# Machine Learning-Guided Optimization of Perovskite Films Using In-Situ Imaging

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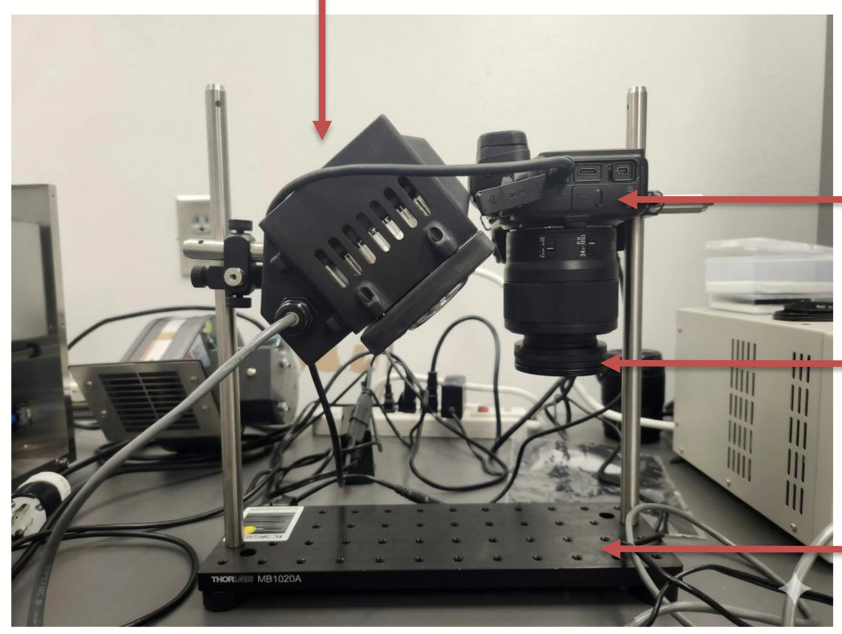
## Introduction

Perovskite solar cells (PSC) are highly promising for manufacturing efficient solar panels, but they tend to degrade quickly under open-air conditions. This degradation is often not visible to the naked eye, making it difficult to monitor. Photoluminescence (PL) imaging has been widely used in traditional silicon-based solar panels to reveal defects and areas of performance loss. In contrast, its use in perovskite-based systems remains relatively limited. This study explores the use of PL imaging as a method to detect and evaluate degradation in PSC samples.

## Procedure

Four PSC sample types were analyzed. Each sample consisted of a layered structure, with variations in substrate and interfacial layers; however, all samples used a silver (Ag) back contact covered with a thin busbar.



Lamp that emits green light

PL camera

Filter to prevent the absorption of green light

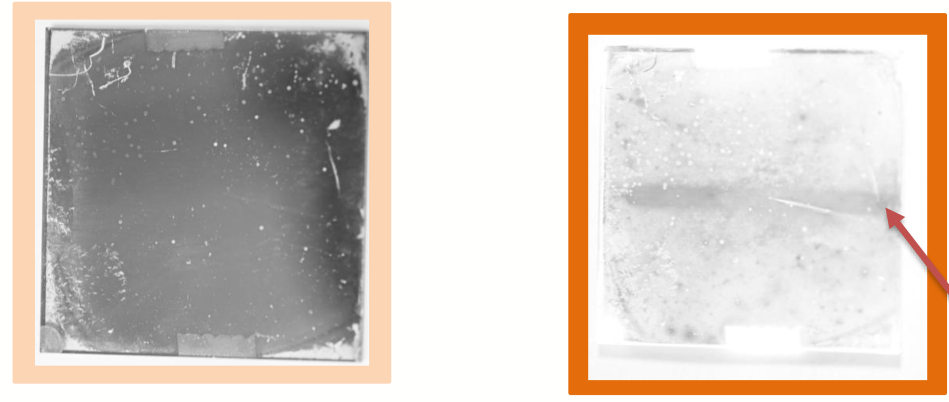
Samples placed here

Fig 1: PL Imaging System

A standard image of each sample was first captured using a conventional camera. This was followed by photoluminescence (PL) imaging, an optoelectronic technique in which the sample absorbs incident light and reemits it as photons. The intensity and uniformity of this emitted light are directly related to the material’s electronic quality. Regions with strong, uniform emission typically indicate better-performing areas, while darker or non-uniform regions can reveal defects, non-radiative recombination sites, or degradation.

