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Broadband single-layer dielectric anti-reflective solar cell coatings

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A third to a half of solar radiation is reflected from a silicon surface of a bare solar cell. That is why a problem of creation additional anti-reflective coatings gathers lots of attention even today. In our submission, we demonstrate that a single patterned polycrystalline silicon layer can suppress average reflectance to $\approx 2\%$ at normal incidence and below 5 % up to 60° across the 500–1200 nm band—performance that rivals state-of-the-art multilayer dielectric stacks while remaining fully CMOS-compatible. We describe two complementary strategies. First, a forward parametric sweep explores hybrid cross-circle meta-atoms, optimizing five geometric parameters with rigorous coupled-wave analysis (RCWA). Second, an inverse free-form route employs a ResNet-based generative latent optimization network (GLOnet) accelerated by adjoint RCWA, allowing the optimizer to discover manufacturable binary patterns on a 380 nm lattice in only a few hours on a modest CPU cluster.

Both routes independently converge on Huygens-type unit cells that satisfy a generalized Kerker condition, forwarding light efficiently into silicon with negligible absorption. The best cross-circle design already reduces weighted reflectance to 5 %, but the machine-learning-derived free-form geometry pushes it down to 4.4 % while retaining a manufacturable design.

Our results reveal that rapid forward sweeps give valuable physical intuition, while AI-assisted inverse design locates near-global optima that human intuition alone might miss, all within a single-layer process window. The demonstrated combination of ultrabroadband performance, wide angular acceptance, polarization insensitivity and single-step fabrication positions such silicon metasurfaces as practical antireflection solutions for next-generation solar cells, photodetectors and integrated photonic systems.

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