Adhesion and Excitation Lifetime of Perovskites on Modified Substrates

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Perovskites possess numerous attractive electrical and optical properties with a wide range of applications.[2] Enhancing adhesion between perovskites and the surrounding substrates is a key factor in increasing the mechanical integrity, overall stability, and improving electronic performance of the final device.[1] Therefore, it is important to manufacturers and researchers to improve the adhesion of perovskites on respective substrates.

In this work thin film TiO_2 substrates are synthesized using a sputter deposition technique on transparent cover slips. The thickness of these thin films is 50 nm and is determined using profilometry. The thin films are then further modified using various annealing treatments to recrystallize the rutile and anatase phases. $CsPbBr_3$ perovskite microstructures are synthesized on the substrates using solution-based synthesis methods including drop casting and spin coating. Perovskite morphologies and composition are then characterized using electron microscopy (Figures 1-4).

Reliable measurement of adhesion for isolated crystals on substrates is challenging as the size scale of these materials approaches the nanoscale. Using a modified nanoindentation method, we will use the indenter to dislodge perovskite crystals off the substrates using a scratch mode test. Continuous monitoring of the lateral and normal loads enables estimates of the adhesion energy to the substrate, in this case TiO_2, to be determined.

We hypothesize that increased adhesion at the perovskite substrate interface will correlate to faster and more efficient electron transfer into the electron transport later (ETL). In this work, we will quantify the adhesion of perovskites on various modified TiO_2 substrates and determine excited state lifetimes along with optoelectronic properties using ultrafast pump-probe microscopy and time-resolved photoluminescence spectroscopy. Optical measurements will be taken at the perovskite-substrate interface by positioning the sample with the cover slip facing the laser. Results of these studies will be used to evaluate correlation between the mechanical and optoelectronic properties of perovskites on the modified substrates and provide a method for investigating adhesive forces at the nanoscale.

[1] Dogan, F., Lin, H., Guilloux-Viry, M., & Peña, O. (2015). Focus on properties and applications of perovskites. *Science and Technology of Advanced Materials*, *16*(2), 020301. https://doi.org/10.1088/1468-6996/16/2/020301
[2] Dou, J., & Chen, Q. (2022). Interfacial engineering for improved stability of flexible perovskite solar cells. *Energy Material Advances, 2022*. https://doi.org/10.34133/energymatadv.0002

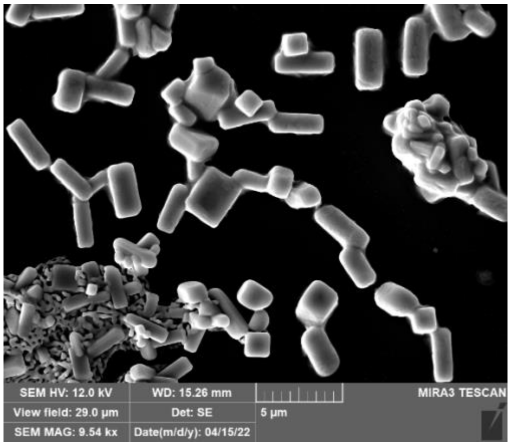

Fig. 1. SEM micrograph depicting rectangular $CsPbBr_3$ perovskites on the surface of a TiO_2 substrate that was annealed at 400 °C.

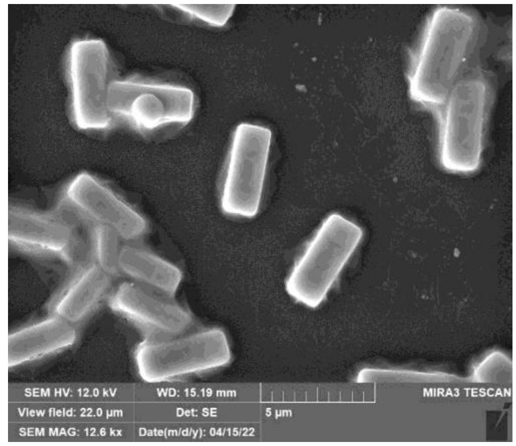

Fig. 3. SEM micrograph of rectangular $CsPbBr_3$ perovskites on the surface of a TiO_2 substrate that was annealed at 1000 °C.

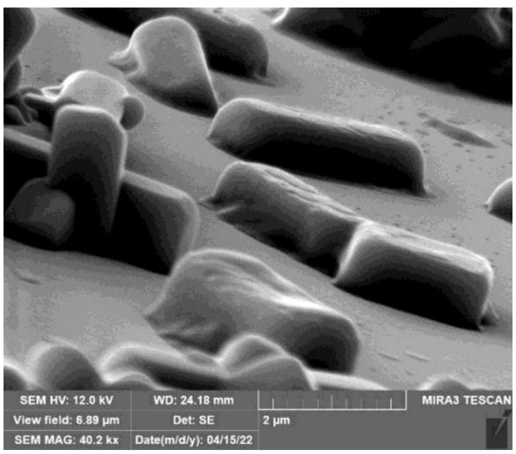

Fig. 2. A high-angle SEM micrograph of rectangular $CsPbBr_3$ perovskites depicted on the surface of a TiO_2 substrate that was annealed at 400 °C.

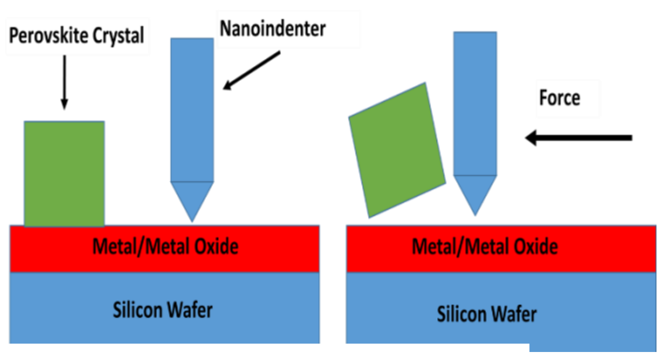

Fig. 4. A depiction of the modified nanoindentation method dislodging perovskite microcrystals using a scratch mode test.