

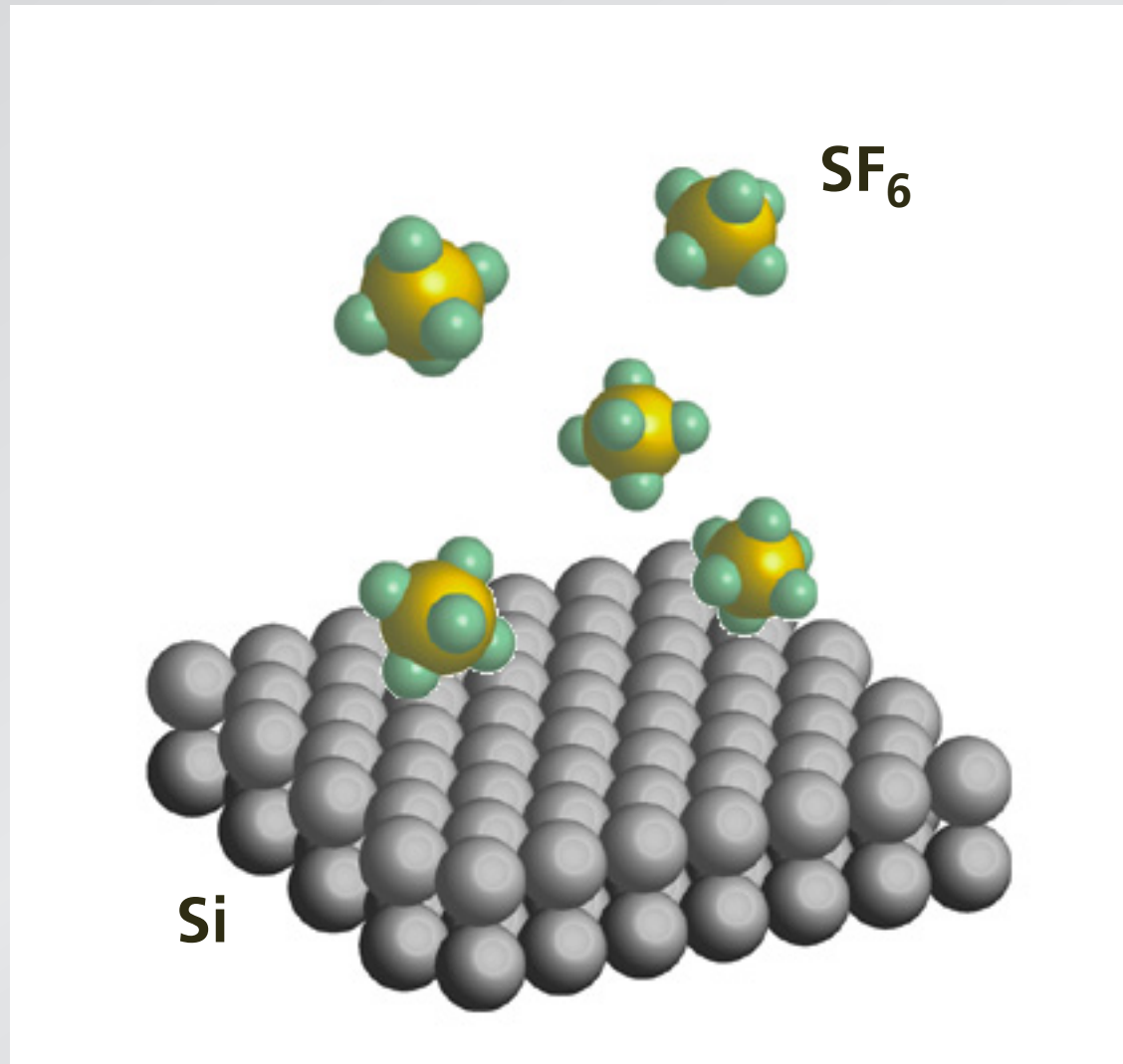
Black silicon: better photovoltaics?



Harvard Energy Innovation Showcase
Harvard University
Cambridge, MA, 29 November 2011



