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# 光トラップ効率増大に向けたフォトニック結晶構造の検討

## (B) トポロジー最適化と部分的ランダム化に基づくアプローチ

## Enhancing light trapping with a photonic-crystal slab based on topology optimization and partial disorder

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Lambertian surfaces for light trapping, consisting of a complete random texturing to isotropically scatter incident light rays into the plane of the absorbing film to increase the optical path length, first proposed nearly thirty years ago, have remained the simplest and most effective means for photon absorption over the broadest range of frequencies and incident angles; though an experimental realization of this ideal structure has proven to be challenging. Recent nanophotonic designs exploiting the more complicated wave effects of photons have suggested the possibility of superior performance though as of yet no proposal employing an absorbing high-index semiconductor film relevant for practical applications has in fact been made. Here we describe a general strategy for the design of absorbing semiconductor thin films suitable for solar applications based on a controlled, partially-disordered photonic-crystal (PC) slab that has large absorption approaching the Lambertian light-trapping limit over a broad bandwidth and angular range. Our two-part design strategy consists of first maximizing the number of resonant-absorption modes in the PC through a few-parameter gradient-free topology optimization made possible by recent advances in computational electrodynamics and then adding an optimal amount of disorder to maximize the light-trapping efficiency and boost robustness. We use intrinsic crystalline silicon as our absorbing material and incorporate its full broadband complex refractive index profile into the FDTD simulations (accurate even near its indirect bandgap of 1108nm where absorption is almost negligible) to obtain experimentally-realistic results. Also we show analytically why a partial amount of disorder controllably introduced into the PC increases broadband light trapping while too much disorder is sub-optimal. Further details will be reported at the meeting. *This work is supported by Core Research for Evolutional Science (CREST) of the Japan Science and Technology Agency and the Japan Society for the Promotion of Science (JSPS).*

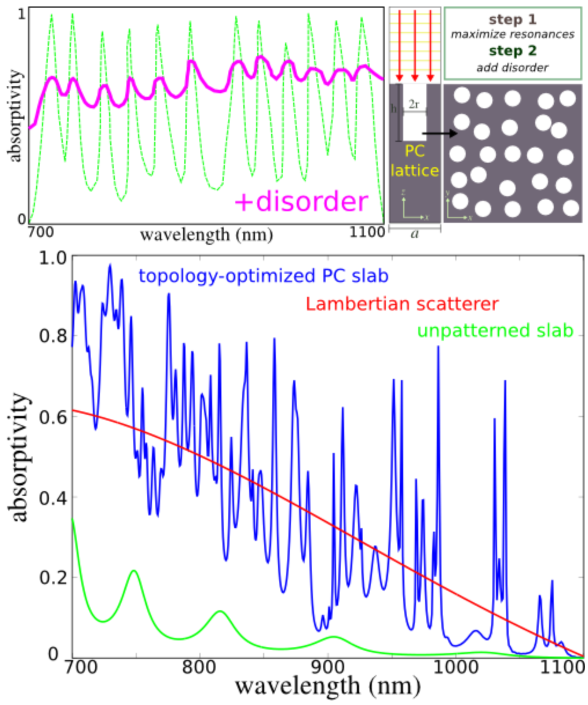


**FIG. 1** TOP: General two-part design strategy for enhancing the light-trapping performance and boosting robustness of a photonic-crystal (PC) slab. The first part involves maximizing the number of resonant-absorption modes via a few-parameter gradient-free topology optimization and then adding an optimal amount of disorder to make a more uniform absorption profile that is insensitive to incident radiation conditions. BOTTOM: Absorption versus normalized wavelength profile at normal incidence for three thin-film (1μm) crystalline Silicon designs: a topology-optimized photonic crystal with maximal number of resonant-absorption modes (blue), a Lambertian-textured (both top and bottom surfaces) film (red) and an unpatterned slab. The PC consists of a square lattice (periodicity, *a*=660nm) of circular air holes (r=264nm, h=400nm) etched into the Silicon.