ionizing Radiation Detection

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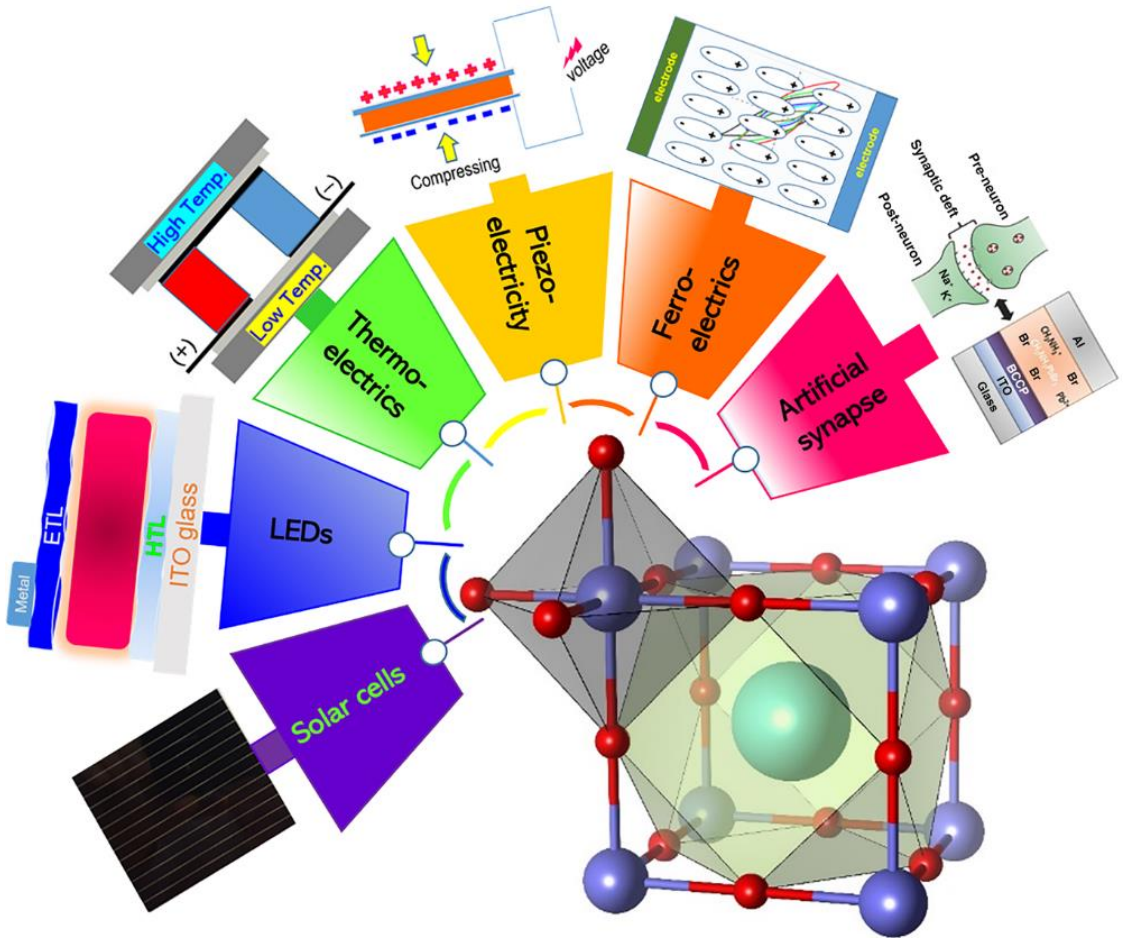
Outline

- Introduction of metal halide perovskites
- Mechanochemical synthesis of $CsPbBr_3$ nanocrystals for plastic scintillators
- $CsPbBr_3$ polycrystalline direct X-ray detector
- Conclusion
- Acknowledgements