Introduction



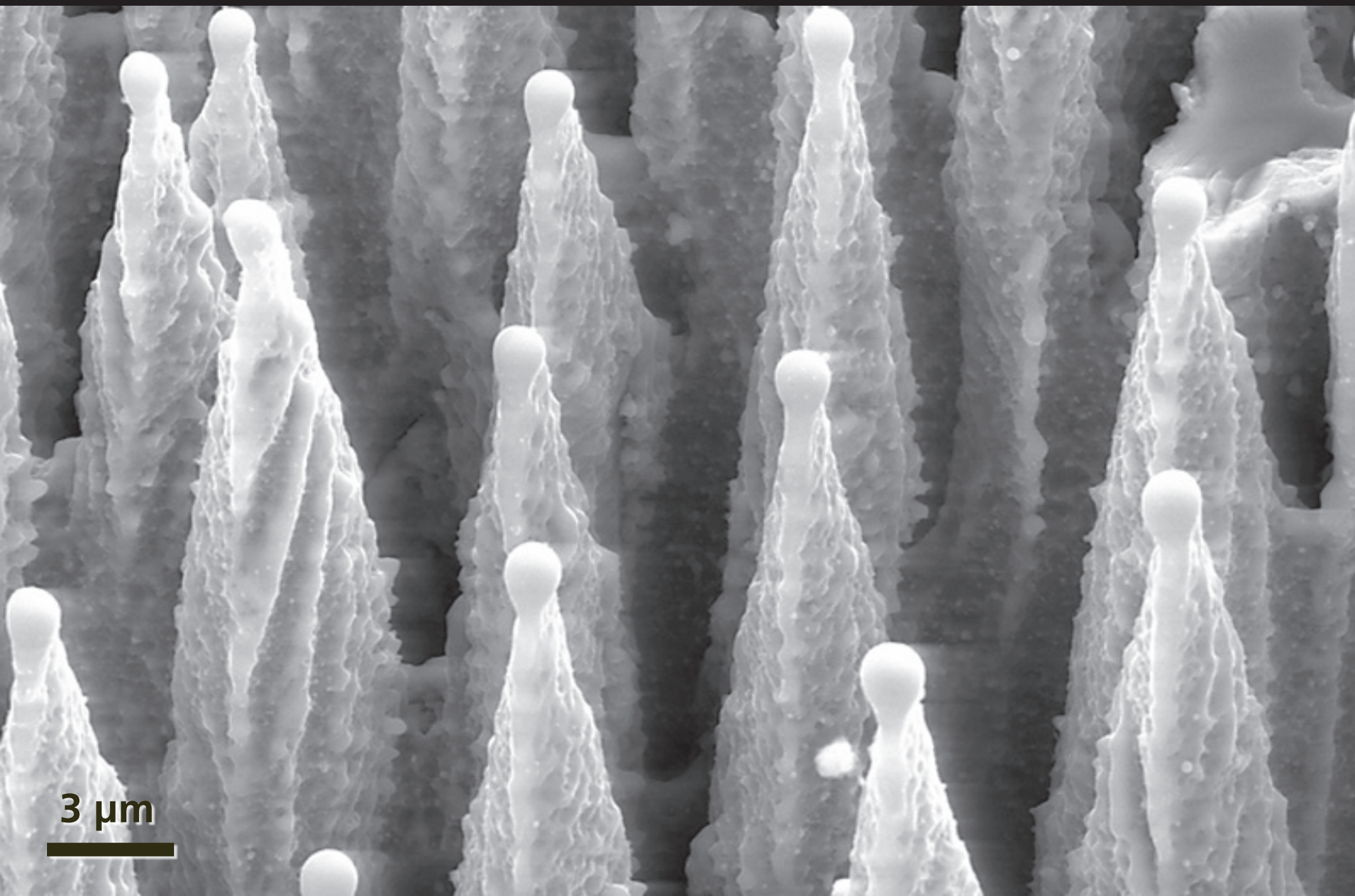
irradiate with 100-fs 10 kJ/m² pulses

Introduction



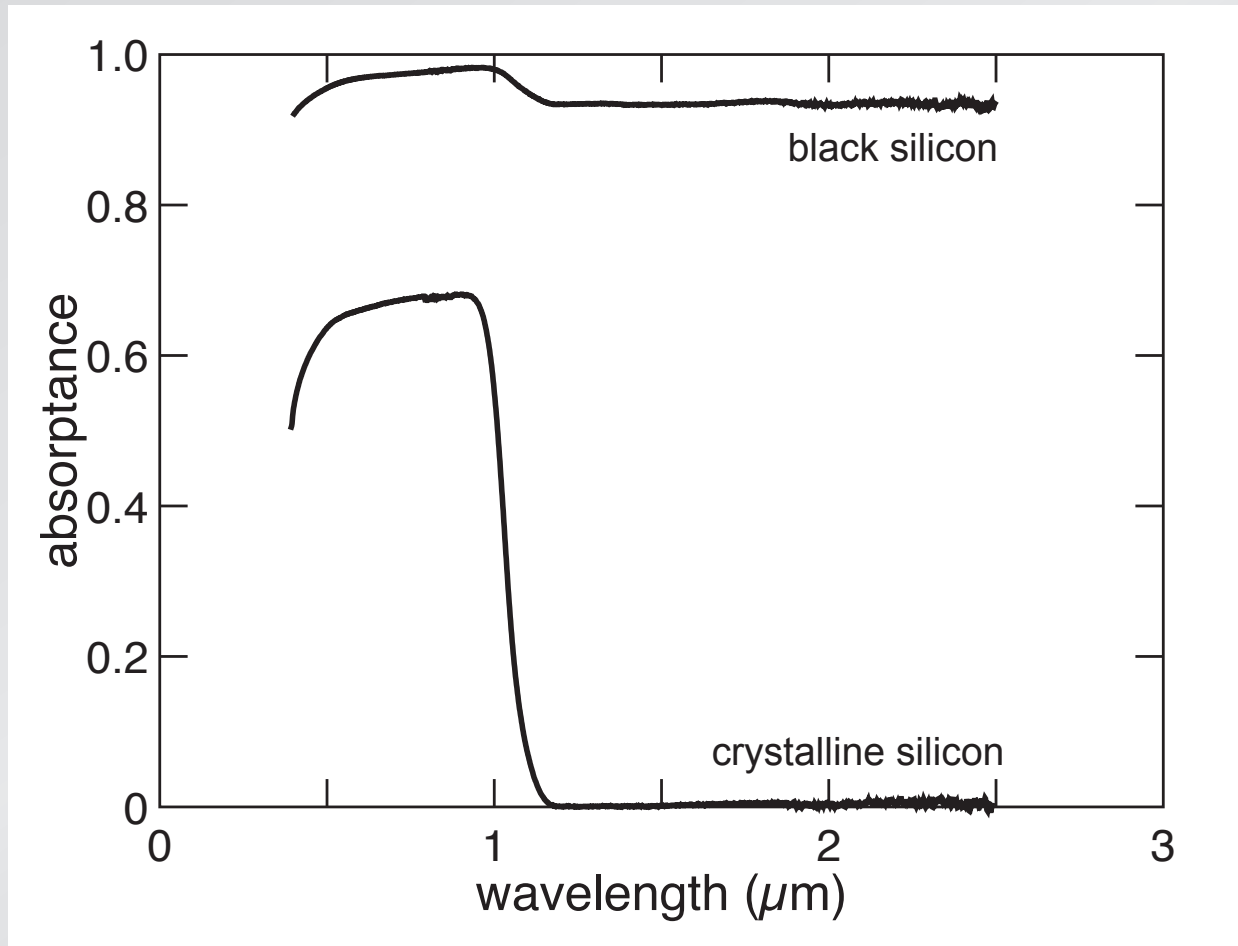
"black silicon"

Introduction

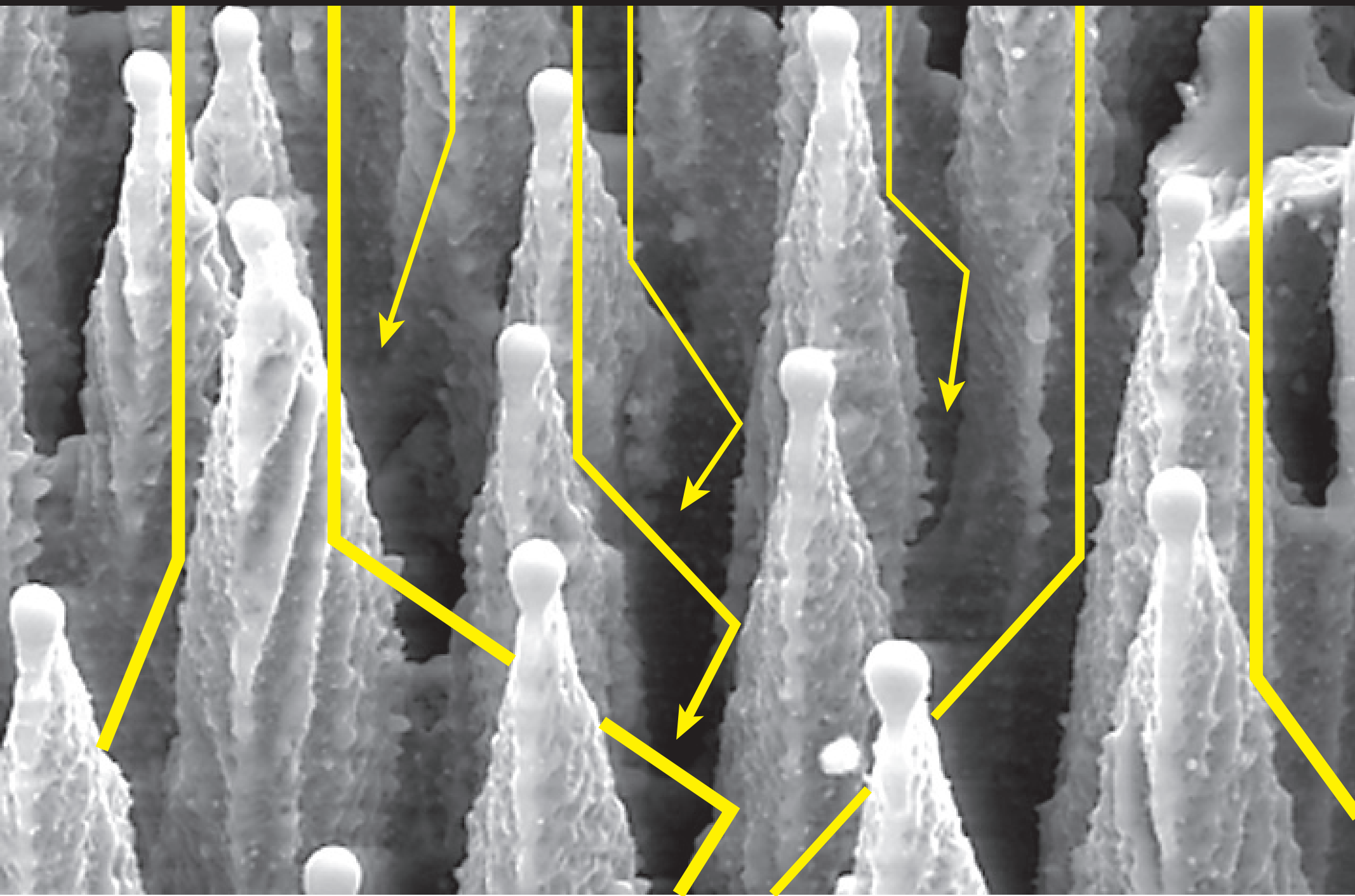


Introduction

absorptance ($1 - R_{int} - T_{int}$)

