Dimensionality and composition modifications for highly efficient and durable perovskite solar cells

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Abstract:

This thesis presents a comprehensive study aimed at enhancing the performance and stability of perovskite photovoltaic cells. This generation of solar cells represents a promising area in solar technology, but they face challenges including repeatability of the fabrication process and cell degradation over time. In addressing these challenges, the research focused on modifications of both perovskite chemical composition and perovskite solar cell structure.

It was shown that the addition of camphorsulfonic acid (CSA) in the active layer of solar cells is an effective method for enhancing performance. This strategy resulted in significant improvements in material quality and grain sizes, boosting the efficiency by 20% compared to CSA-free reference.

The research also delves into the development of a unique hole transport layer (HTL) using chemically synthesized polyaniline protonated with CSA. While this approach led to slightly lower efficiency compared to conventional methods, it demonstrated potential for boosting the long-term stability of the cells.

A substantial portion of this work investigates the degradation mechanisms in perovskites, with a particular focus on the influence of oxygen and water diffusion. The study presents insightful findings on the impact of environmental factors on perovskite stability and proposes potential mitigation strategies, among others fabrication of quasi-3D perovskites or a partial substitution of iodine with bromine. Besides perovskite chemistry modifications, an Al_2O_3 protective layer onto the perovskites using Atomic Layer Deposition (ALD) was applied. This method showed effectiveness in limiting both oxygen and water diffusion, thereby enhancing the stability of the perovskite layers and solar cells.

A non-standard *in-situ* technique of solidification processes, as well as hydration of perovskite materials, was utilized. It proved to be very fruitful in understanding the impact of precursor composition on the rate of crystallization processes and the resulting structure of the material. Moreover, this technique allowed for tracing the hydration processes and determining the conditions for reversible hydration of perovskites.

Systematic studies of degradation of modified perovskites (quasi-3D), iodide and those mixed with bromine were conducted over a period of 120 days. While *classic* 3D perovskites completely degraded after this period, the new perovskite formulas (quasi-3D) developed in this work retained a significant portion of their original form, demonstrating the effectiveness of the approach applied.

The work conducted provides new information about understanding degradation processes, as well as new strategies for improving repeatability, efficiency, and durability of perovskite-based solar cells. The author of the work hopes that they will form the basis for future research in this exciting area.