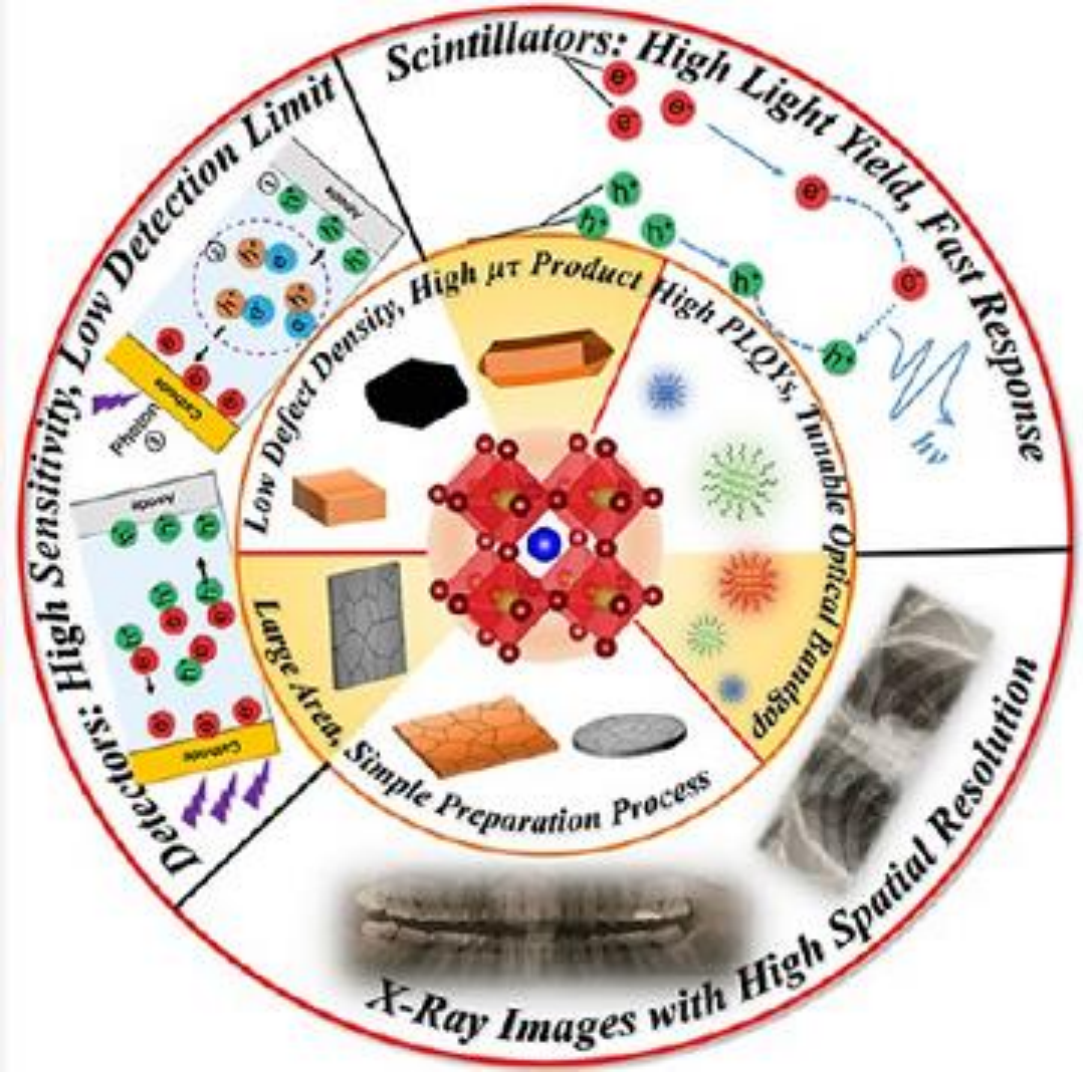
Metal halide perovskite



- Halide perovskites with formula ABX_3, where A is a large cation, B is a metal cation, and X is halide anion (Cl, Br or I))
- Simple fabrication
- Tunable bandgap
- Excellent performance in solar cell (PCE>23%), photodetector, LEDs
- Promising in radiation detection

MRS Bulletin, 45(6), 427-430, 2020

Halide Perovskite for Radiation Detection

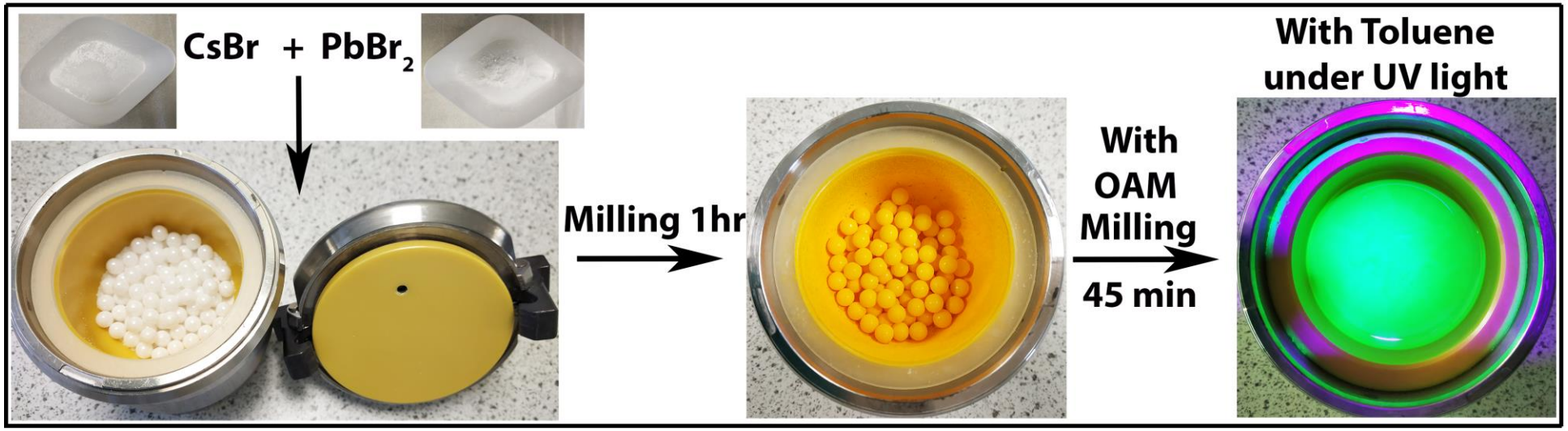


Metal halide perovskite for radiation detection

- Large absorption coefficient
- High μτ product and large resistivity
- Tunable bandgap and high PLQYs
- Low-cost, simple solution processable fabrication.

ACS Energy Lett.2021, 6, 739−768

Gram Scale Solid-state Synthesis of $CsPbBr_3$ nanocrystals



- Gram scale $CsPbBr_3$ nanocrystals (NCs) was synthesized by nearly solvent free two-step surfactant (Oleylamine) assisted ball milling method.
- The surfactant (OAM) concentration was varied to tune the optical properties of the NCs.
- The surfactant reduces the aggregation of the NCs in plastic scintillator.