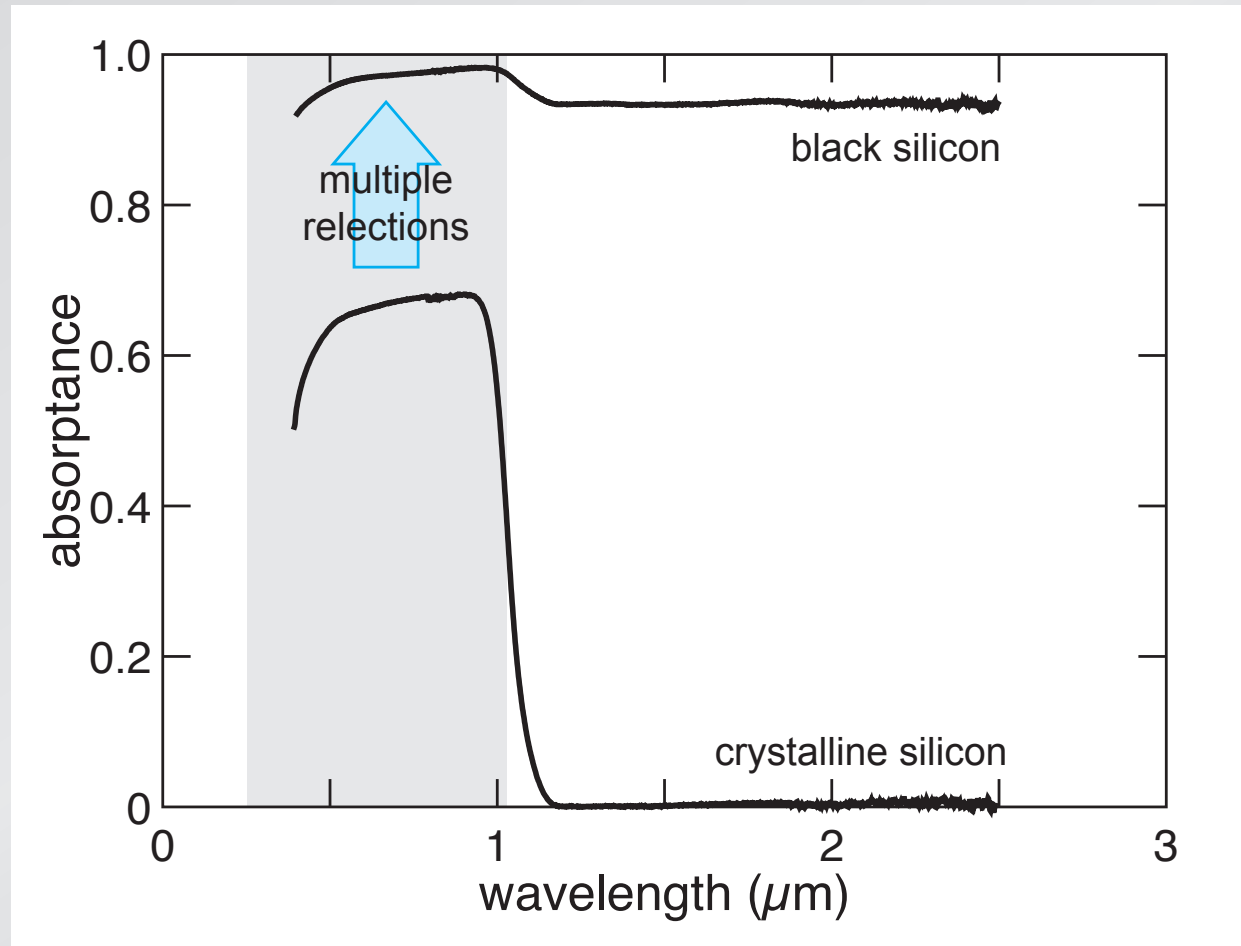


Introduction

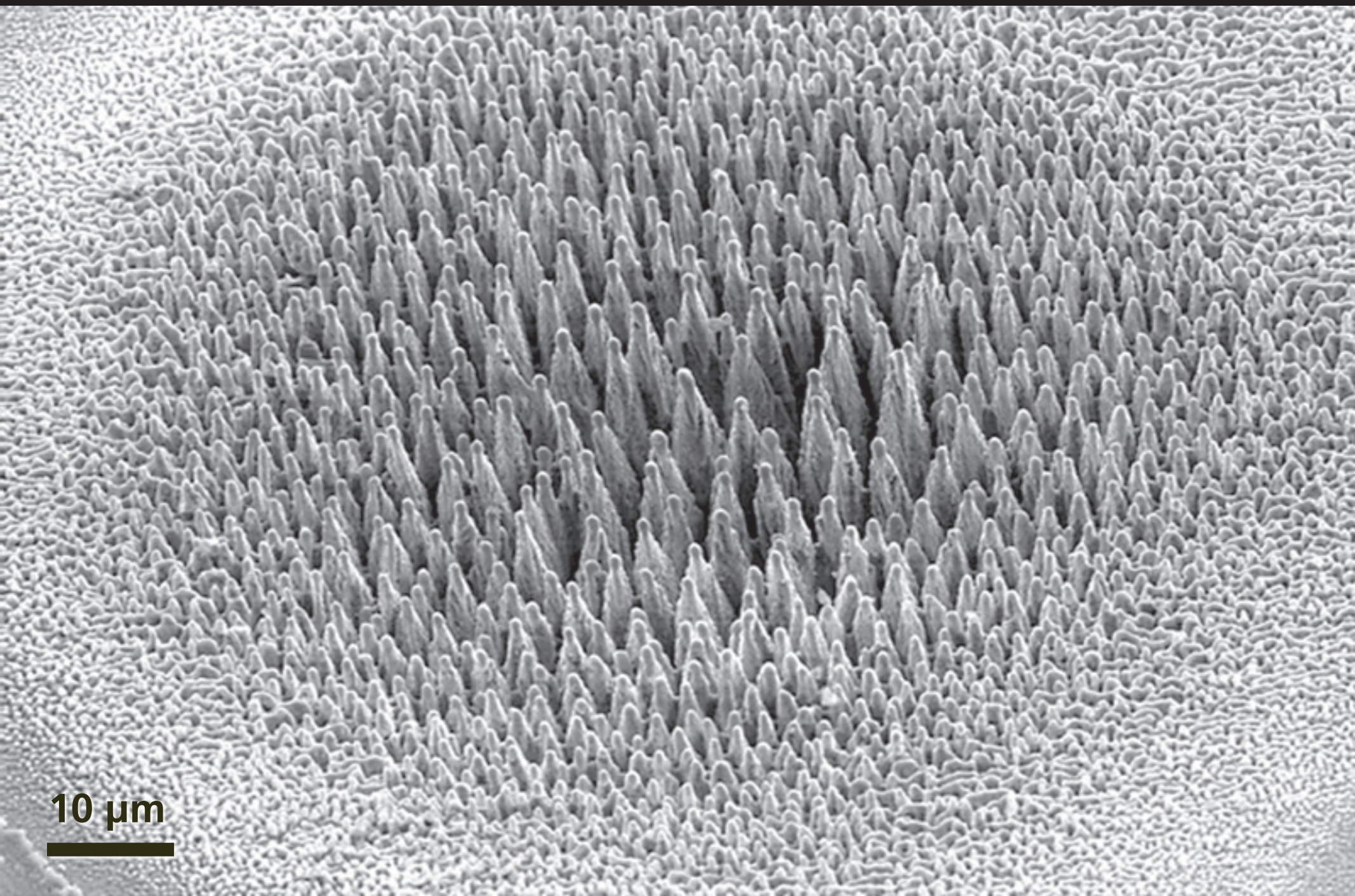


Introduction

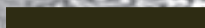
absorptance ($1 - R_{int} - T_{int}$)



