High Performance Single Crystal Organic Inorganic Hybrid Perovskite Direct Radiation Detectors

Allen Challie Wood III
Advisor: Jinsong Huang
The University of North Carolina at Chapel Hill
wooda98@live.unc.edu

Abstract:

The efficient detection of special nuclear materials, (SNMs), in nuclear fuel cycle monitoring is vital for global security and energy management. Traditional detection technologies, while effective, face challenges in cost, complexity, and sensitivity. [1] This gap underscores the need for cost effective, high performance and well understood radiation detectors. These requirements are addressed in part by organic-inorganic hybrid perovskite, (OIHP), direct radiation detectors, which offer a unique combination of high radiation stopping power, low energy resolution, and cost-effectiveness, when compared to Cadmium Zinc Telluride, (CZT), based detectors. [2] UNC has developed methods to synthesize perovskite single crystals to produce unprecedented performance, such as energy resolution of close to 0.8% at room temperature, and operation under temperatures up to 150°C. Our approach leverages the novel use of digital signal processing, and detector performance analysis, allowing for precise characterization of the device's photon induced voltage and time from a digitally converted analog signal. This marks an advancement in the field which enables a more accurate measurement of OIHP-based signal detection efficiency and a deeper understanding of the shallow trap band contribution to the signals affects performance in OIHP detectors. The results reveal that OIHP detectors not only excel in terms of efficiency but also stand out in their ability to operate under real-world environmental conditions. Their performance in detecting ionizing radiation is comparable, if not superior, to current state-of-the-art radiation detectors under various measurement conditions. These findings are critical in the context of the nuclear fuel cycle, where the accurate and efficient detection of SNMs can be utilized. The impact of our work extends beyond the immediate application of SNM safeguards to the use of OIHP detectors in various fields requiring radiation detection. [3] By demonstrating the unique advantages and practical applications of OIHP based detectors, the price, quality and operational conditions for which reliable ionizing radiation detection improves.

[1] Rintoul, E., Brown, H., Everett, C., Green, K., Harkness-Brennan, L. J., Judson, D., Wells, D., & Cherlin, A. (2023). Sub-voxel identification of gamma-ray interaction positions within a pixelated CZT detector through signal analysis. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 1046, 167639. https://doi.org/10.1016/j.nima.2022.167639

[2] Zhao, L., Zhou, Y., Shi, Z., Ni, Z., Wang, M., Liu, Y., & Huang, J. (2023). High-yield growth of FACsPbBr3 single crystals with low defect density from mixed solvents for gamma-ray spectroscopy. Nature Photonics, 17(4), 315–323. https://doi.org/10.1038/s41566-023-01154-8

[3] He, X., Deng, Y., Ouyang, D., Zhang, N., Wang, J., Murthy, A. A., Spanopoulos, I., Islam, S. M., Tu, Q., Xing, G., Li, Y., Dravid, V. P., & Zhai, T. (2023). Recent development of halide perovskite materials and devices for ionizing radiation detection. Chemical Reviews, 123(4), 1207–1261. https://doi.org/10.1021/acs.chemrev.2c00404