Exploring Degradation Mechanisms in Perovskite Solar Cells using Extensive Electronic Microscopic Techniques

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Empowered by their outstanding characteristics, perovskite materials have settled in a couple of years their place among the best candidates for future photovoltaic applications. Although exhibiting strong performances, perovskite-based devices suffer from long-term instability, which remains a major drawback for industrialization and is currently one of the main concerns in the research community.

Investigations on this subject aim at relating device's macroscopic properties to its micro and nanoscale crystal structure and chemical composition. Combination of multiple characterization techniques with high spatial resolution is then required. Electron microscopy - based techniques are ideal to provide the information needed, despite a concern associated with the effect of e-beam on halide perovskites.

In this work, we analyze double cation mixed halide perovskite solar cells, fresh and aged, using energy-dispersive X-ray spectroscopy (EDX) in a scanning transmission electron microscope (STEM), and cathodoluminescence (CL) microscopy at various sample temperatures in a scanning electron microscope (SEM). The former enables investigation of the morphology and elemental composition, while the latter yields optical information on the specimen. We assess these complex data using a post-processing data treatment based on multivariate statistical analysis.

This approach reveals key details on the material properties, which are useful to understand completely perovskite degradation. In this context, we report investigation results of samples fabricated with different processes. Initial observations suggest that addition of Methylammonium Chloride (MACl) into perovskite precursor can improve morphology and flatness of the absorber. Furthermore, this additive coupled with a strong annealing seems to enhance device stability by reducing perovskite degradation. These results corroborate with macroscopic characterizations presented further in another communication.

Finally, we discuss preliminary results on a procedure based on examination of HAADF images contrast, to quantify beam damage during characterization. This study underlines relevance and feasibility of our characterization approach which will take one-step further perovskite solar cell performances.

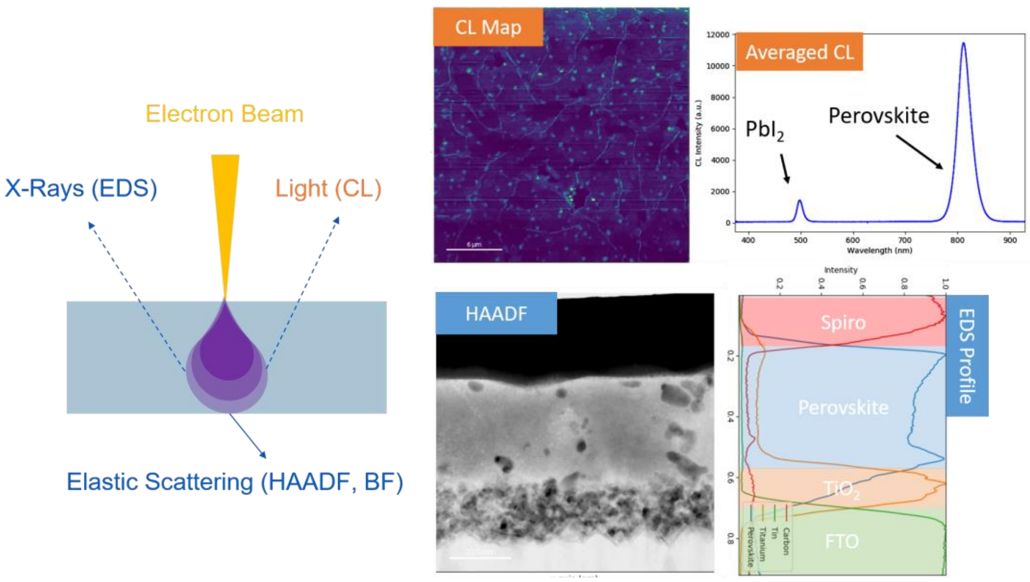

Figure – Representative Results using Electron Microscopy. A) Schematic of electron-material interactions. B) CL panchromatic map and CL spectrum averaged over the full area. C) HAADF image of perovskite cross-section and Element profile corresponding.