Bismuth-Based Detectors for Near-Infrared and X-ray Sources: Speed and Limit of Detection

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Abstract of the talk

Bismuth-based semiconductors have gained increasing attention as potential nontoxic alternatives to lead-halide perovskites.[1] This is because of their ability to replicate key features of the electronic structure of lead-halide perovskites, which is believed to be conducive towards achieving defect tolerance, whilst overcoming the toxicity and stability limitations. This talk discusses our recent work on two such materials: $AgBiS_2$ and BiOI. Whilst both materials have been demonstrated in photovoltaics with moderate performance, this talk focusses on our recent application of these materials as photodetectors and X-ray detectors with strong performance.

$AgBiS_2$ is a cation-disordered compound (where Ag^+ and Bi^{3+} occupy the same lattice site), and controlling this cation disorder affords the material strong light absorption.[2] As a result, only 30 nm thick absorbers are required to achieve adequate light absorption. Furthermore, this material has a low bandgap (~1 eV). We discuss our development of this material as near-infrared photodetectors (940 nm wavelength) with high cut-off frequencies reaching 0.5 MHz, along with cut-off frequencies reaching >1 MHz in the visible wavelength range. Furthermore, we demonstrate the application of these fast near-infrared photodetectors for heart beat monitoring, and examine the underlying reasons behind the fast performance of this material.

For BiOI, the composition of heavy elements Bi and I leads to stronger X-ray attenuation than commercial Cd-Zn-Te and amorphous-Se, as well as lead-halide perovskites. We show that the high stopping power, as well as its large mobility lifetime products and low dark currents enable these devices to have a limit of detection >250x improved over commercial amorphous-Se and Cd-Zn-Te detectors. This can improve the safety of medical imaging, and we examine the fundamental reasons behind the properties of BiOI enabling this strong performance.[3]

[1] Ganose, Scanlon, Walsh, Hoye,* *Nat. Commun.*, 2022, *13*, 4715.
[2] *Nat. Photon.*, 2022, *16*, 235.
[3] Jagt, Bravić, …, Hoye,* *Nat. Commun.*, 2023, *14*, 2452

Short Biography

Robert Hoye is an Associate Professor of Inorganic Chemistry at the University of Oxford, where he is also a Fellow of St. John's College and a Royal Academy of Engineering Research Fellow. Prof. Hoye obtained his PhD from the University of Cambridge in 2014, and was a postdoctoral research associate at MIT (2015-2016). He subsequently returned to the University of Cambridge as a research fellow (2016-2019). In 2020, he moved to Imperial College London as a Lecturer, then Senior Lecturer (Aug. 2022 -). In Oct. 2022, he moved to Oxford as Associate Professor. Prof. Hoye's group focuses on developing inorganic semiconductors for energy applications, particularly focussing on lead-free perovskite-inspired materials. His group's research spans from fundamentals (including spectroscopy and computations) to materials synthesis and applications in photovoltaics, light-emitting diodes and detectors. More information: hoyegroup.web.ox.ac.uk

Prof. Hoye was awarded the 2021 Imperial President's Award for Outstanding Early Career Researcher, and has also been awarded a European Research Council Starting Grant.