In-situ investigation of the degradation of hybrid halide perovskite materials in environmental scanning electron microscope

Faculty Advisor: Prof Yeng Ming Lam (MSE/FACTS)

Co-Advisors: Teddy Salim (FACTS) & Jason Herrin (FACTS)

Overview & Purpose

The project aims to investigate how the morphology and chemical distribution change in-situ as hybrid halide perovskites are exposed to environment with controlled humidity, temperature and vapor pressure. This study will be the first of its kind as most degradation studies performed with scanning electron microscope have been done ex situ. As a result of this study, we hope to achieve a fuller understanding of the degradation mechanism and kinetics under different degradation parameters.

Background

The project primarily involves the degradation study of hybrid halide perovskites, which, owing to their unique optoelectronic properties, are a promising family of materials for various applications such as photovoltaics, LEDs, photodetectors, lasers, etc, but which unfortunately have high susceptibility to moisture and heat. The processes of degradation of hybrid perovskites can occur at microscopic and sub-microscopic spatial scales, evident in localized changes in surface morphology and chemical composition. We will investigate these microscopic changes in situ, as they occur, in an environmental scanning electron microscope. Morphological changes can be viewed from secondary electron (SE) imaging, while the change in chemical distribution can be studied with energy-dispersive X-ray spectroscopy (EDS) or possibly wavelength-dispersive X-ray spectroscopy (WDS). Since perovskite degradation tends to be facilitated by vulnerable sites such as highly defective grain boundaries (GB), we intend to compare the degradation behavior of GB-rich perovskite polycrystalline films and GB-free perovskite single crystals. The effect of the choice of the organic cation and inorganic metal halide anion on the degradation will also be examined. Localized variation in conductivity could be tested using an electrical sourcemeter, if initial experiments prove successful and the student shows an interest in coding data output.

Role of Student

The student will firstly prepare hybrid halide perovskite thin-film and single-crystal samples with suitable properties in inert environment. The student will subsequently characterize the degradation behaviour of these materials in a heating stage equipped environmental scanning electron microscope (ESEM), varying the parameters of temperature, time, and partial pressure of water vapor, and finally establish the spatial–temporal dynamics of perovskite decomposition.

Instrumentation/Technical Training

- Materials synthesis: glovebox, spincoater and hotplate.
- Materials characterization: Thermo Quattro ESEM equipped with heating stage and Keithley sourcemeter.