# Adhesion and Excitation Lifetime of Perovskites on Modified Substrates

Xavier Vorhies,[1,2] Jessica M. Andriolo,[1,2] Erik M. Grumstrup,[3] David F. Bahr,[4] Joseph J. Thiebes,[3] Emma K. Orcutt,[3] Jack L. Skinner[1,2]

[1]Mechanical Engineering, Montana Technological University, Butte, MT 59701
[2]Montana Tech Nanotechnology Laboratory, Montana Technological University, Butte, MT 59701
[3]Chemistry and Biochemistry, Montana State University, Bozeman, MT 59717
[4]Materials Engineering, Purdue University, West Lafayette, IN 47907

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 and overall stability and improving electronic performance of the final device.[2] 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 were synthesized using a sputter deposition technique on transparent cover slips. Profilometry was used to verify a nominal thin film thickness of 50 nm. $TiO_2$ thin films were then further modified using various annealing treatments to recrystallize the rutile and anatase phases and modify surface roughness. $CsPbBr_3$ perovskites were precipitated on the substrates using a solution-based drop casting synthesis method. Perovskite morphologies and composition were characterized using scanning electron microscopy (**Figure 1**).

Quantifying the adhesive forces of isolated perovskite crystals 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 (**Figure 2**). Continuous monitoring of the lateral and normal loads will enable estimation of the adhesion energy of perovskite crystals on the substrate.

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 correlate the adhesion of perovskites on various modified $TiO_2$ substrates and determine excited state lifetimes along with optoelectronic properties using time-resolved photoluminescence spectroscopy (**Figure 3**). 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

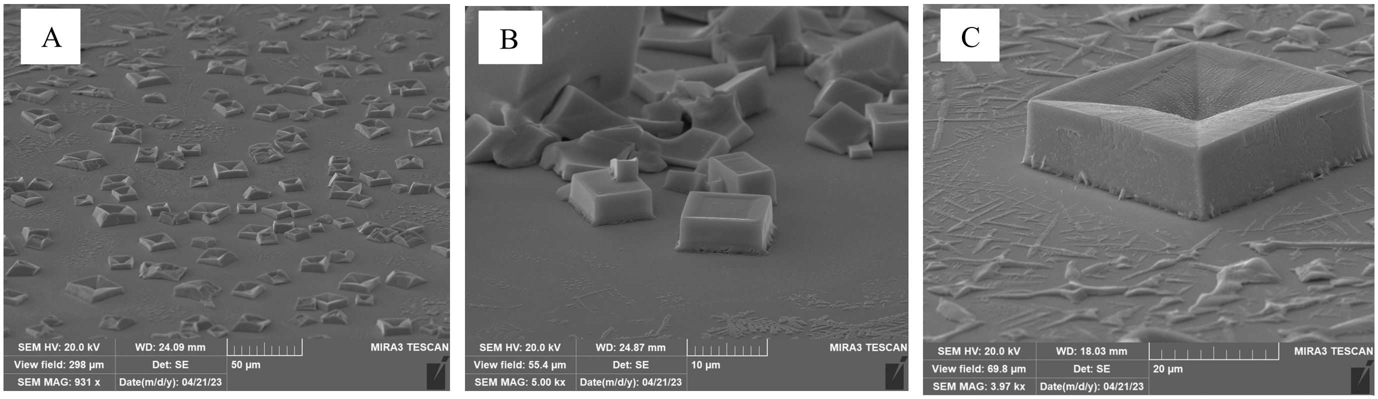


**Figure 1. A**. SEM micrograph depicting cuboid $CsPbBr_3$ perovskites on the surface of a $TiO_2$ substrate that was annealed at 400 ºC. **B**. SEM micrograph of cuboid $CsPbBr_3$ perovskites on the surface of a $TiO_2$ substrate that was annealed at 400 ºC. **C**. A high-angle SEM micrograph of cuboid $CsPbBr_3$ perovskites depicted on the surface of a $TiO_2$ substrate annealed at 400 ºC.

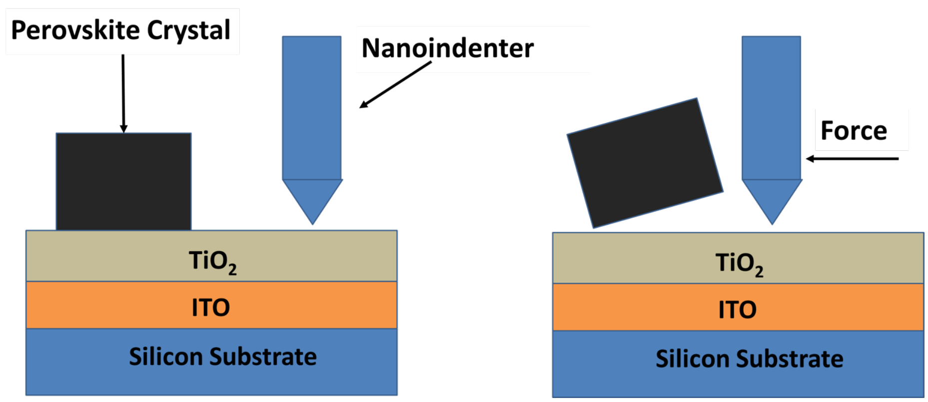


**Figure 2.** Graphic demonstrating the modified nanoindentation method used to quantify adhesive forces of perovskites on substrates. The nanoindenter will be used to dislodge perovskite crystals off the substrates using a scratch mode test.

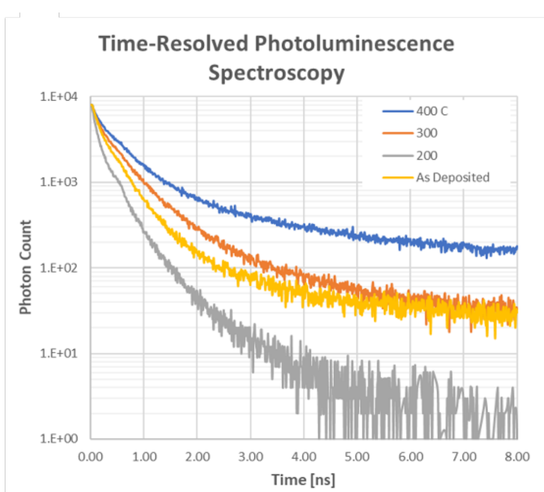


**Figure 3.** TRPL analysis of perovskites on substrates treated with various annealing temperatures. This method will be used to determine excitation lifetime of perovskites deposited onto various substrates. The data will be compared to adhesive characterization to determine how adhesion impacts excitation lifetime of the perovskites.