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X-ray nanoanalysis to probe radiation-induced ion migration in hybrid lead-halide perovskite

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X-ray direct detectors based on hybrid organic/inorganic lead-halide perovskite (HOIP) have gained significant attention from the research community over the last decade. In this context, the research has focused on identifying the optimal perovskite material. Among the HOIPs, 3D perovskites have demonstrated very good performances as X-rays detectors, but they are limited by high trap states density and significant ion migration effects leading to large dark currents. To overcome some of these limitations, 2D layered perovskites have gained interest for their lower dark current and reduced ion migration which leads to better environmental stability [1].

Nanoanalysis is a powerful tool to investigate microscopically the properties of perovskite films used for x-ray detectors. The simultaneous acquisition of X-ray Fluorescence (XRF) and X-ray Beam Induced Current (XBIC) can be exploited to study the correlation between charge collection and elemental distribution in perovskite films [2]. Indeed, through XRF it is possible to map the elemental distribution of the film, obtaining an image of the crystalline formations (nanocrystals or grains) composing the film. Combining XRF with XBIC it is possible to study the collection of radiation-induced charges with the boundary and bulk features of the film.

The stability of perovskite films under ionizing radiation and bias can be probed at the microscopic level to uncover degradation mechanisms and develop more stable films. A known issue in radiation detectors based on perovskites is the migration of metal ions from the electrode into the perovskite. In this work, we mapped the gold electrode degradation in two different perovskite materials: 3D $MAPbI_3$ [3] and 2D $(PEA)_2PbBr_4$ polycrystalline thin films deposited on interdigitated gold contacts. The film stability and the gold migration were probed at the nanoscale by simultaneous XRF and XBIC performed at the ID16B beamline of the European Synchrotron Radiation Facility. Gold ion migration was observed across the perovskite film in both materials. We investigated the origin of metallic ion migration, tying to decouple the effect of bias and radiation damage.

[1] Lédée, F. et al. *Ultra-Stable and Robust Response to X-Rays in 2D Layered Perovskite Micro-Crystalline Films Directly Deposited on Flexible Substrate.* Adv. Opt. Mater. 10, 2101145 (2022).
[2] Stuckelberger, M. et al. *Engineering solar cells based on correlative X-ray microscopy.* J. Mater. Res. 32, 1825–1854 (2017).
[3] Verdi, M. et al. *X-ray nanoanalysis revealing the role of electronically active passivation layers in perovskite X-ray film detectors*; in press in Adv. El. Mater

Primary authors: BORDONI, Camilla; VERDI, Matteo

Co-authors: CIAVATTI, Andrea (DIFA - Università di Bologna); PETROZZA, Annamaria (Center for Nano Science and Technology@PoliMi, Istituto Italiano di Tecnologia); FRABONI, Beatrice (University of Bologna); BOSCHERINI, Federico (Department of Physics and Astronomy, University of Bologna); SEGURA-RUIZ, Jaime (ESRF, The European Synchrotron); BASIRICÒ, Laura; MARGOTTI, Lorenzo (Department of Physics and Astronomy, University of Bologna); SORRENTINO, Roberto (Center for Nano Science and Technology@PoliMi, Istituto Italiano di Tecnologia); BONINO, Valentina (ESRF, The European Synchrotron)

Presenter: BORDONI, Camilla

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