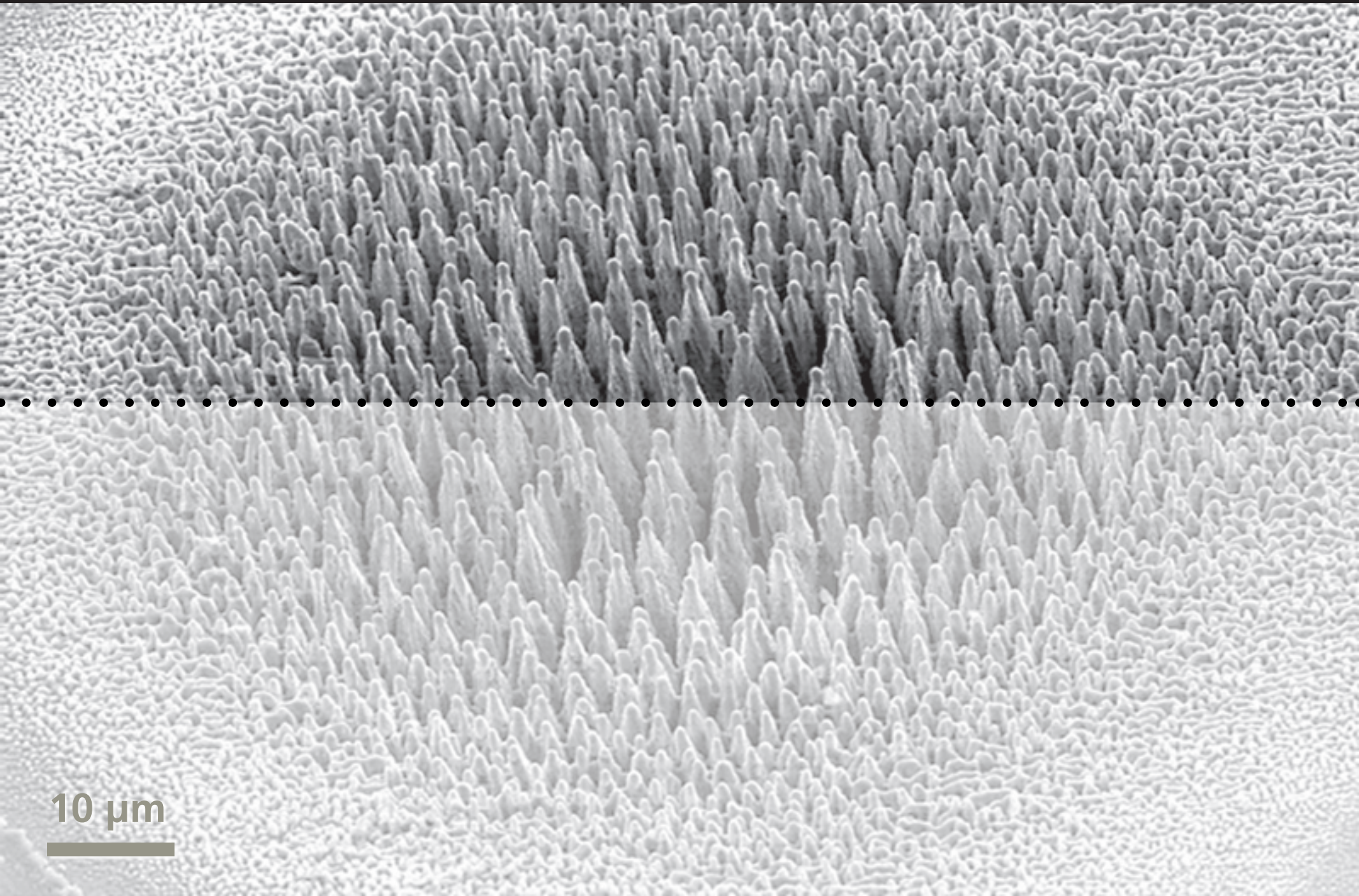
Structure



10 μm

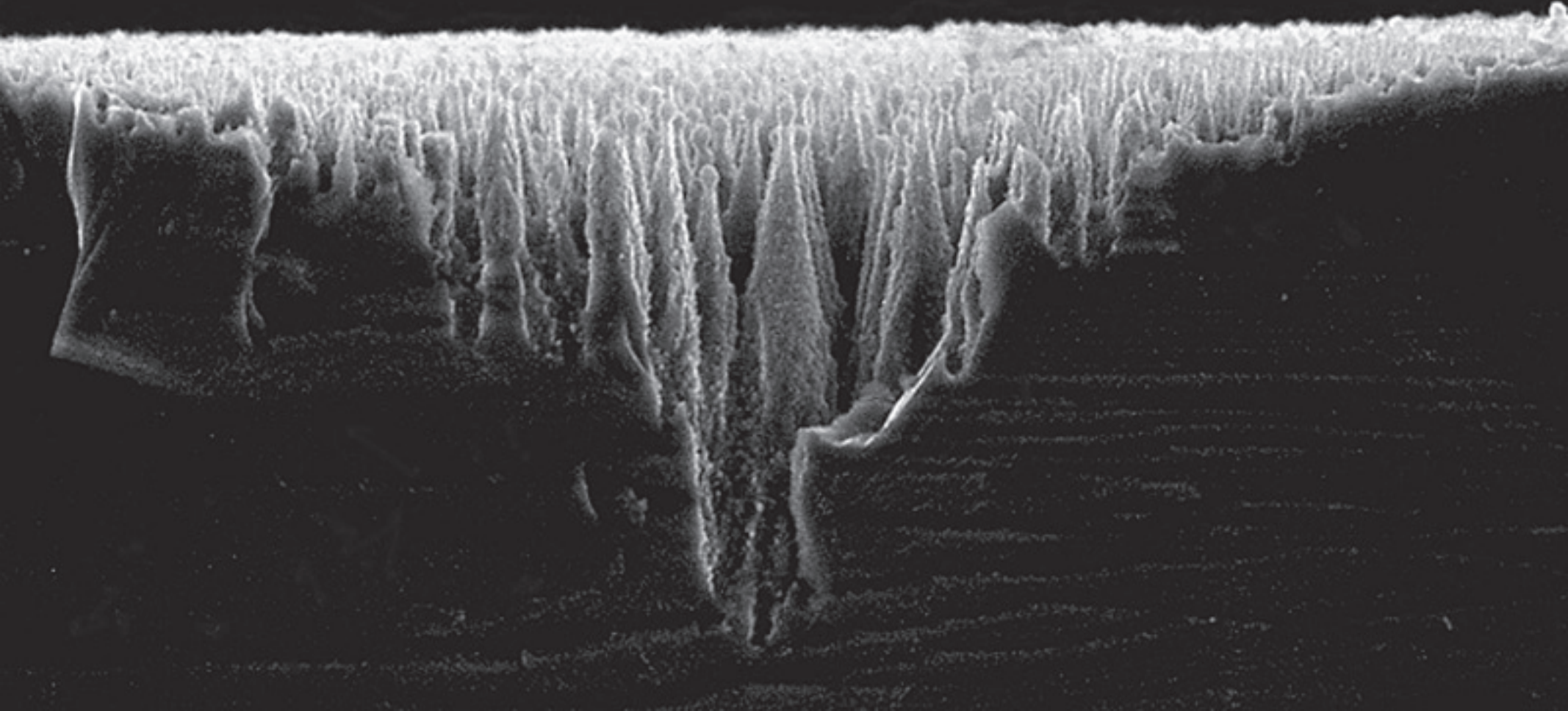


Structure

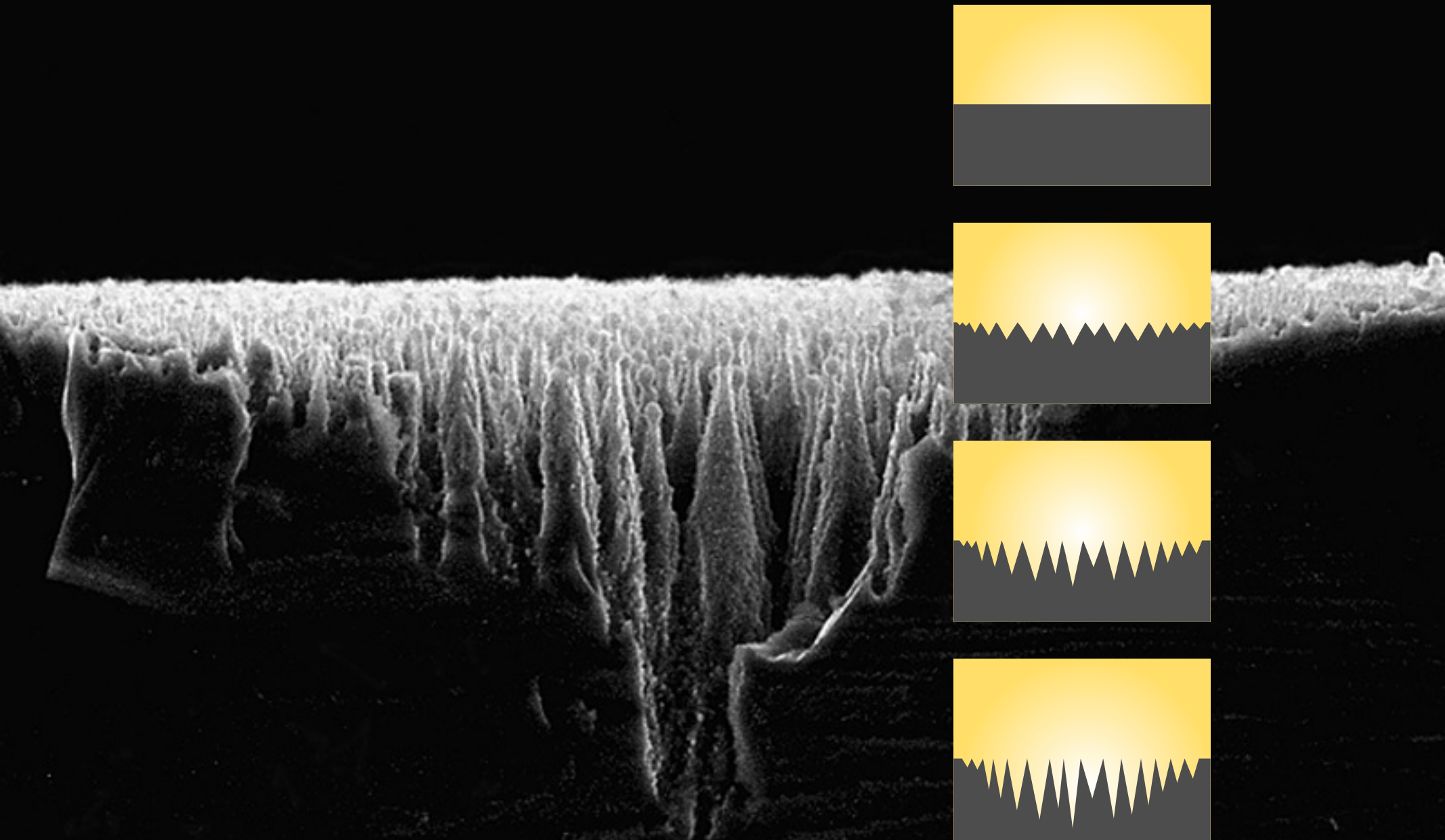