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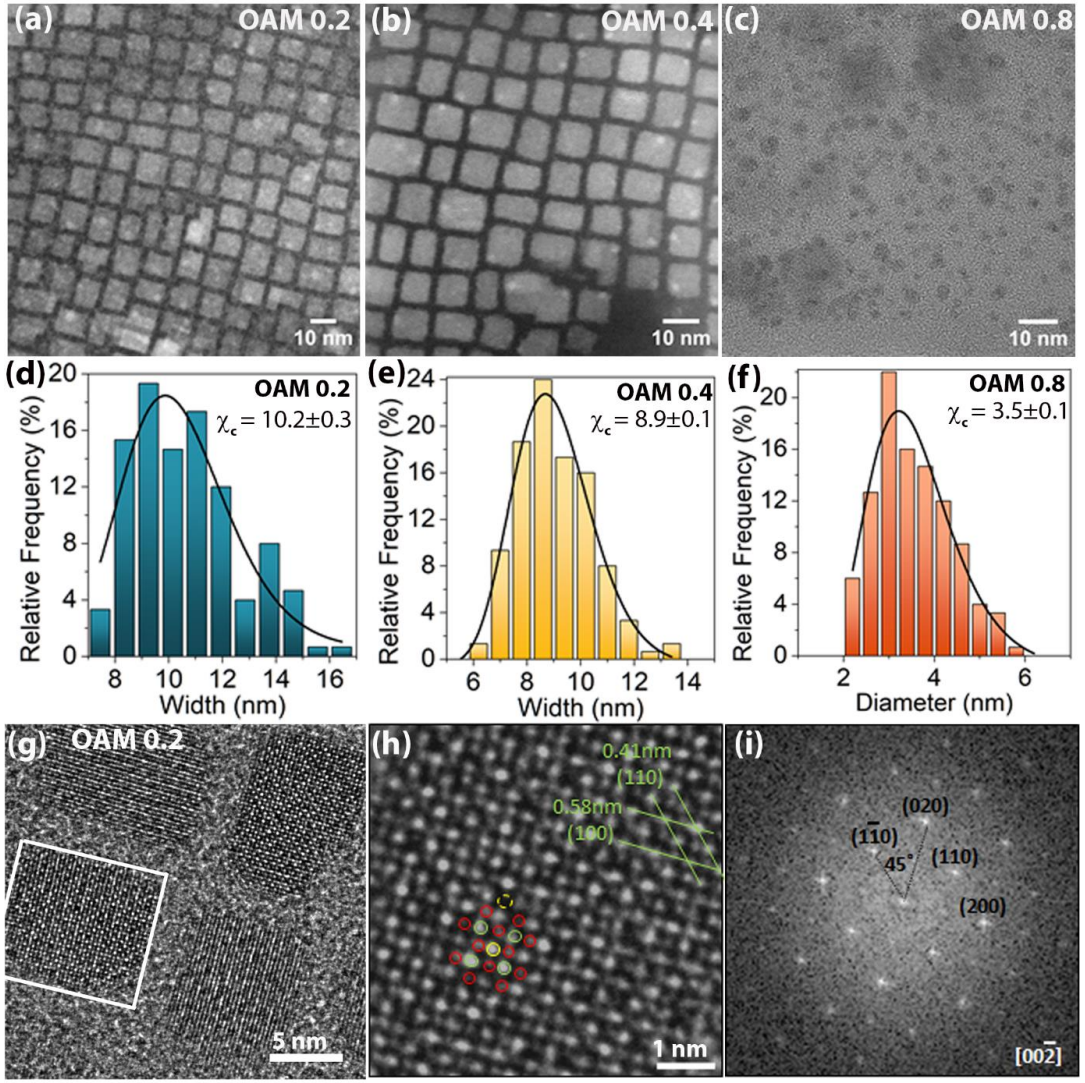
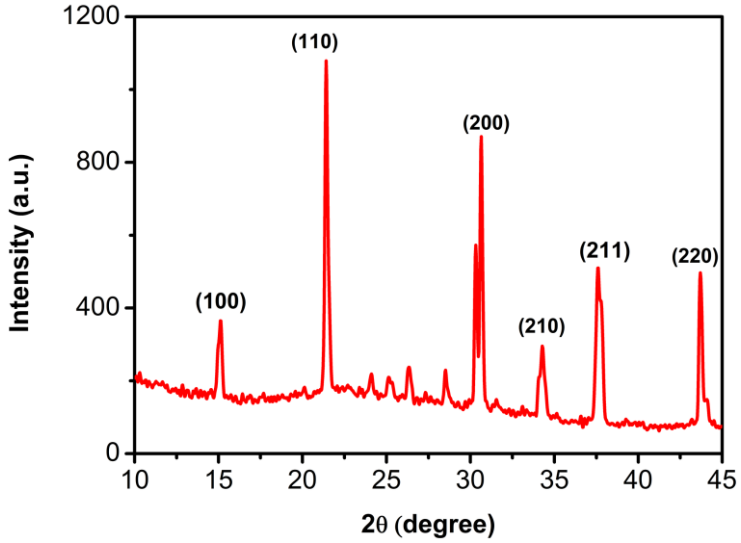
Morphology with Different OAM Concentration

TEM imaging



- Cubic shaped morphology with high crystalline quality of $CsPbBr_3$ NCs.
- Particle size decreased with the increase of OAM concentration.
- XRD confirms proper crystalline phase of $CsPbBr_3$.

XRD pattern



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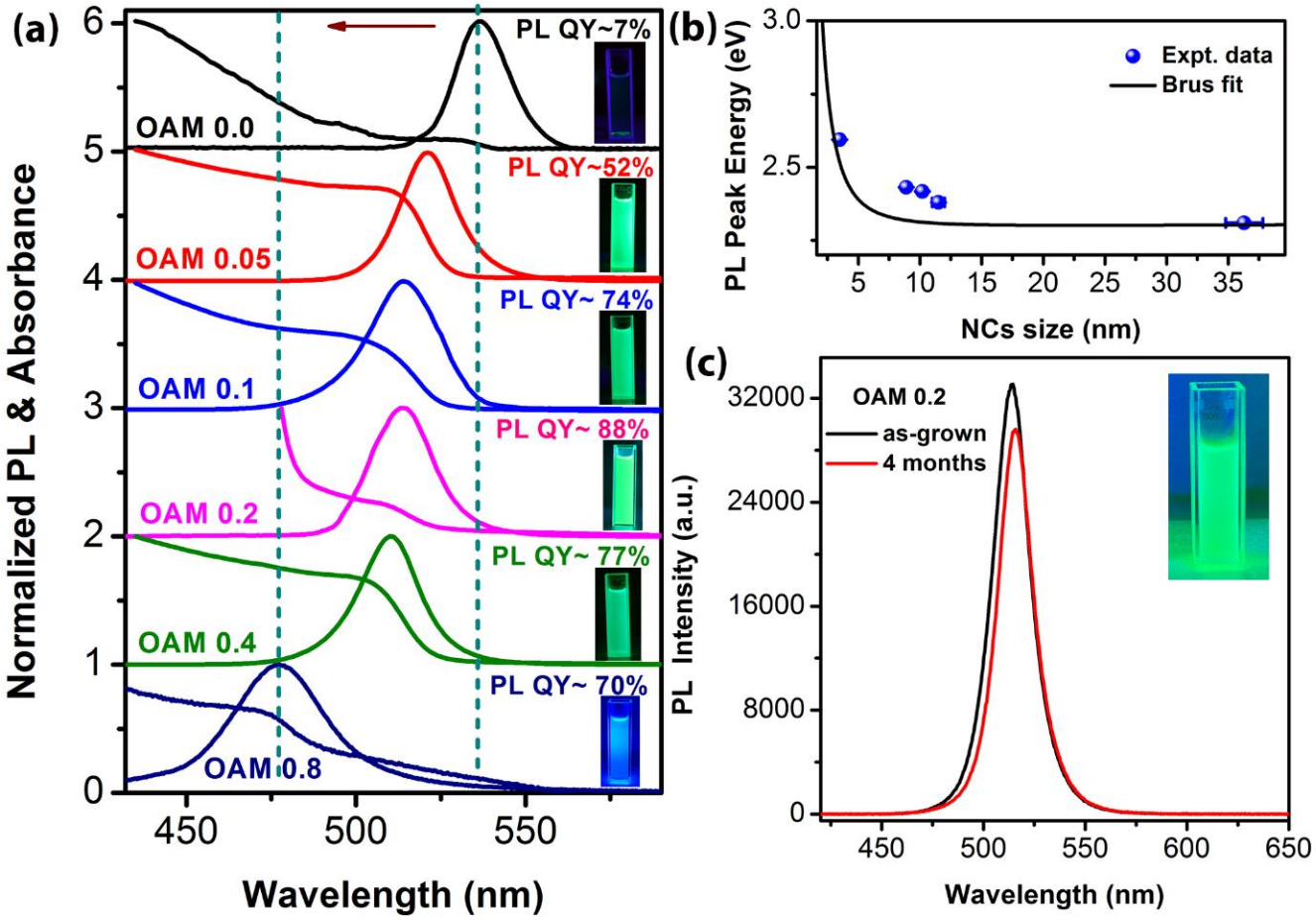
Optical Properties of Perovskite NCs Dispersed in Toluene

PL & Absorbance



- Highest PL quantum yield was observed for 0.2 ml of OAM.
- Blue shift in PL peak - particle size decreased with the increase of OAM concentration.

