Operando in a transmission electron microscope characterization of two terminal devices

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Due to high energy demand and intermittent electricity production of green energy, new devices architectures have been developed. In this contribution, we will present operando in a transmission electron microscope (TEM) characterizations of newly developed photo-voltaic devices based on organic-inorganic perovskite active layer, resistive switching memories based of SiOx dielectric layer and all-solid-state batteries. These new devices architectures lead to new problems, mainly the stability over operation related to the creation of irreversible defects and micro-structural changes. The first approach used to tackle these problems from a micro-structural point-of-view is the use of post-mortem characterization techniques[1–3]. When a high spatial resolution is needed, the use of TEM allows in the same time to characterize the micro-structure and the composition. More recently, the need to understand the degradation mechanism as they are happening at atomic scale and the parallel development of MEMS-based in situ capabilities inside a TEM made possible the observation at atomic scale of the degradation mechanism of devices operando in a TEM[4–6].

The challenging part for operando in a TEM characterizations is the device preparation. We have previously demonstrated the approach consisting on fabricating a micro-sized solar cell on a MEMS chip[3]. More recently, an organic-inorganic $MAPbI_3$ perovskite solar cell was operated inside a TEM. In forward bias, Pb and I migrates at the hole transport layer, when in reversed biased, the overall perovskite layer get degraded and leads to the creation of PbI_2 nanoparticles and voids at the electron transport layer/perovskite interface[4]. We have applied the same methodology to all-solid-state batteries to determine and locate the degradation mechanism happening under operation inside a TEM. We found a careful control of the total electron beam dose is needed to prevent degradation from the electron beam. For this knowledge, we have been able to cycle the battery inside the TEM and determine the species involved in the degradation mechanism using a combination of TEM and spectroscopic techniques.

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