10 μm

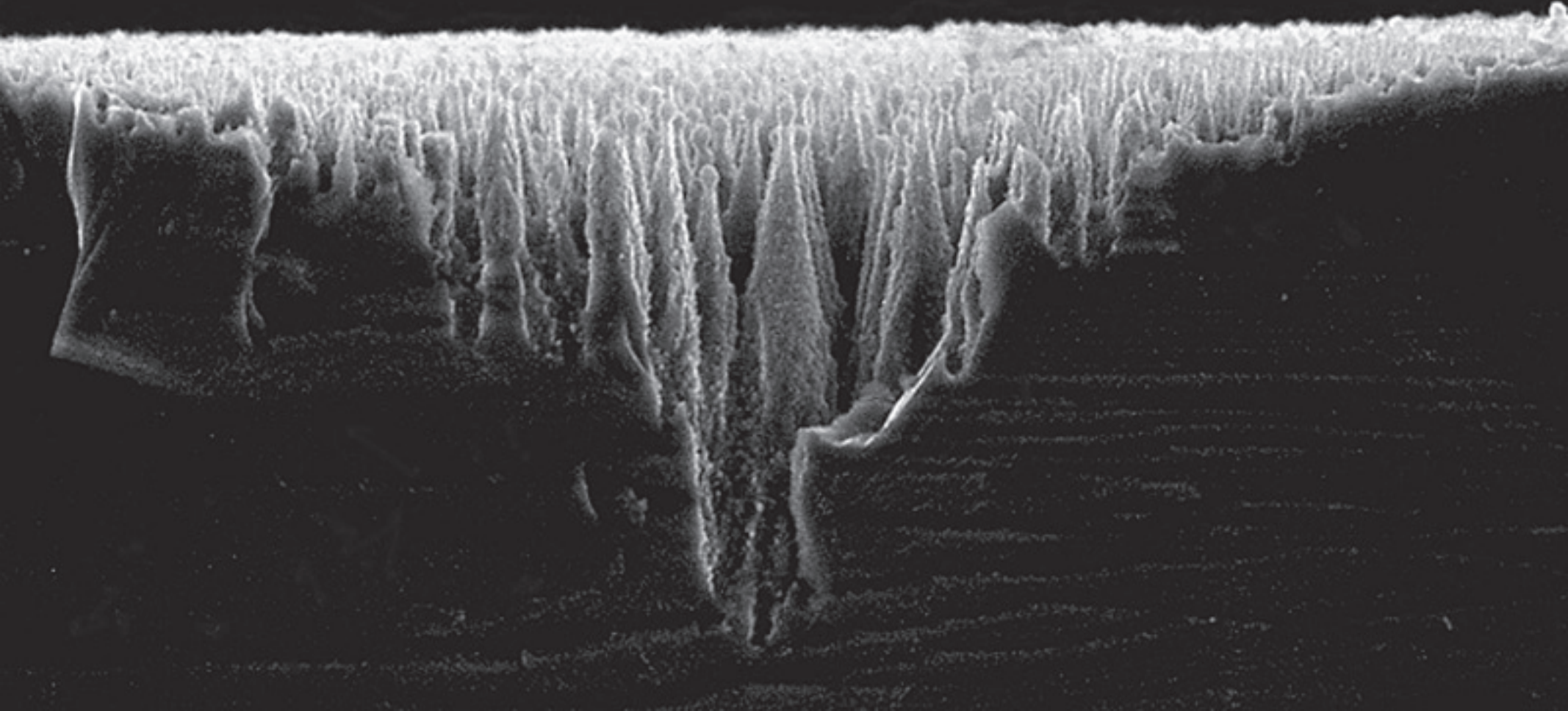
Structure



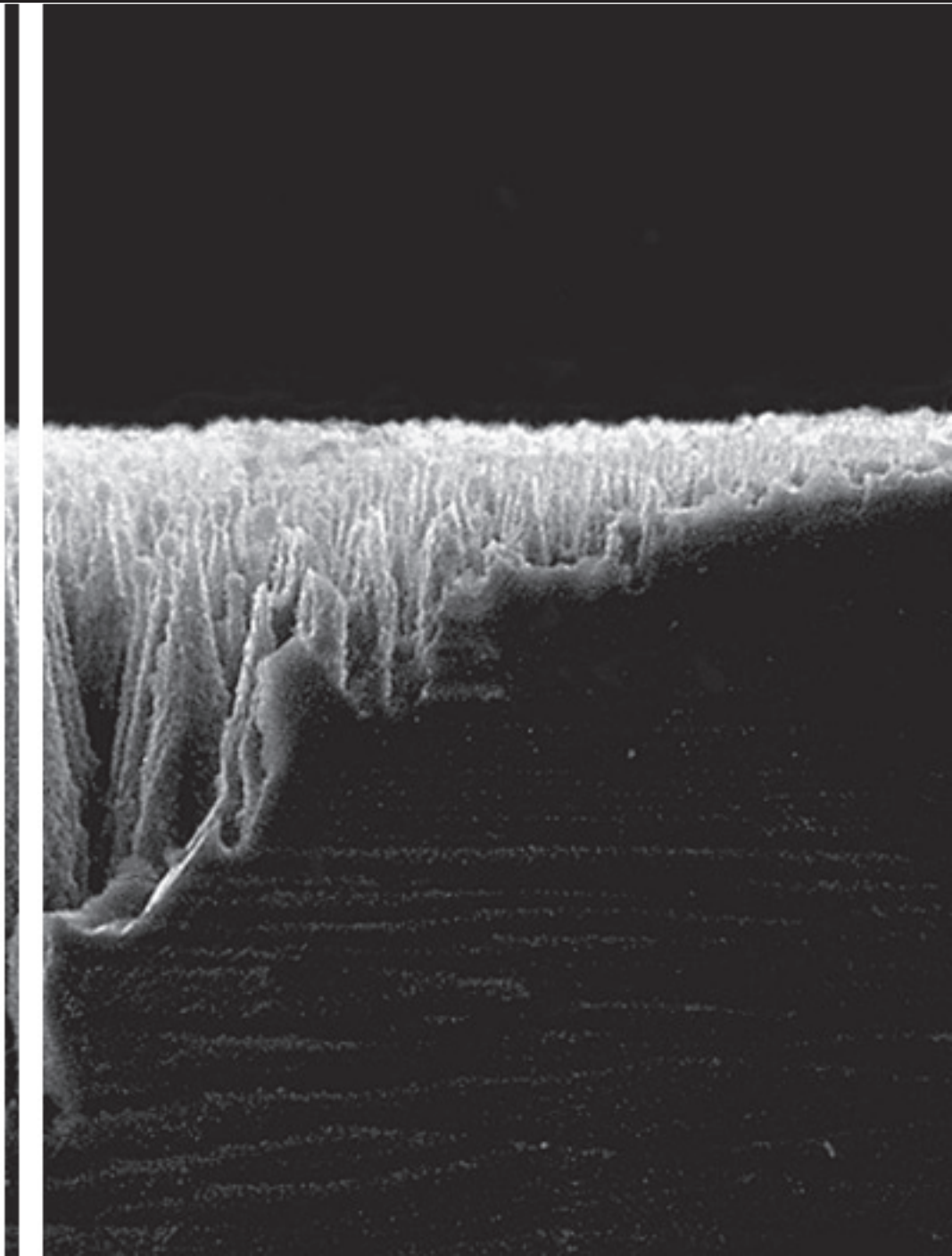
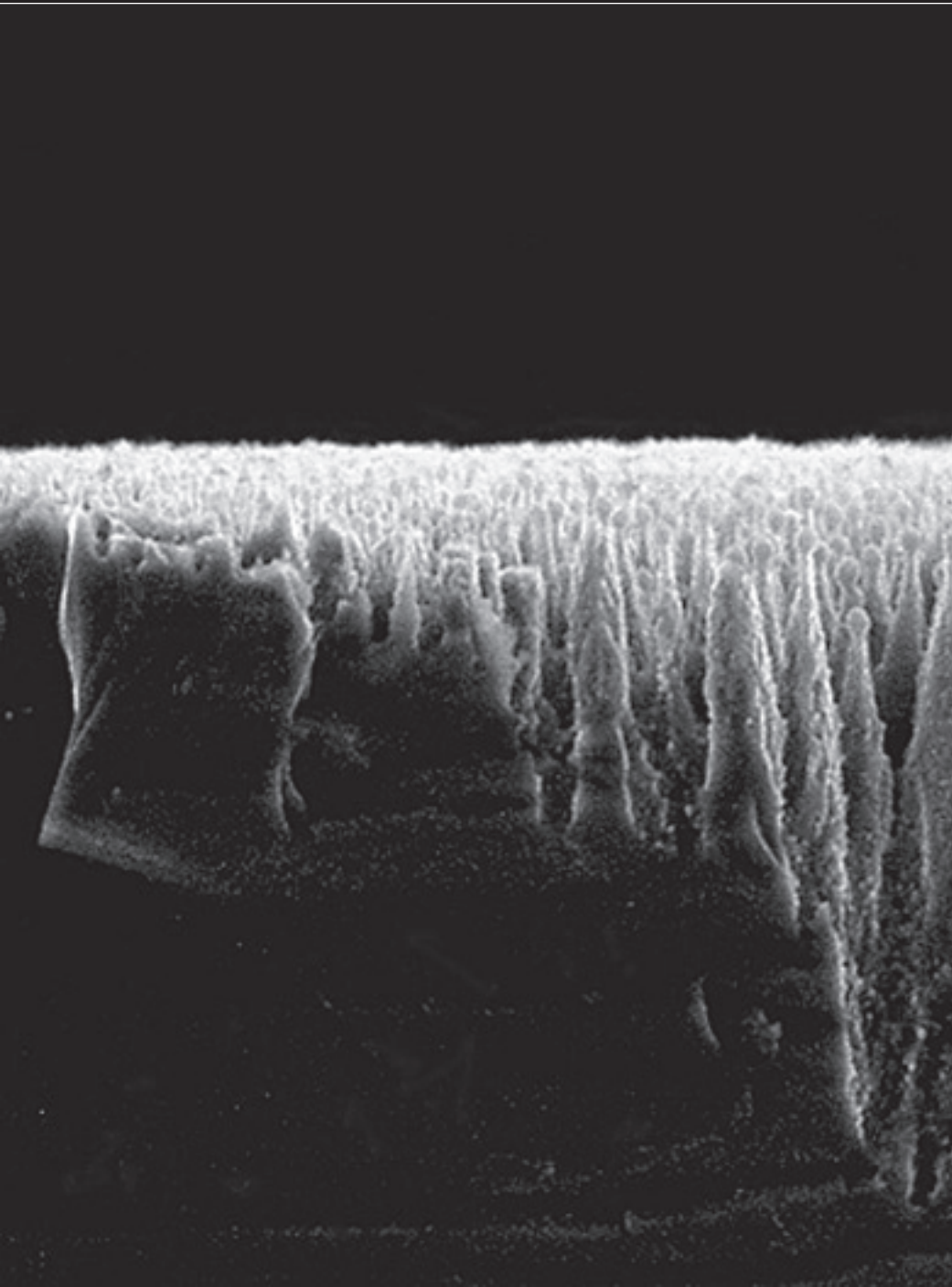
Structure