## Measurements & Results

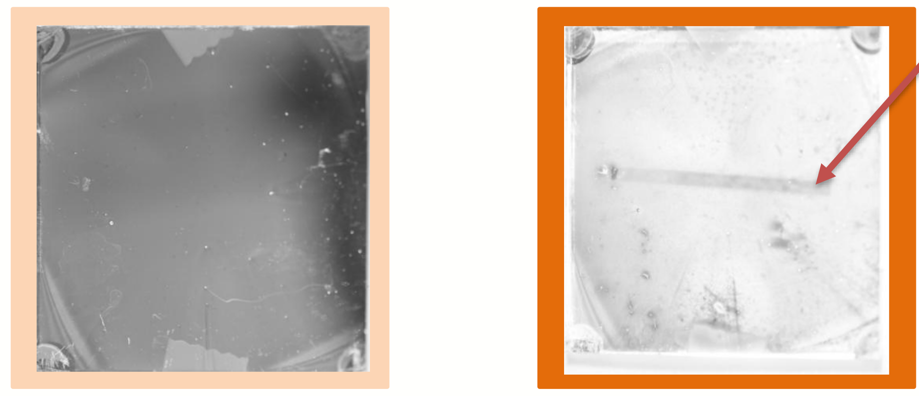
(1) G-PVR-C60-Ag-B



Standard Image PL image

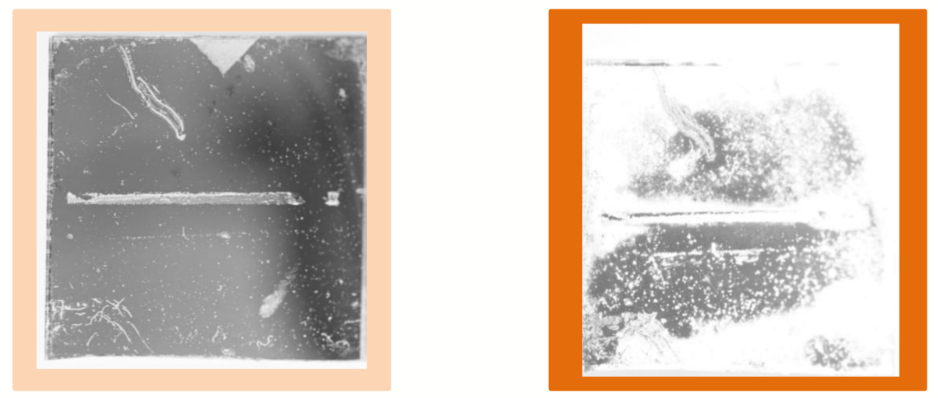
Visible busbar

(2) G-SAM-PVR-PMMA-Ag-B



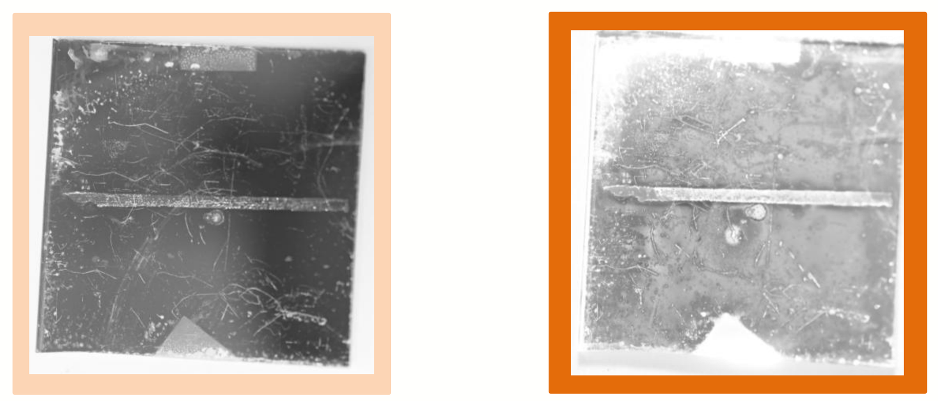
Standard Image PL image

(3) ITO-SAM-PVR-PMMA-Ag-B



Standard Image PL image

(4) ITO-SAM-PVR-C60-Ag-B



Standard Image PL image

**Note:** In (1) and (2), the lower PL intensity under the busbar suggests efficient charge extraction and good interfacial contact, with no strong evidence of delamination; the reduced signal is likely due to effective extraction or minor localized degradation. In contrast, (3) and (4) show higher PL intensity, indicating poorer charge transfer at the interface, possibly due to weaker contact or partial delamination, leading to charge accumulation and increased radiative recombination.