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Optical Properties of Perovskite NCs in PMMA plastic

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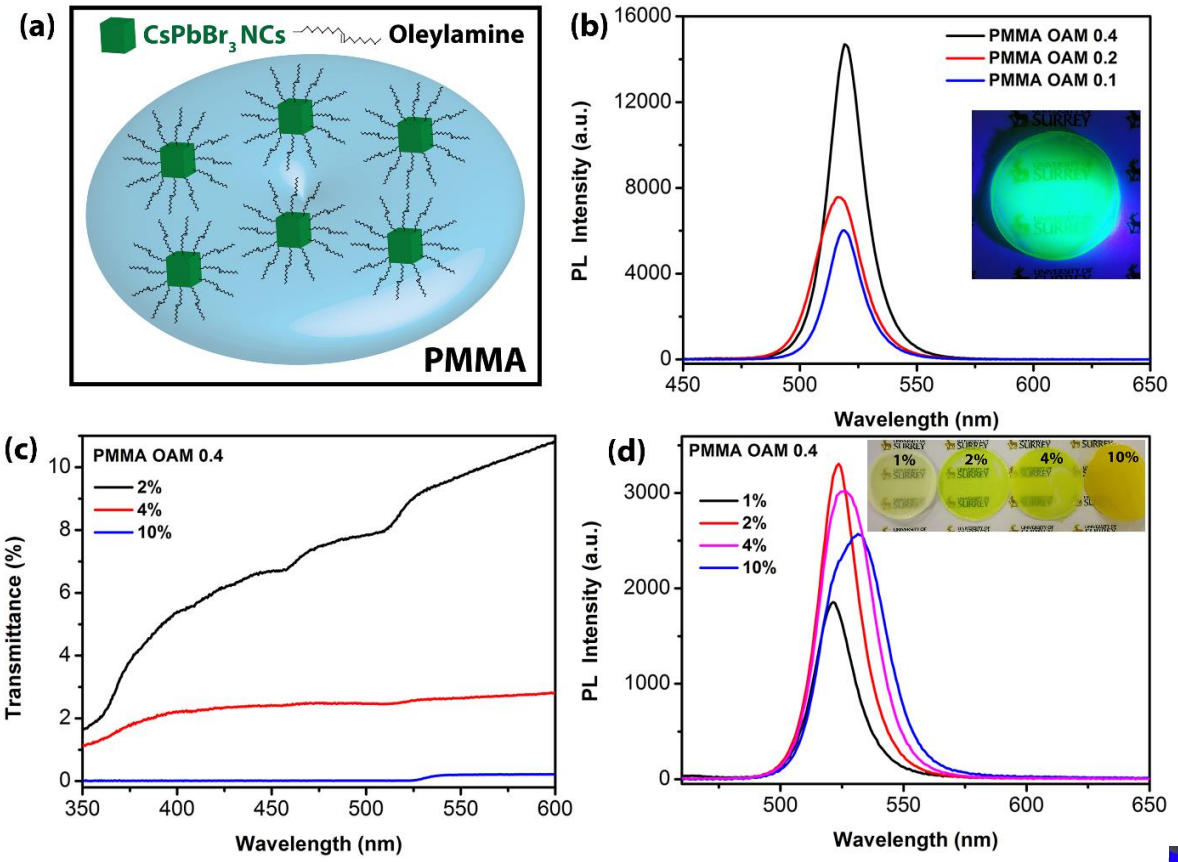
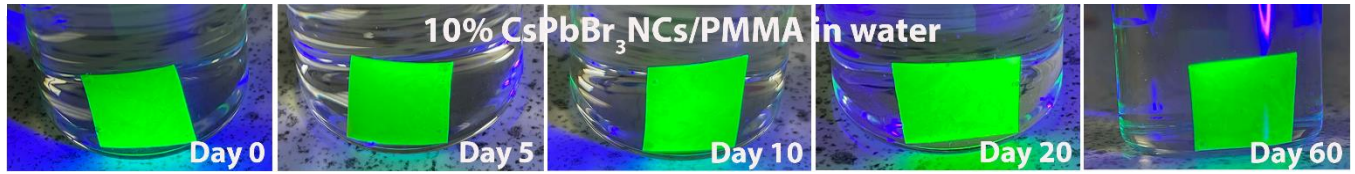
Perovskite PMMA disc **PL of Perovskite@PMMA**



- Different concentration of $CsPbBr_3$ NCs were loaded in PMMA polymer.
- PMMA disc with 0.4 OAM shows highest PL emission which may be due to the less aggregation.
- The nanocomposite scintillator exhibits high stability.

Storage stability of the nanocomposite in water



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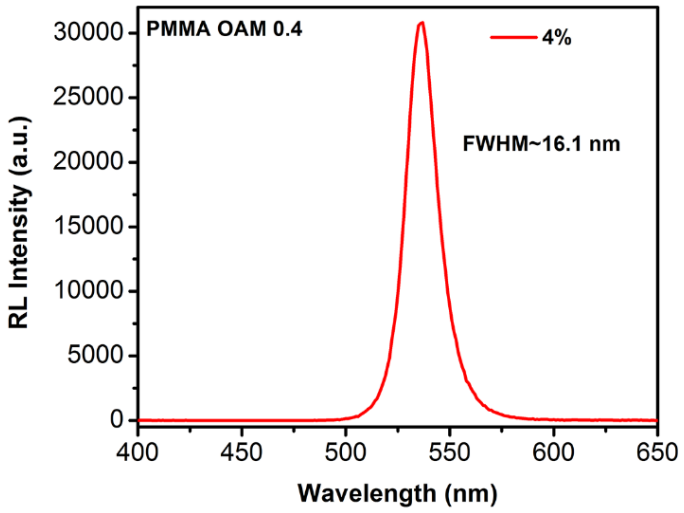
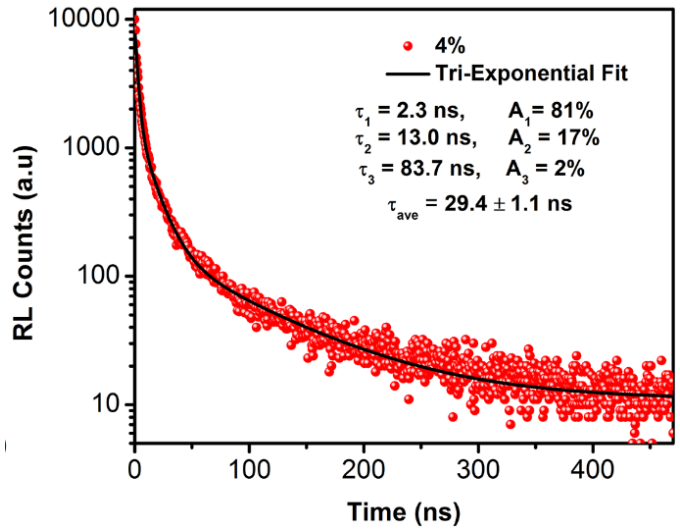
Radioluminescence Properties