Structure

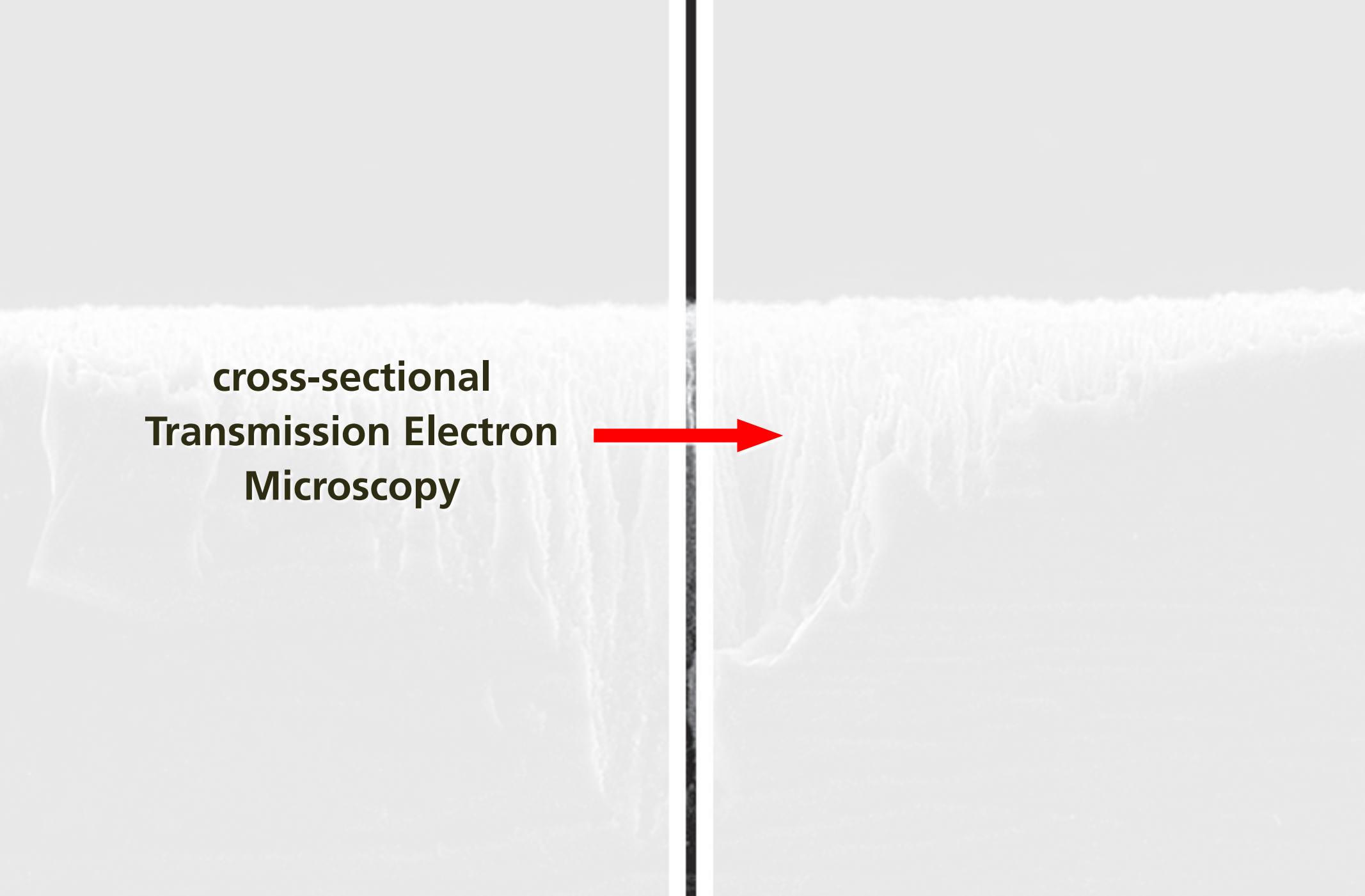


Structure



Structure

**cross-sectional
Transmission Electron
Microscopy**

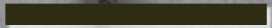


Structure

disordered
surface layer



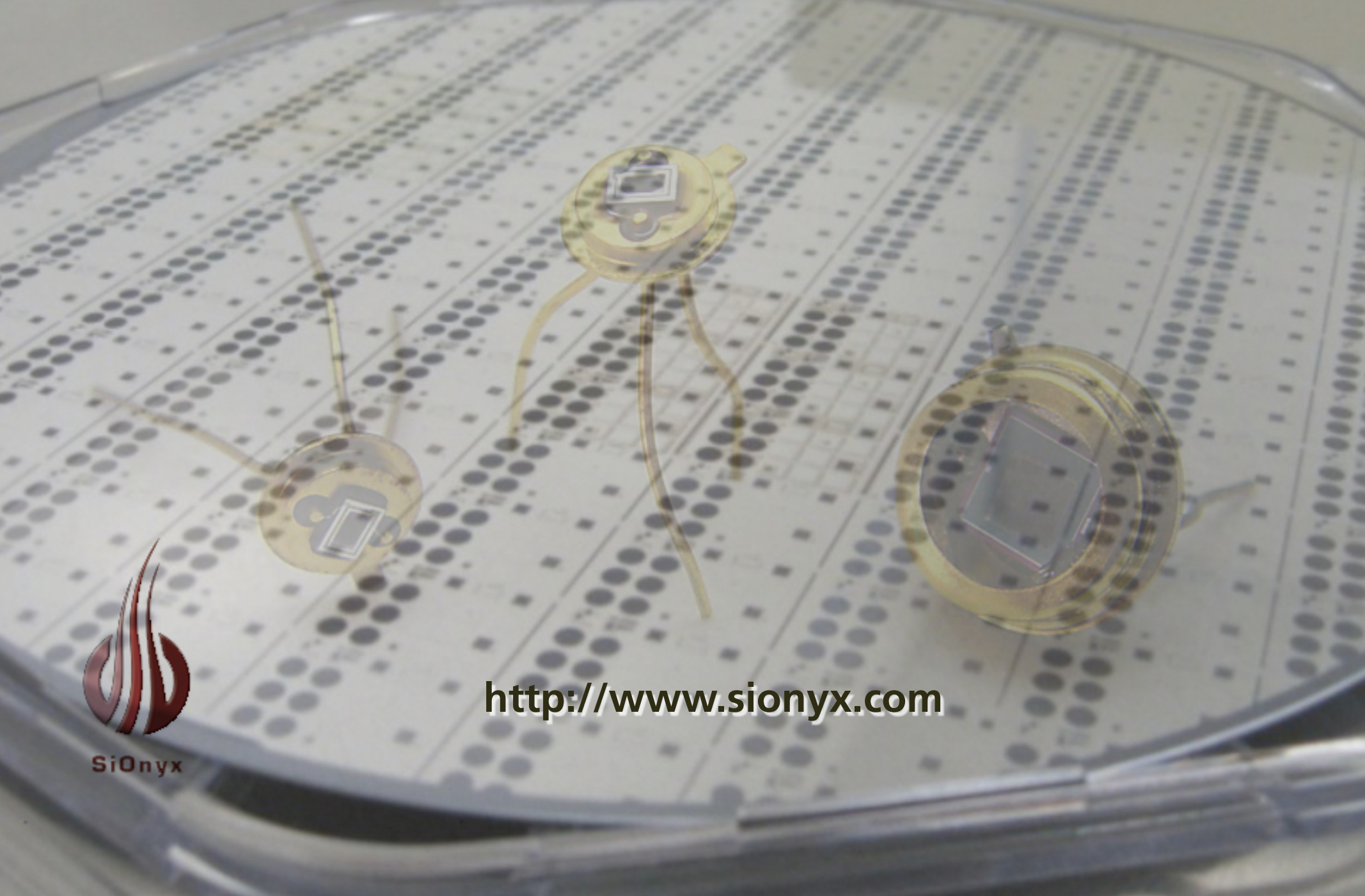
1 μm



Devices



Devices



SiOnyx

<http://www.sionyx.com>

Better photovoltaics?



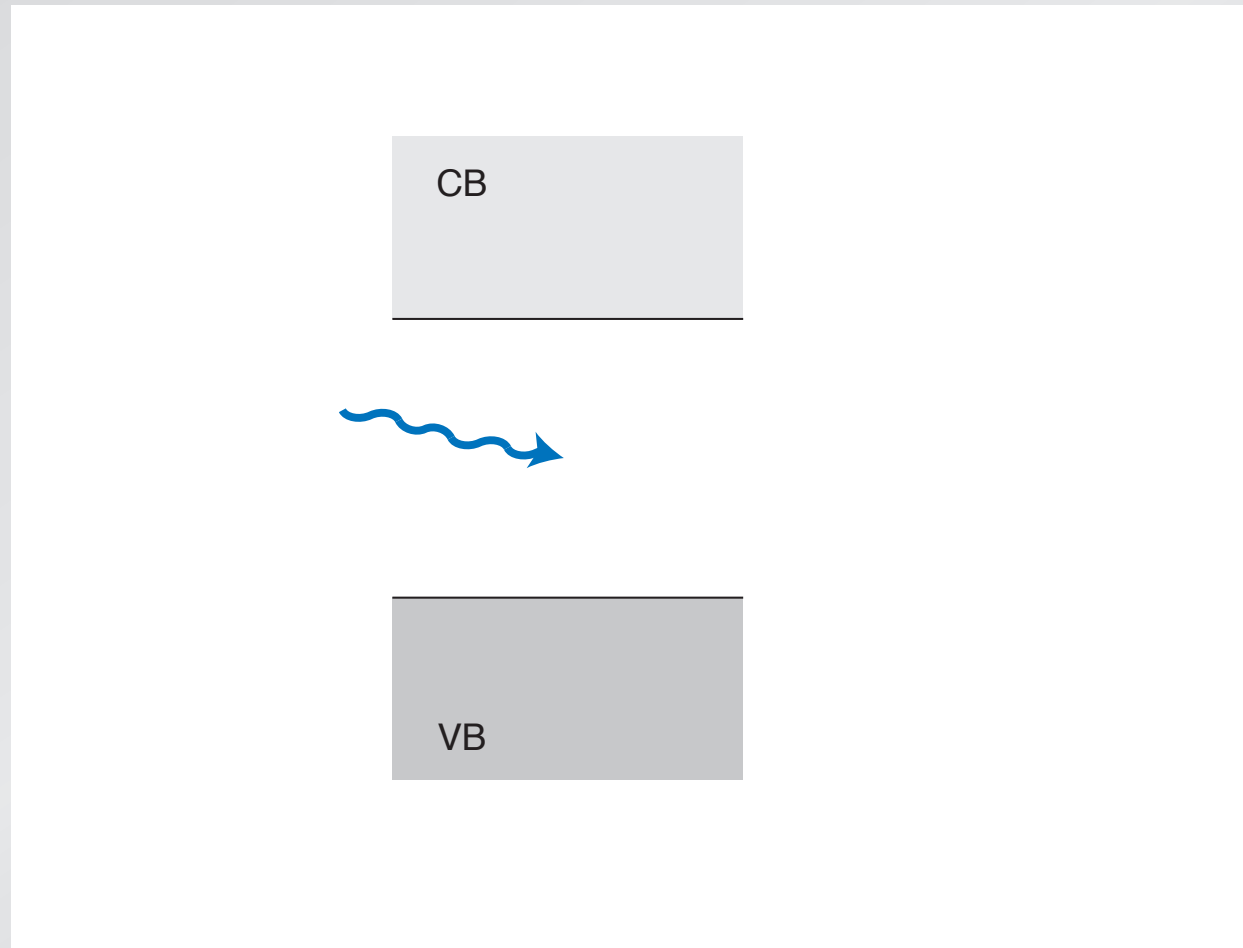
CB

The diagram illustrates a two-layer structure. The top layer is a light gray rectangle labeled 'CB' (Conduction Band). Below it is a darker gray rectangle labeled 'VB' (Valence Band). A thin horizontal line separates the two layers. The entire structure is centered within a white rectangular area, which is itself centered on a gray background.

