

**Title: Comparative Analysis of Inorganic-Organic Interface Engineering in Lead-Free
MASnI₃-Based Perovskite Solar Cells**

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Abstract (Minimum 200 words and maximum 250 words)

The urgent transition toward lead-free, environmentally sustainable photovoltaic technologies has necessitated the exploration of novel charge transport layers to improve the stability and power conversion efficiency (PCE) of tin-based perovskite solar cells (PSCs). This study evaluates the comparative performance of two distinct device architectures: Cu₂O-MAGeI₃-MASnI₃-BrNiPc and CuSCN-MAGeI₃-MASnI₃-BrNiPc. The primary objective of this research is to systematically investigate the interfacial charge extraction capabilities and band-alignment dynamics of Cuprous Oxide (Cu₂O) versus Copper(I) thiocyanate (CuSCN) when integrated into a lead-free heterojunction. By utilizing Brominated Nickel Phthalocyanine (BrNiPc) as a robust hole transport layer (HTL) across both configurations, we aim to overcome the intrinsic degradation pathways associated with traditional organic transport materials. These architectures leverage the synergistic integration of Methylammonium Tin Iodide (MASnI₃) as the primary absorber, further stabilized by a Germanium-doped (MAGeI₃) interface layer which serves to modulate the bandgap and bolster the structural integrity of the perovskite lattice. Cu₂O is selected for its high carrier mobility and p-type conductivity, while CuSCN is evaluated for its exceptional optical transparency and proven moisture resistance, both of which are critical for mitigating the rapid oxidation of tin-based

absorbers. Furthermore, the incorporation of BrNiPc provides a thermally resilient interface that minimizes energy loss at the HTL-perovskite junction. By performing a comparative analysis of the charge collection efficiency and long-term device stability, this research elucidates how these inorganic and phthalocyanine-based transport layers influence the optoelectronic performance of the heterojunction, providing a viable strategy for the development of high-performance, non-toxic, and commercially scalable perovskite solar cells.

Keywords:

- Perovskite Solar Cells (PSCs)
- Lead-free Perovskites
- MASnI_3 (Methylammonium Tin Iodide)
- Interface Engineering
- Charge Transport Layers