Ultrafast and Close-Space Processing Methodologies for Scalable Perovskite Thin-Film Growth

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Project Background and Motivation

Metal–halide perovskites have demonstrated exceptional optoelectronic properties and rapid performance gains across photovoltaics, photodetectors, and light-emitting devices. However, a major bottleneck for industrial translation remains the scalability, reproducibility, and throughput of perovskite thin-film growth.

Most laboratory-scale demonstrations rely on slow, solution-based processing routes that are sensitive to ambient conditions and difficult to control over large areas. In contrast, ultrafast and close-space deposition techniques—such as close-space sublimation (CSS), flash evaporation, and high-rate thermal evaporation—offer compelling advantages, including:

- Deposition times reduced from minutes to seconds
- Excellent thickness and stoichiometry control
- Compatibility with large-area and roll-to-roll manufacturing
- Reduced solvent-related variability
- Direct integration with vacuum-processed device stacks

Recent advances have shown that perovskite films grown under extreme growth rates and short source–substrate distances can achieve high crystallinity, low defect density, and excellent device performance, challenging the traditional paradigm that slow crystallization is required for high-quality perovskite films.

This project aims to systematically investigate ultrafast and close-space processing methodologies for perovskite thin-film growth, with a focus on understanding growth kinetics, structure–property relationships, and process–performance trade-offs.

Objectives

The main objectives of this Master's thesis are:

1. To understand the physical principles governing ultrafast and close-space thin-film growth.
2. To develop perovskite thin films using close-space and high-rate vacuum deposition techniques.
3. To study how growth parameters affect crystallization dynamics, microstructure, and optoelectronic properties.

4. To benchmark ultrafast-grown perovskite films against conventionally processed films.
5. To identify scalable process windows suitable for industrial translation.