VB

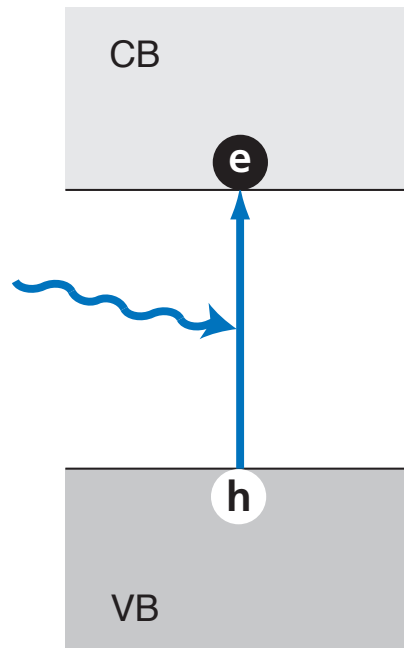
Better photovoltaics?

photon with gap energy



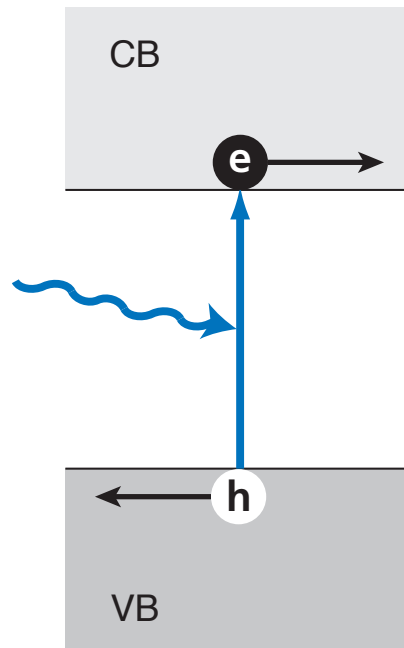
Better photovoltaics?

photon creates electron-hole pair...



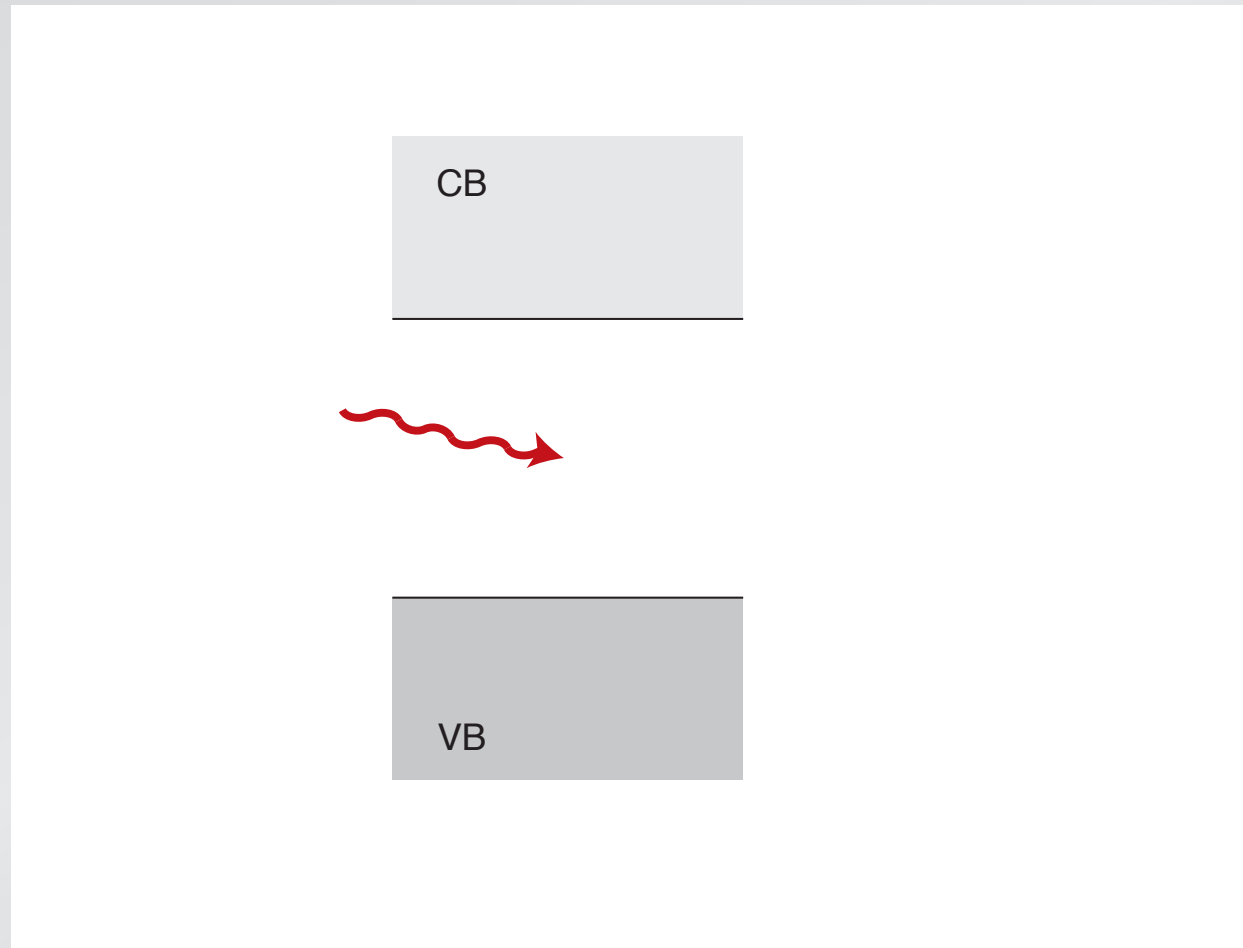
Better photovoltaics?

...whose energy can be extracted



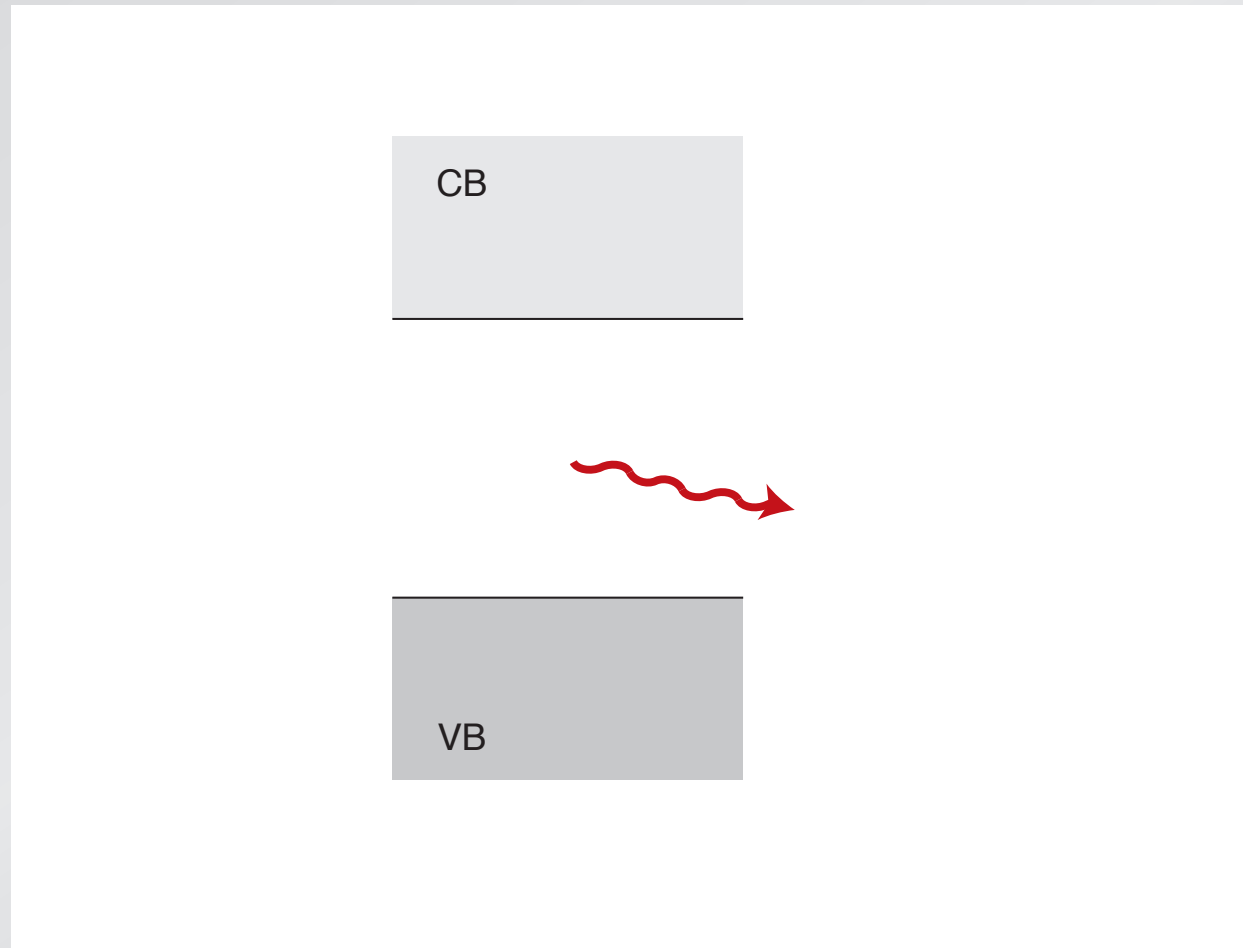
Better photovoltaics?

photons with energy smaller than gap...



