Synergistic Mechanical-Optoelectronic Engineering Enables Highly Deformable and Efficient Flexible Sb_2Se_3 Solar Cells

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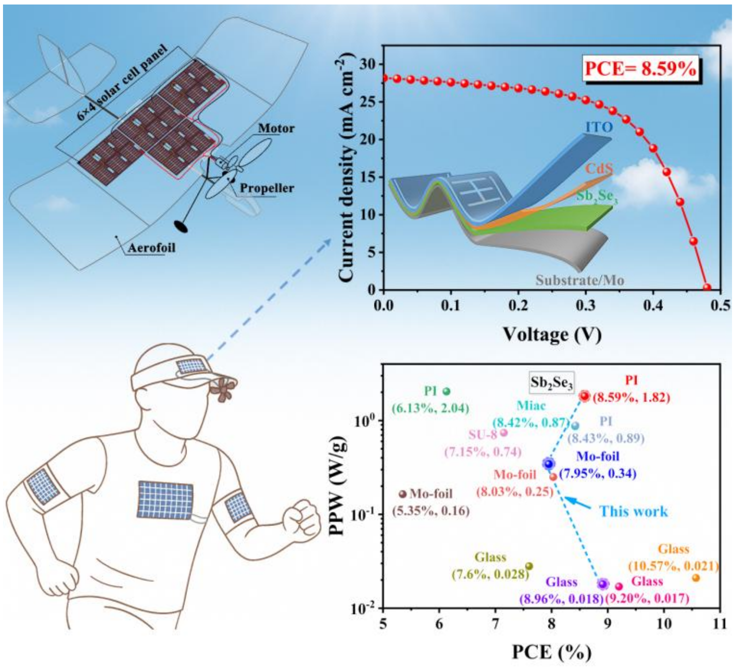
Abstract

Flexible Sb_2Se_3 solar cells have emerged as a promising photovoltaic technology for lightweight, portable, and wearable energy applications. However, simultaneously achieving excellent structural flexibility and high efficiency remains challenging due to the inherent brittleness of critical functional layers and stringent absorber layer requirements. Herein, we report a synergistic strategy integrating mechanical and optoelectronic engineering to overcome these limitations. Analytical modeling combined with finite element method (FEM) simulation precisely guides device structure optimization by tuning the polyimide (PI) substrate thickness to shift the mechanical neutral plane toward the center of the brittle Mo electrode layer, significantly reducing bending-induced strain and enhancing mechanical durability. Concurrently, the structurally optimized configuration facilitates the formation of high-quality Sb_2Se_3 absorber films with compact grains, preferred [hk1] orientation, and reduced defect densities, boosting charge-carrier transport and photovoltaic performance. As a result, the flexible PI-based devices achieve a record efficiency of 8.59%, an outstanding power-per-weight ratio of 1.82 W g^{-1}, and exceptional stability under extreme bending and repeated deformation. Moreover, the successful demonstration of large-area flexible modules integrated into wearable electronics and unmanned aerial vehicles underscores the practical feasibility and application potential of mechanically and optoelectronically co-engineered flexible Sb_2Se_3 solar cells.



Reference

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