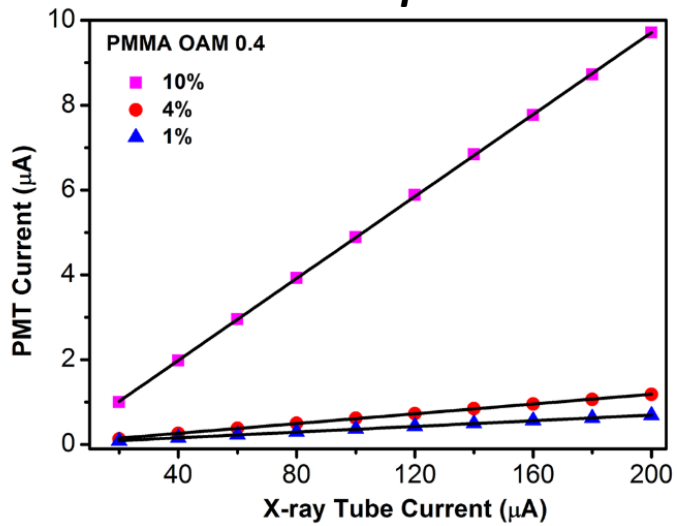
RL



RL decay



PMT *response*



The $CsPbBr_3$/PMMA nanocomposite disc shows a highly intense RL emission peak at 536 nm with FWHM ~ 16 nm with a fast RL decay time of 29.4 ns.

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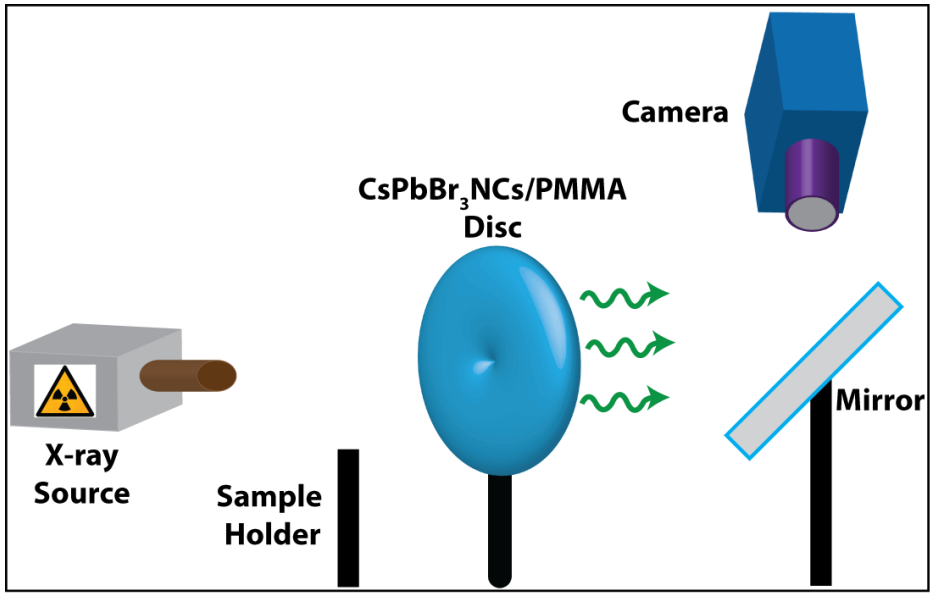
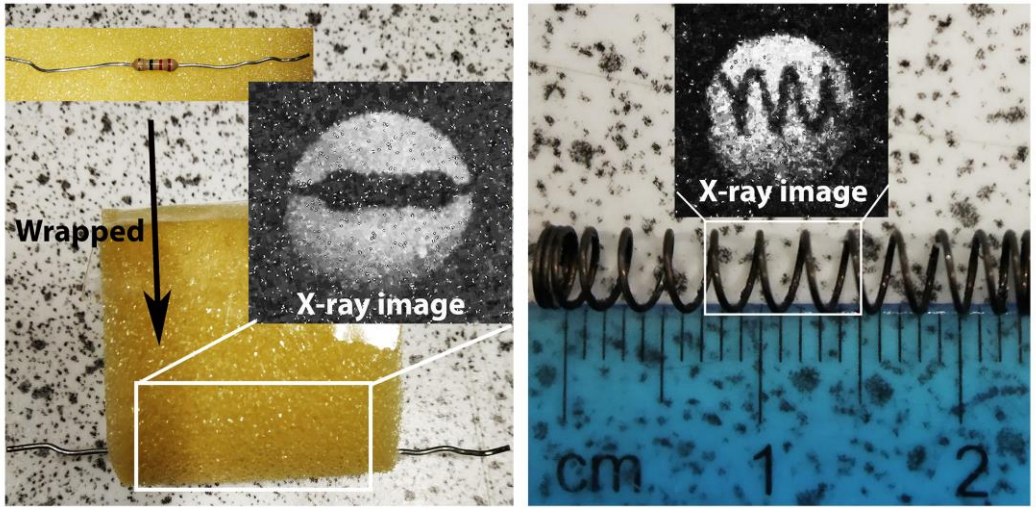
X-ray imaging

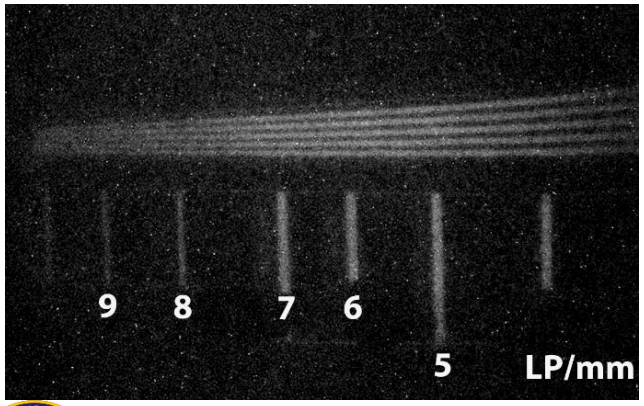
X-ray imaging set up



X-ray imaging



Resolution



- PMMA disc with 10% perovskite loading shows good performance in X-ray imaging with high resolution.
- High X-ray imaging resolution of ~8 lp/mm.