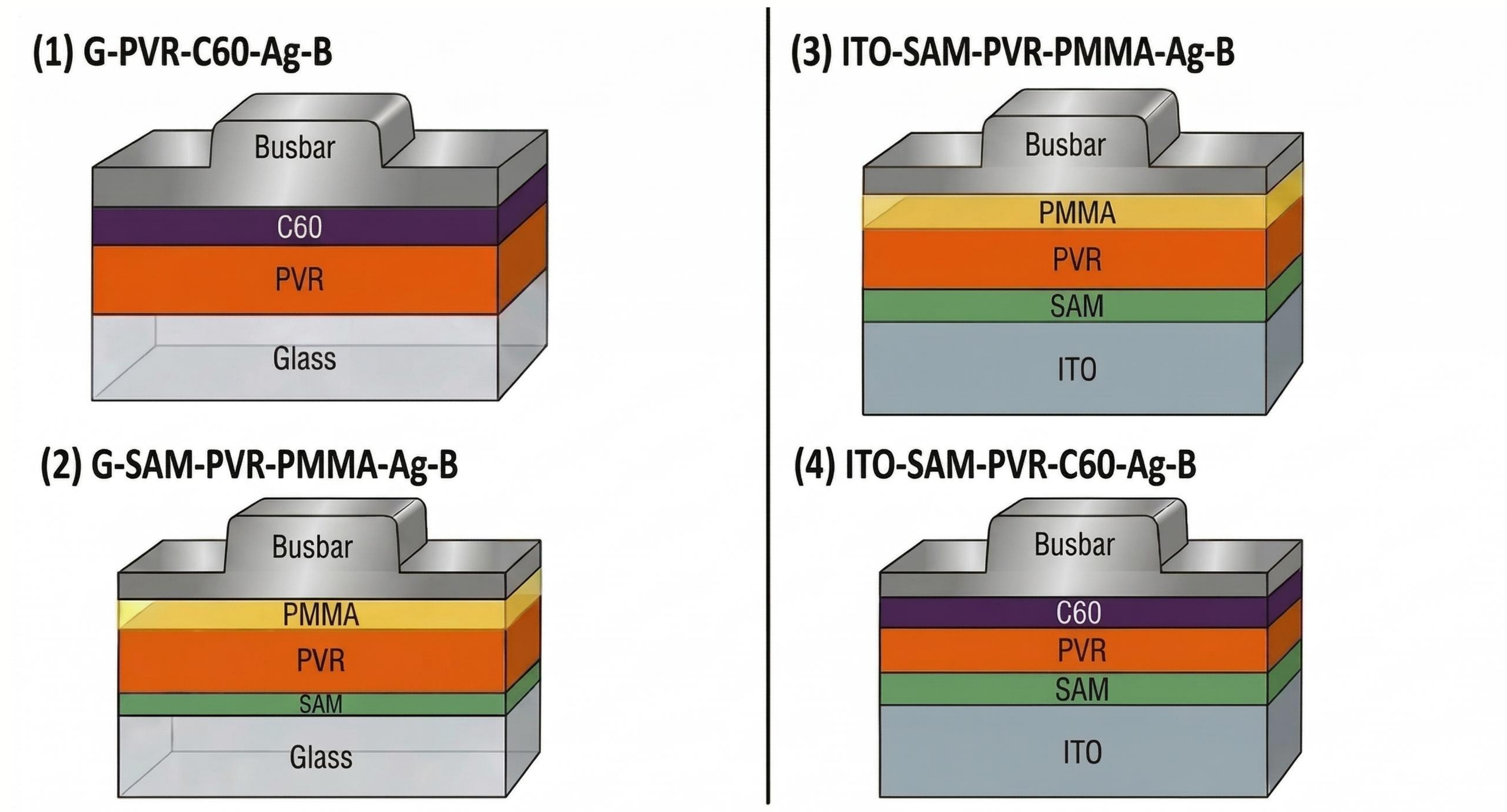



Fig 2: Cross Sections of the Sample Layers

## Conclusion

This research demonstrates that degradation in perovskite solar cells is difficult to detect with the naked eye or standard imaging methods. The use of photoluminescence (PL) imaging enables more effective identification of degradation. Furthermore, automating the PL imaging system allows for more consistent and detailed observation of degradation in samples over time.

## Future Work

The degradation of perovskite solar cell samples will be observed by placing them on a hot plate while capturing photoluminescence (PL) images at regular intervals using an automated PL system. The hot plate is used to simulate elevated temperature conditions. Higher temperatures can be applied to accelerate the degradation process, while imaging during controlled heating and cooling cycles can replicate day–night environmental variations. Using the results from the automated PL, a machine learning model will be created to better analysis the defects.

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