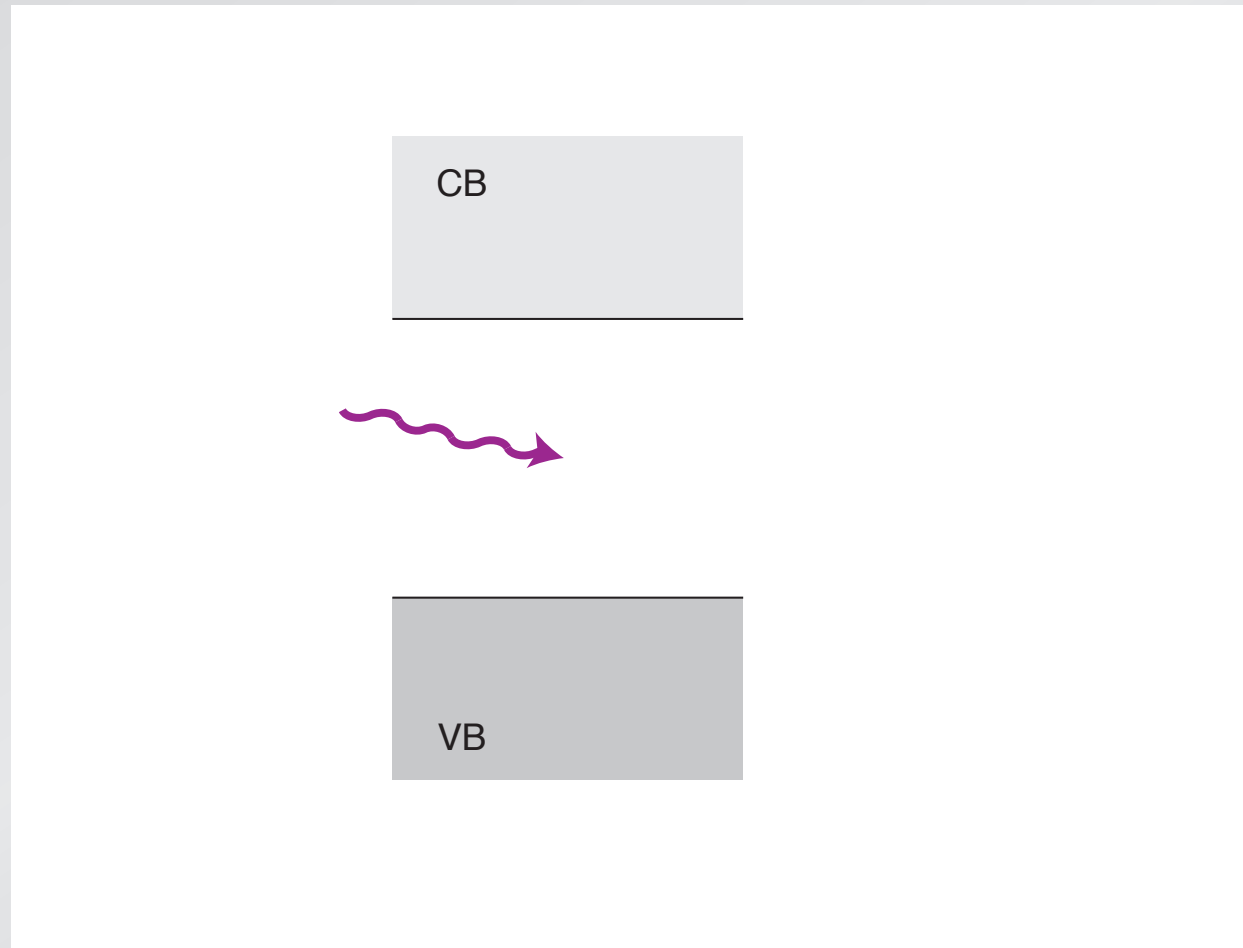
Better photovoltaics?

...do not get absorbed



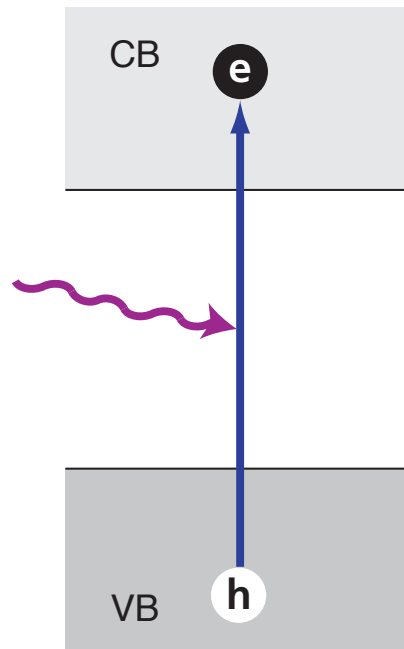
Better photovoltaics?

photons with energy larger than the gap...



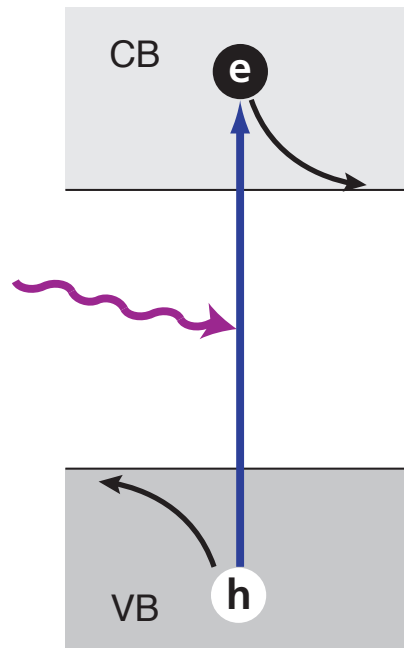
Better photovoltaics?

...create electron-hole pairs with excess energy...



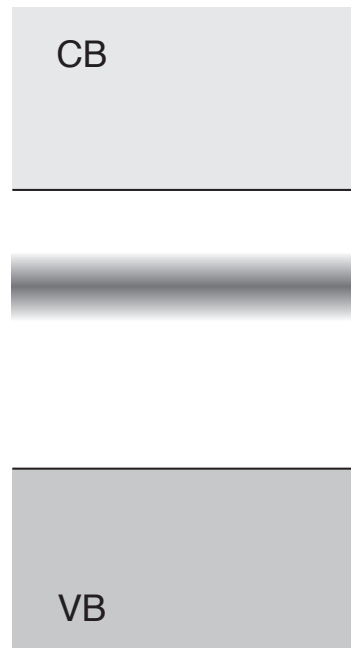
Better photovoltaics?

...which is lost rapidly



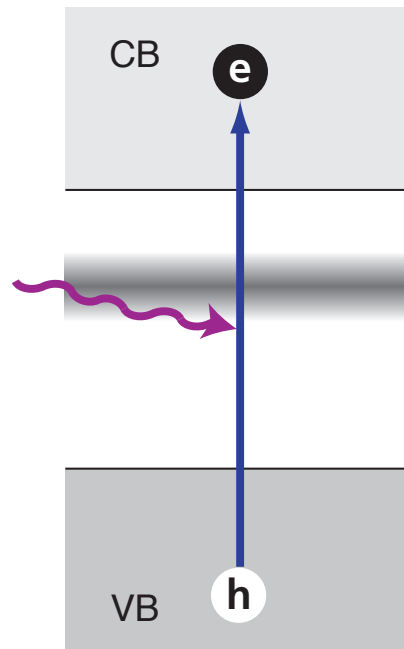
Better photovoltaics?

black silicon has an intermediate band



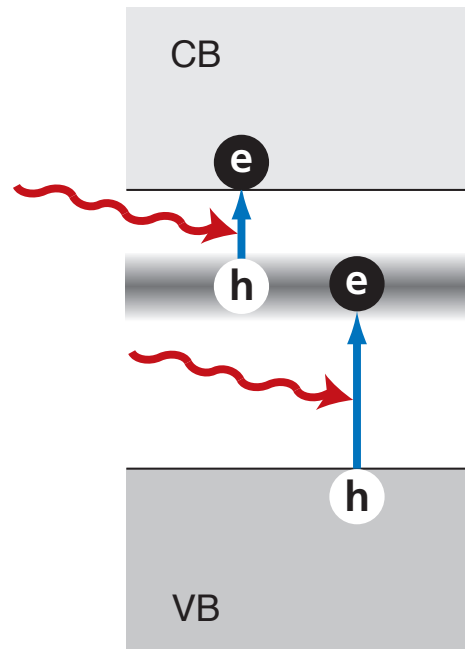
Better photovoltaics?

absorbs same photons as ordinary silicon...



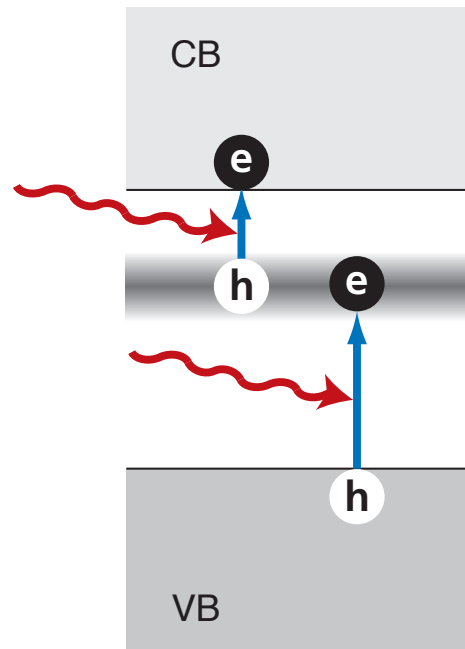
Better photovoltaics?

...but extends absorption to longer wavelengths



Better photovoltaics?

could theoretically get efficiencies over 50%



Funding:

Army Research Office

DARPA

Department of Energy

NDSEG

National Science Foundation

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