PHOTONIC MATERIALS

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The Photonic Materials group designs and fabricates optical metasurfaces for photovoltaic energy conversion to increase light absorption and photovoltaic energy conversion beyond current limits. In parallel, we develop optical metasurfaces for analog optical information processing. To characterize nanostructured surfaces we study electron-light-matter interaction using time-resolved cathodoluminescence spectroscopy. Our overarching goal is to develop fundamental insights that help speed up the energy transition, to realize novel concepts for low-power opto-electronics, and to demonstrate novel analysis and metrology tools for materials research.

Highlights

- **Photovoltaics:** Integrated near-field/far-field scattering matrix formalism creates (with Fraunhofer ISE) record Si-based multi-junction solar cell (36.1%).
- **Cathodoluminescence:** Ultrafast time-resolved photoemission electron microscope and first demonstration of electron-pump/optical-probe spectroscopy.
- **Metamaterials:** Silicon metasurfaces solve an integral equation using visible light.
- **Startup:** cathodoluminescence spectroscopy inventions created sales by Delmic (co-funded by us) that added 16 M€ to the Dutch economy.
- **SolarNL:** National research, innovation and industrial development program for PV industry in NL and EU (312 M€ grant).

Plans

We will further develop ultrafast cathodoluminescence microscopy to study carrier dynamics and nanoscale optical phenomena in opto-electronic materials. We aim to develop the microscope into a quantum instrument in which electron wavepackets are tailored in space and time to enable novel materials spectroscopies. Using 2D materials, we will develop tunable optical metasurfaces for optical processing and exploit them in advanced geometries including optical neural networks. We will use our expertise in microscopy and optical metasurfaces to develop perovskite-silicon solar cells with ultrahigh efficiency. In parallel, we will carry out the SolarNL plan to grow the photovoltaics industry in NL and EU.

Key research items

1. A. Cordaro, V. Nikkhah, A. Alu, N. Engheta, and A. Polman, *Solving integral equations in free space with inverse-designed ultrathin optical metagratings*, Nature Nanotechn. 18, 365 (2023)
2. N. Schilder, H. Agrawal, E.C. Garnett, and A. Polman, *Phase-resolved surface plasmon scattering probed by cathodoluminescence holography*, ACS Photon. 7, 1476 (2020)
3. V. Neder, S.L. Luxembourg, and A. Polman, E*fficient colored silicon solar modules using integrated resonant dielectric nanoscatterers*, Appl. Phys. Lett. 111, 073902 (2017)
4. *National Agenda Materials: Accelerating materials technologies:* establishment of national Agenda for materials research. See: https://materialennl-platform.nl/.
5. SolarNL: *Circular integrated high-efficiency solar panels:* establishment of a national research, innovation and industrial plan to start a photovoltaics industry in the Netherlands and Europe (312 M€ grant). See: https://www.solarnl.eu.

Multiple light scattering from optical metasurfaces. (Left) Silicon metasurface that solves a Fredholm integral equation using light. (Right) light trapping metasurface backcontact results in record photovoltaic conversion efficiency for Si-based multi-junction solar cells of 36.1%.