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Multi-Model Deep Learning Framework for Defect Detection in Mixed-Dimensionality $FAPbI_3$ Perovskite Films

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Abstract: *This study explores the preparation and morphological analysis of $FAPbI_3$ perovskite films for photovoltaic applications, focusing on defect engineering along grains and grain boundaries. Scanning electron microscopy (SEM) images of the films were categorized into five distinct types: pure 3D perovskite, 3D perovskite with PbI_2 excess, 3D perovskite with pinholes, 3D-2D mixed perovskite, and 3D-2D mixed perovskite with pinholes. To enhance defect analysis, we developed a comprehensive deep learning framework, benchmarking nine architectures—YOLOv8, ResNet50V2, DenseNet169, EfficientNetB3, MobileNetV3 Large, Vision Transformer, CoCa, YOLOv9, and InceptionV3—on a curated dataset of these defect types. Despite challenges posed by limited SEM image availability due to specialized laboratory requirements, our framework, supported by data augmentation and transfer learning, achieved robust performance, with YOLOv8 attaining 100% test accuracy. The models were integrated into a user-friendly Streamlit web application, facilitating practical defect identification. This work provides valuable insights into optimizing perovskite film quality for improved solar cell performance and stability*

Keywords: Classification, Pinholes, Defect Engineering, Transfer Learning, Perovskite solar cells