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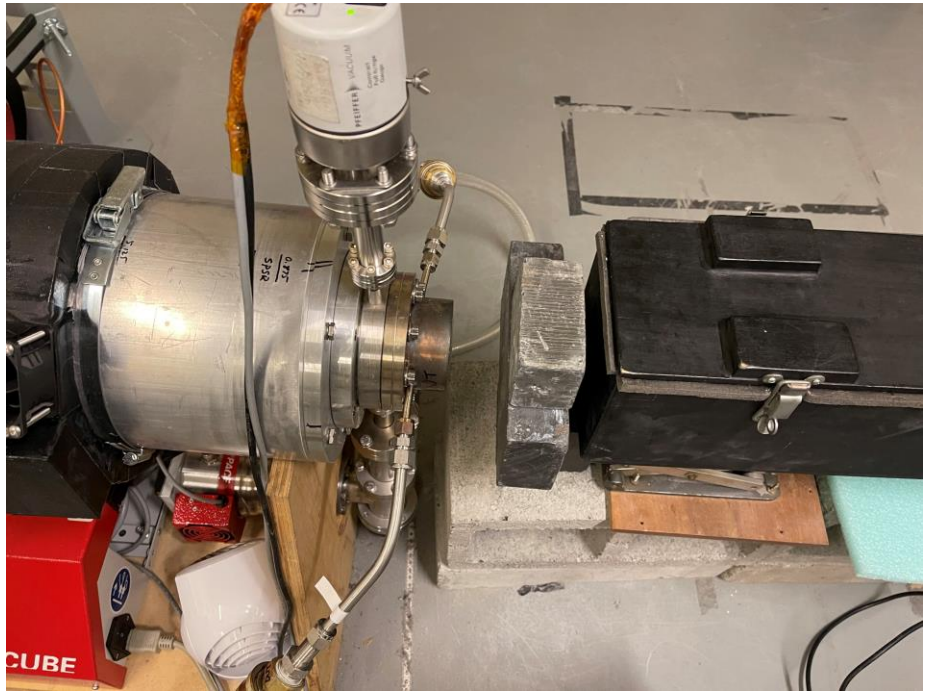
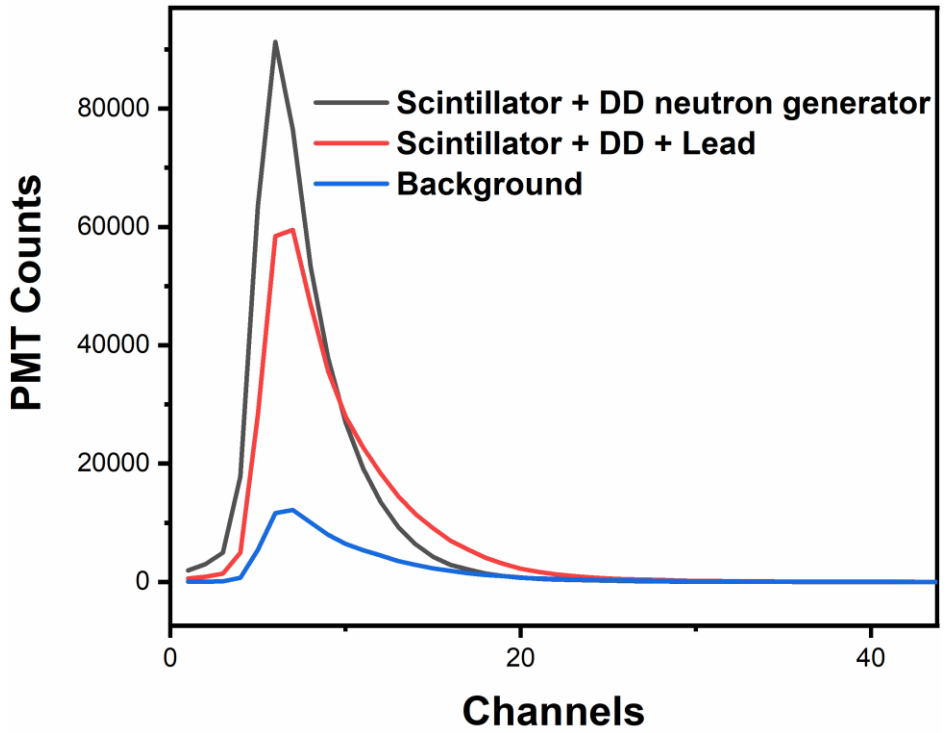
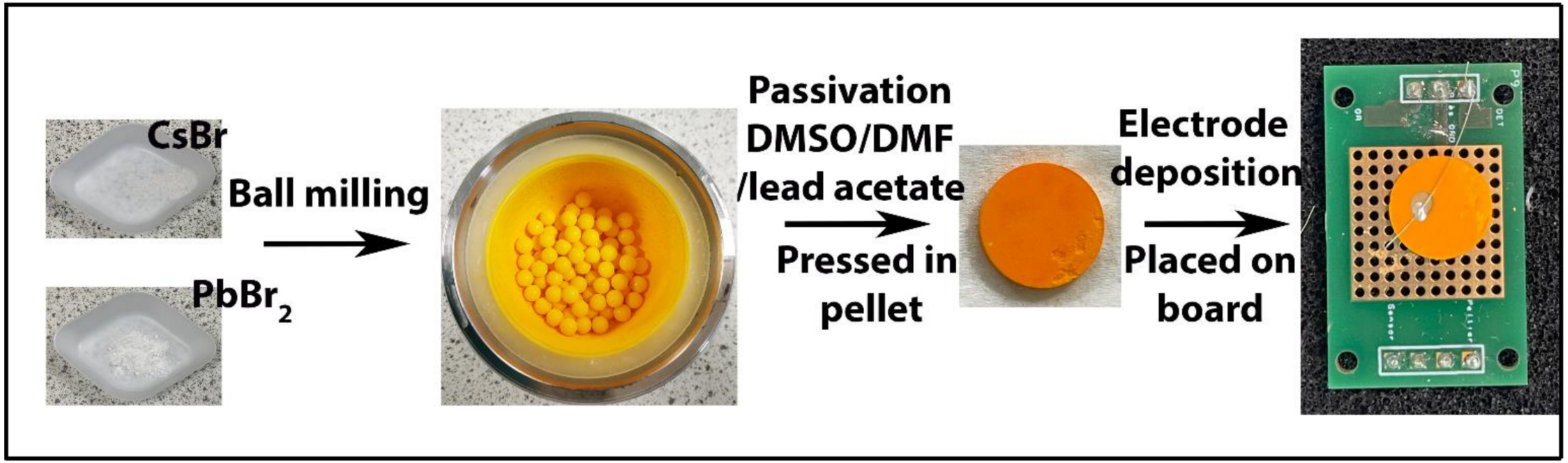
Neutron response of the scintillator





