Photonic solutions for improved photovoltaics

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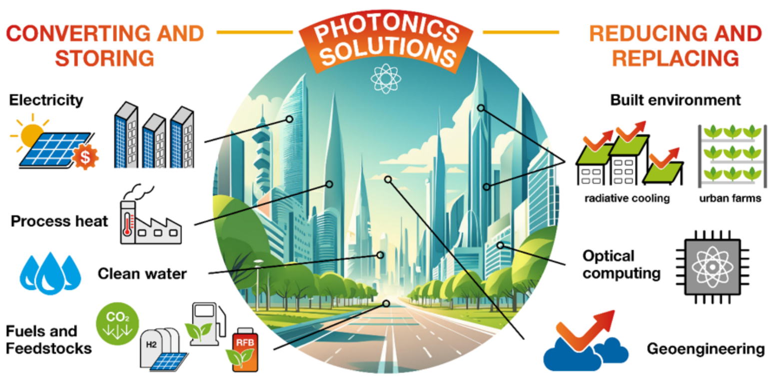
The mitigation of climate change requires major transformations in the ways we generate energy and operate technologies that release CO_2. Photonic concepts and novel light-driven technologies provide many opportunities to mitigate CO_2 emissions, transforming our current modes of energy use into more effective and sustainable ones. In a recent review paper, we describe several of these concepts that are in the early stage of scientific discovery, with at the same time great technological potential.[1]

In this presentation, we focus on how to create photovoltaics with improved properties that have potential for large-scale implementation. I will present an integrated near field/far-field multiple scattering formalism to control the absorption of light in multijunction solar cells. As a model system we use III-V/Si multi-junction solar cell and enhance the light trapping inside the silicon bottom cell by multiple scattering, creating a record photovoltaic energy conversion efficiency for silicon-based multijunction solar cells of 36.1%.[2] A similar light trapping concept can be applied in other multijunction solar cell geometries, such as perovskite/silicon tandem solar cells.

We then present a study on the nanoscale incoupling of light in textured perovskite/silicon solar cells, and show how optical Mie resonances create strong light inhogeneities in the tandem solar cell that can affect its performance. In addition we create micron-scale light scattering structures in solar cells to enhance emission in the (far-)infrared to create passive radiative cooling, enhancing the efficiency of and long-term stability of the solar cell. Light-driven processes can also help fabricate novel photovoltaics materials, and we show our most recent work on laser-induced crystallization of methyl-ammonia lead iodide perovskite directly from solution, with the crystal formation monitored in-situ through photoluminescence and Raman spectroscopy.

I will also present the 900 M€ Dutch national research, innovation and industrial development program SolarNL, in which universities, research institutes, and companies work together to develop photovoltaics technology and industry to help create a fully sustainable energy generation system in our society by 2050.[3]



References

1) *Photonic solutions to fight climate change*, G. Tagliabue, H.A. Atwater, A. Polman, and E. Cortes, Nature Photon. **18**, 897 (2024)
2) *Wafer-bonded two-terminal III-V//Si triple-junction solar cell with power conversion efficiency of 36.1 % at AM1.5g,* P. Schygulla, R. Müller, O. Höhn, M. Schachtner, D. Chojniak, A. Cordaro, S. Tabernig, B. Bläsi, A. Polman, G. Siefer, D. Lackner, and F. Dimroth, Progr. Photovolt. **32**, 1-9 (2023); *Nano-patterned back-reflector with engineered near-field/far-field light scattering for enhanced light trapping in silicon-based multi-junction solar cells*, A. Cordaro, R. Müller, S. Tabernig, N. Tucher, P. Schygulla, O. Höhn, B. Bläsi, and A. Polman, ACS Photon. **10**, 4061 (2023)
3) SolarNL: www.solarnl.eu