

Light-trapping for next-generation single-junction and tandem solar cells

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Context

Photovoltaics (PV) are a cornerstone of the global energy transition. Today, silicon-based solar cells dominate the market (97%), achieving average conversion efficiencies of 23% and records exceeding 28.2%, typically using 150 μm -thick wafers. The next generation of solar cells could achieve a seemingly paradoxical goal: higher efficiency with less material. For example, tandem architectures could push efficiencies beyond 30% and even up to 45%. Ultrathin solar cells (10x thinner than conventional ones) offer a transformative solution for material savings and reduced carbon footprint, lightweight and flexible applications, and are compatible with tandem solar cells for even higher performance.

However, their performance has been limited by insufficient light-trapping to compensate for the reduced material volume. Our team has already achieved a major milestone: in 2019, we demonstrated a 19.9%-efficient ultrathin solar cell with only 200 nm of GaAs, using a nanostructured back mirror that leverages multi-resonant absorption (Nature Energy, 2019). We've also published a comprehensive review on ultrathin solar cells (Nature Energy, 2020) and derived theoretical upper bounds for light trapping (PRX Energy, 2026), opening new perspectives for ultrathin solar cells.

Scientific project

This internship builds on these results to develop and demonstrate practical solutions for light-trapping in ultrathin solar cells. It will combine clean-room work and optical simulation, and it will explore the potential of correlated-disorder nanostructures for light-trapping using low-cost, self-assembly processes, aiming at their integration in single-junction silicon solar cells and tandems.

After a training to clean-room security and processes, the candidate will develop new fabrication processes in clean room in order to study and compare two emerging concepts: (1) multi-resonant absorption using perfectly ordered structures (arrays) fabricated by nanoimprint lithography, and (2) directional scattering using structures with correlated disorder, fabricated by self-assembled nanopatterning techniques such as polymer-blend and colloidal lithography. The performances will be analyzed by optical spectroscopy (reflection, transmission, absorption measurements) and optical simulation. The best performing nanopatterns will be integrated into thin and ultrathin silicon solar cells.

The team

This project is a joint effort between [C2N](#) (SUNLIT Team) and [UMR IPVF](#), both located on the Paris-Saclay campus (Palaiseau). It is part of the [ERC Synergy UltiMatePV project](#), in collaboration with Glunz's group at Fraunhofer ISE and Ballif's group at EPFL. More information on the SUNLIT Team: <https://sunlit-team.eu>

Profile: We are looking for a high-level student in M2 with a solid knowledge in semiconductor physics and optics. Possibility to continue with a PhD grant on ultrathin, high-efficiency tandem solar cells in 2027.

Send CV and motivation letter to: stephane.collin@cnrs.fr

Starting date: 02/2027 (adjustable).

References:

- [1] [H.-L. Chen et al., A 19.9%-efficient ultrathin solar cell based on a 205-nm-thick GaAs absorber and a silver nanostructured back mirror. Nature Energy 4, 761-767, 2019.](#)
- [2] [I. Massiot, A. Cattoni, S. Collin. Progress and prospects for ultrathin solar cells. Nature Energy 5, 959-972, 2020.](#)
- [3] [S. Collin and M. Giteau, Upper Bounds on Broadband Absorption and Application to Solar Cells. PRX Energy 5, 023006 \(2026\).](#)
- [4] [S. Collin et al., Advances in solar photovoltaic technologies and the role of photonics, Photoniques 128, 41-49 \(2024\).](#)

A short introduction to light-trapping in solar cells

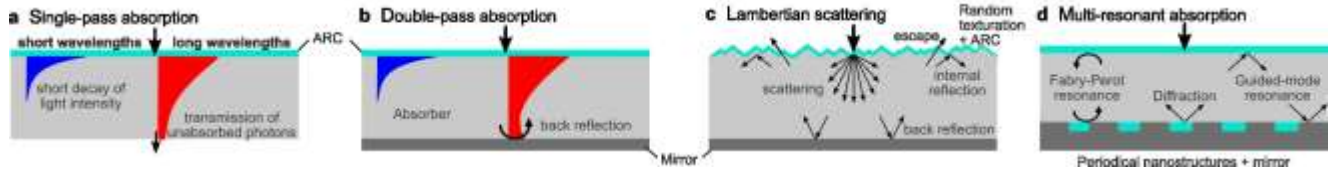


Figure 1. Main strategies and basic mechanisms for light-trapping in solar cells.