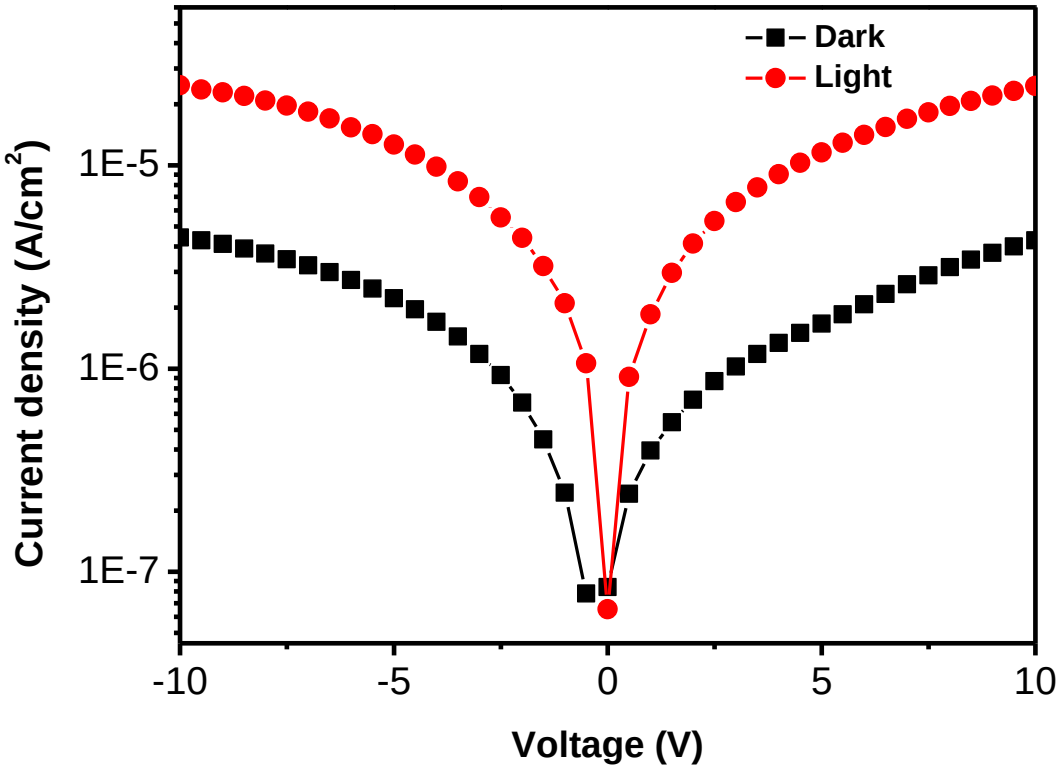
- The NuSec NNSA grant has allowed us to start a new collaboration with Prof Anna Erickson at Georgia Tech.
- The neutron response of the $CsPbBr_3$ plastic scintillator was tested using a DD neutron generation in DD neutron generator during the visit to the Georgia Institute of Technology.

Fabrication steps of the $CsPbBr_3$ polycrystalline direct X-ray detector

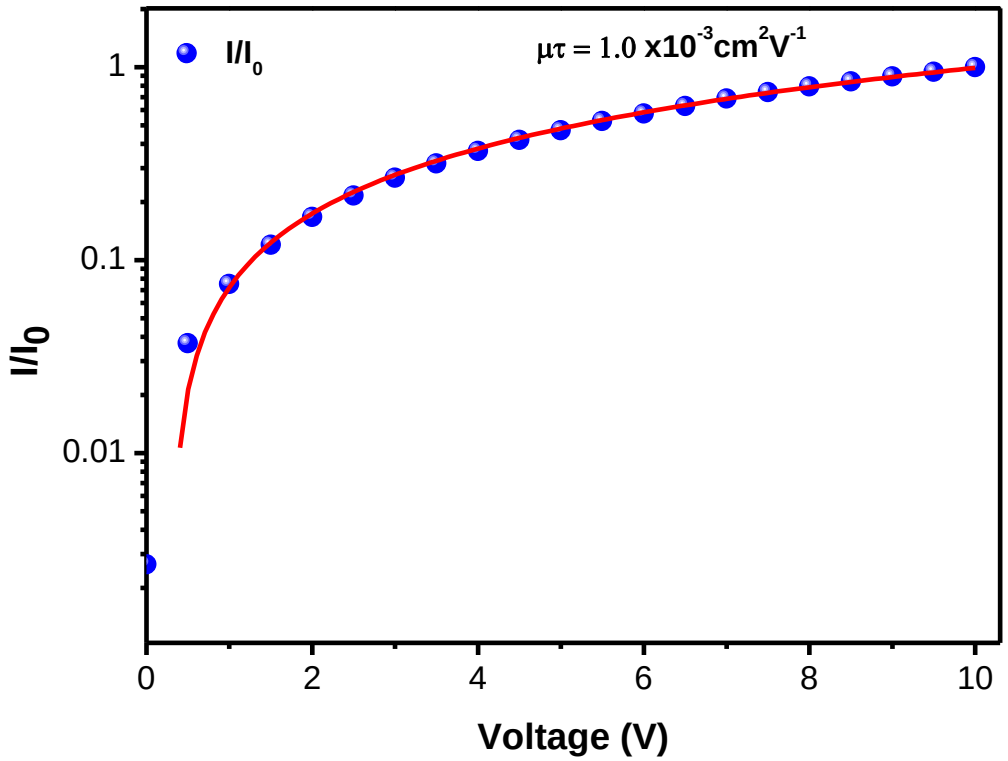


Characterization

I-V characteristics of the polycrystalline detector under dark and illumination of a LED.

