**AI-Optimized Afterglow Functional Coatings for Enhanced Plant-Based Carbon Capture**


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Functional coatings offer a powerful yet underutilized platform for integrating advanced materials with biological carbon capture systems. In this study, we present an AI-optimized afterglow-enabled coating strategy designed to enhance photosynthetic carbon sequestration in indoor plants, positioning thin-film engineering as an active component in next-generation carbon capture solutions.A red-emitting afterglow phosphor system based on strontium sulfide (SrS) co-doped with europium (Eu) and praseodymium (Pr) was engineered to serve as a photonic energy storage layer. To ensure environmental stability and biocompatibility, the phosphor particles were encapsulated with a silica ($SiO_2$) shell and subsequently embedded into a transparent polymeric coating. This functional thin film was applied directly to the leaf surface of Monstera deliciosa, forming a conformal light-management layer that acts as a “light battery,” continuously supplying photosynthetically active radiation during low-light and dark periods.

To maximize luminescence performance and carbon fixation efficiency, an artificial intelligence–driven optimization framework was developed. A Genetic Algorithm–Neural Network (GA–NN) model was constructed to predict photoluminescence intensity as a function of Eu and Pr co-doping concentrations. The training dataset consisted of experimentally synthesized samples across multiple doping ratios and batch processes. A two-hidden-layer neural network architecture was selected to balance nonlinear representational capability with overfitting avoidance. The genetic algorithm employed a crossover rate of 0.7 and a mutation rate of 0.007, enabling rapid convergence while preserving population diversity. Model convergence was achieved within 30,000 generations and 300 evaluation cycles. The optimized dopant composition was further refined using a generative reinforcement learning strategy to jointly maximize afterglow intensity and photosynthetic response. As a result, the afterglow-functionalized coating increased net photosynthetic assimilation to 2.352 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and enhanced sustained carbon capture efficiency by 20.55% compared to untreated controls. Beyond measurable performance gains, the coating provides aesthetic and functional value for indoor environments. This work demonstrates a novel paradigm in which AI-guided thin-film engineering directly augments biological carbon capture. By coupling functional coatings with machine-learning-driven materials optimization, the proposed approach offers a scalable and integrative pathway toward high-efficiency biosequestration in built environments.