The presence of coatings, back mirror, roughness, textured or patterned surfaces can modify the way light enters the cell, propagates, scatters and is trapped in the absorber (see Figure 1). The optical path enhancement factor F is used as a figure-of-merit for light trapping, and absorption can be expressed by the generalized Beer-Lambert law: $A = 1 - e^{-F\alpha d}$, where α is the absorption coefficient and d the thickness. $F=1$ for single-pass absorption with a perfect ARC, and $F=2$ with an additional perfect back reflector (double-pass absorption).

The first requirement to optimize sunlight absorption is the suppression of reflection at the front interface, about 30% for bare silicon or III-V materials. This is commonly achieved by a double-layer anti-reflection coating (ARC). Textured or rough surfaces also help suppress optical reflection by creating a graded effective refractive index.

To compensate for the drop of α near the bandgap, light-trapping is used to increase the optical path. The most common scheme is based on textured silicon surfaces obtained by chemical etching. The resulting randomly-positioned pyramids approximate Lambertian scatterers, whose upper limit is given by the Lambertian scattering model derived by E. Yablonovitch: $A = \alpha d / (\alpha d + 1/F)$ and $F = 4n^2 \approx 50$.

Actually, the Lambertian model is not a fundamental limit, and it could be exceeded by new light-trapping strategies (see Figure 2 and reference [3]). Correlated disorder such as hyperuniform structures have emerged recently in the photonics community and offer new degrees of freedom to investigate the full range of possibilities between fully disordered structures such as currently used in silicon, and fully ordered patterns. Periodical patterning has already been successfully used in III-V/Si tandem solar cells and in ultrathin GaAs solar cells to achieve absorption enhancement via multiple resonances.

Low-cost fabrication processes are favoured in the search for new light-trapping solutions. They should enable the development of ultrathin solar cells with thickness 10 times lower than conventional solar cells without performance degradation, enabling material savings and cost reduction.

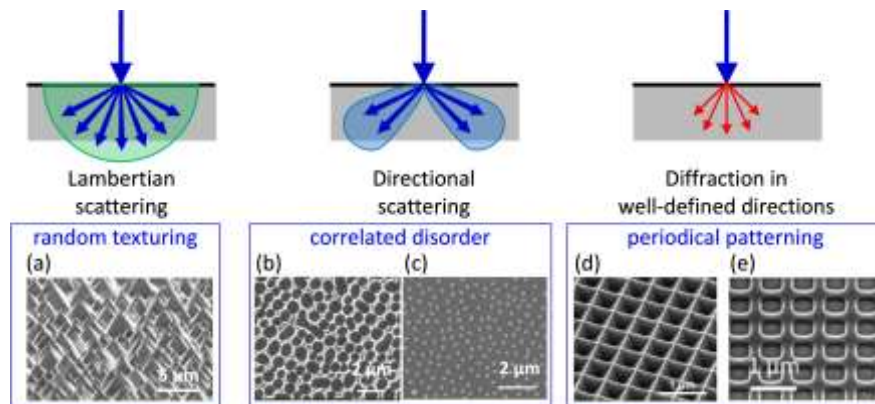


Figure 2. Scattering and diffraction effects and structures used to trap light in solar cells. (a) Chemical etching of silicon by KOH leads to randomly-positioned pyramids with well-defined angles, acting as a good approximation of Lambertian scatterers. (b,c) Recent advances in the physics of correlated disorder open new routes to achieve directional scattering using low-cost nanopatterning techniques such as polymer-blend (b) and colloidal (c) lithography. (d,e) Perfectly ordered structures fabricated by nanoimprint lithography result in diffraction in well-defined directions and absorption enhancement by multi-resonant effects: (d) inverted pyramids chemically etched in silicon, and (e) nanogrid made from sol-gel-based material. Credit: Images from C2N-CNRS.