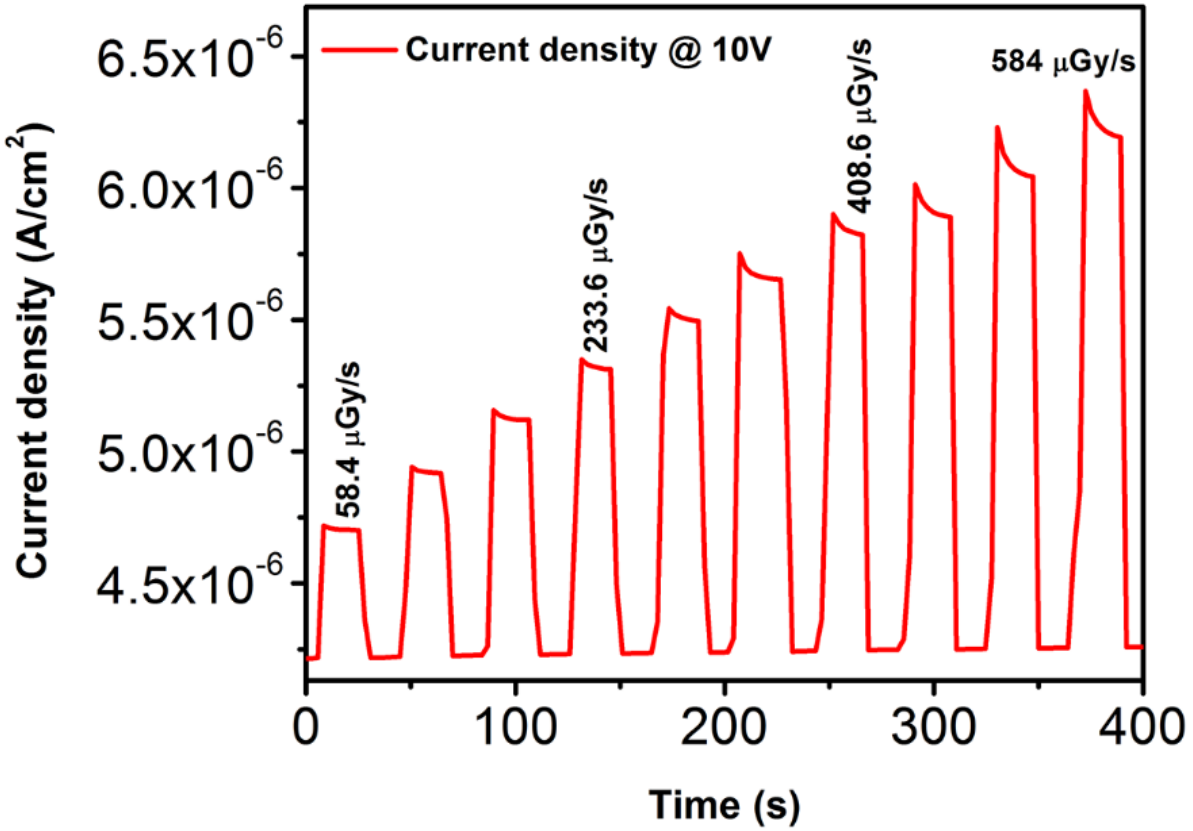


The Hecht plot using the photocurrent of the device. High μτ value of 1.0×10^{-3} cm^2V^{-1} was obtained.

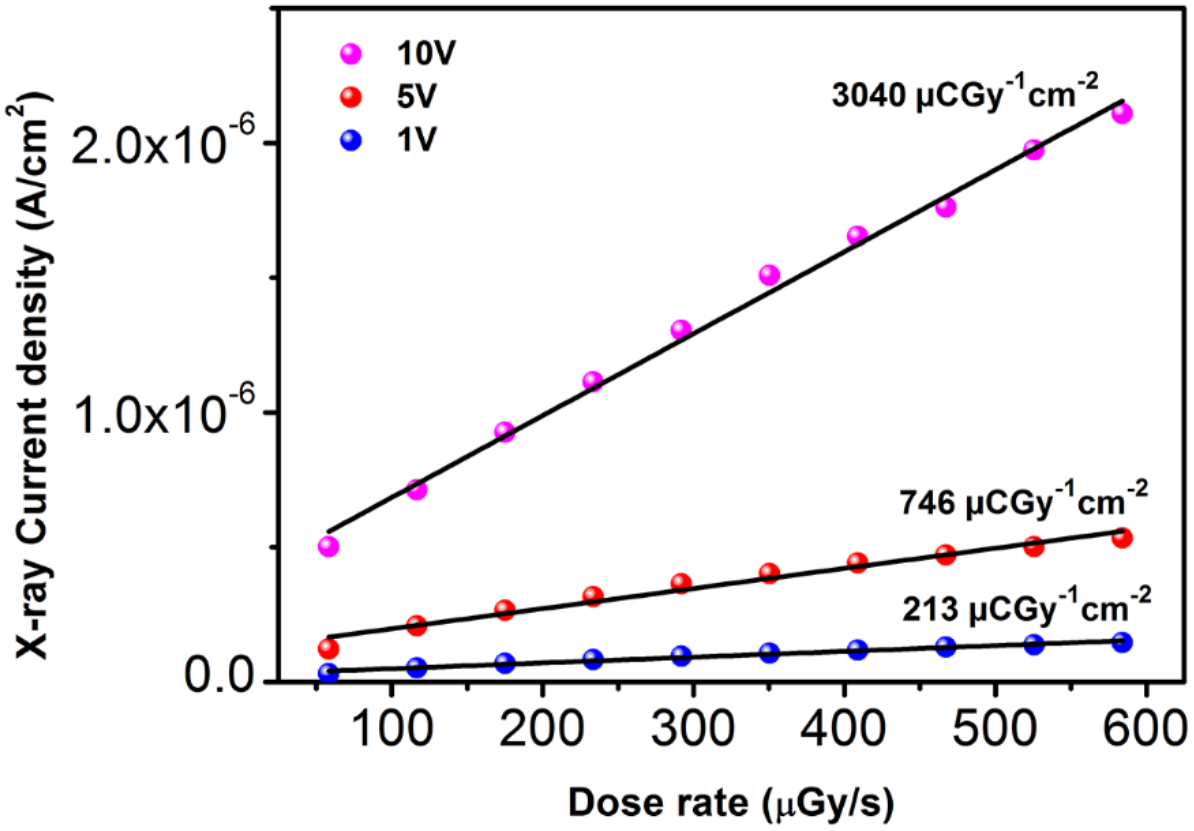


X-ray sensitivity measurement

Temporal X-ray current response



X-ray current density vs dose rate



High X-ray sensitivity of 3040 µCGy^{-1}cm^{-2} was obtained under 10 V of applied bias.

Conclusions

- Highly luminescent $CsPbBr_3$ NCs were synthesized by ball milling method.
- X-ray and neutron response of $CsPbBr_3$ plastic scintillators were studied.
- Polycrystalline $CsPbBr_3$ X-ray detectors were fabricated by using ball milled $CsPbBr_3$ powder.
- The optimized X-ray detector exhibits sensitivity of 3040 $\mu CGy^{-1}cm^{-2}$ under 10 V of applied bias.
- We are further optimizing the device performance by different additive and passivation technique.

Acknowledgements

We acknowledge support from the DTRA ‘IIRM’ University Research Alliance and NuSec, UK.

Thank you