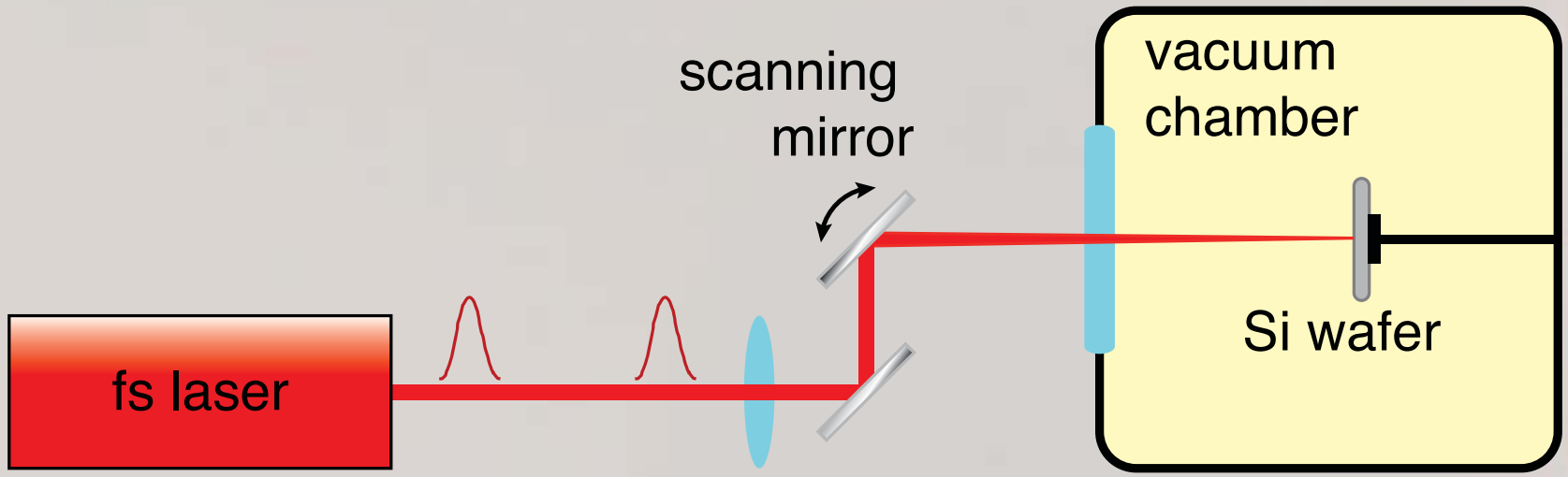
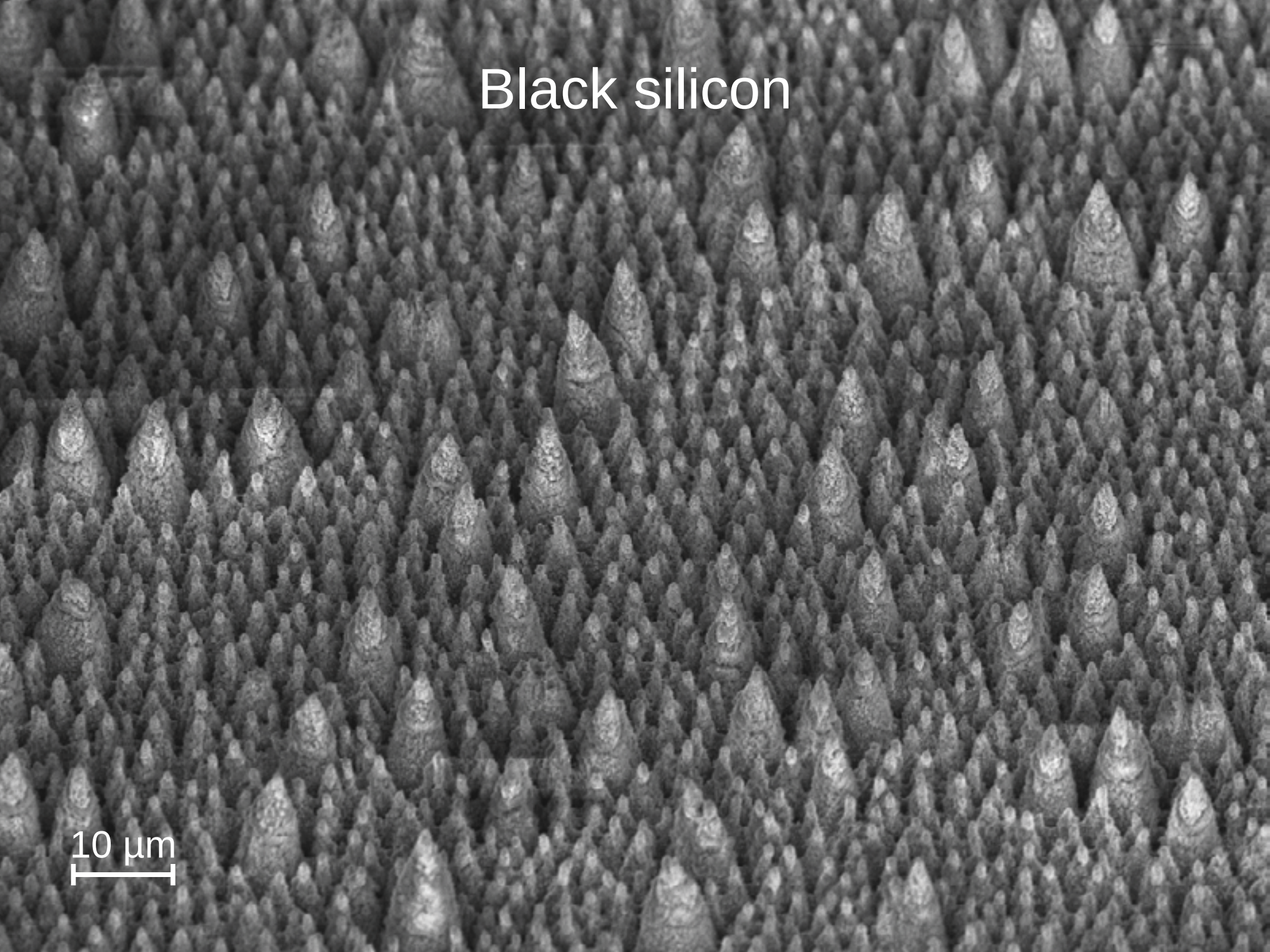
The photovoltaic potential of femtosecond-laser textured amorphous silicon

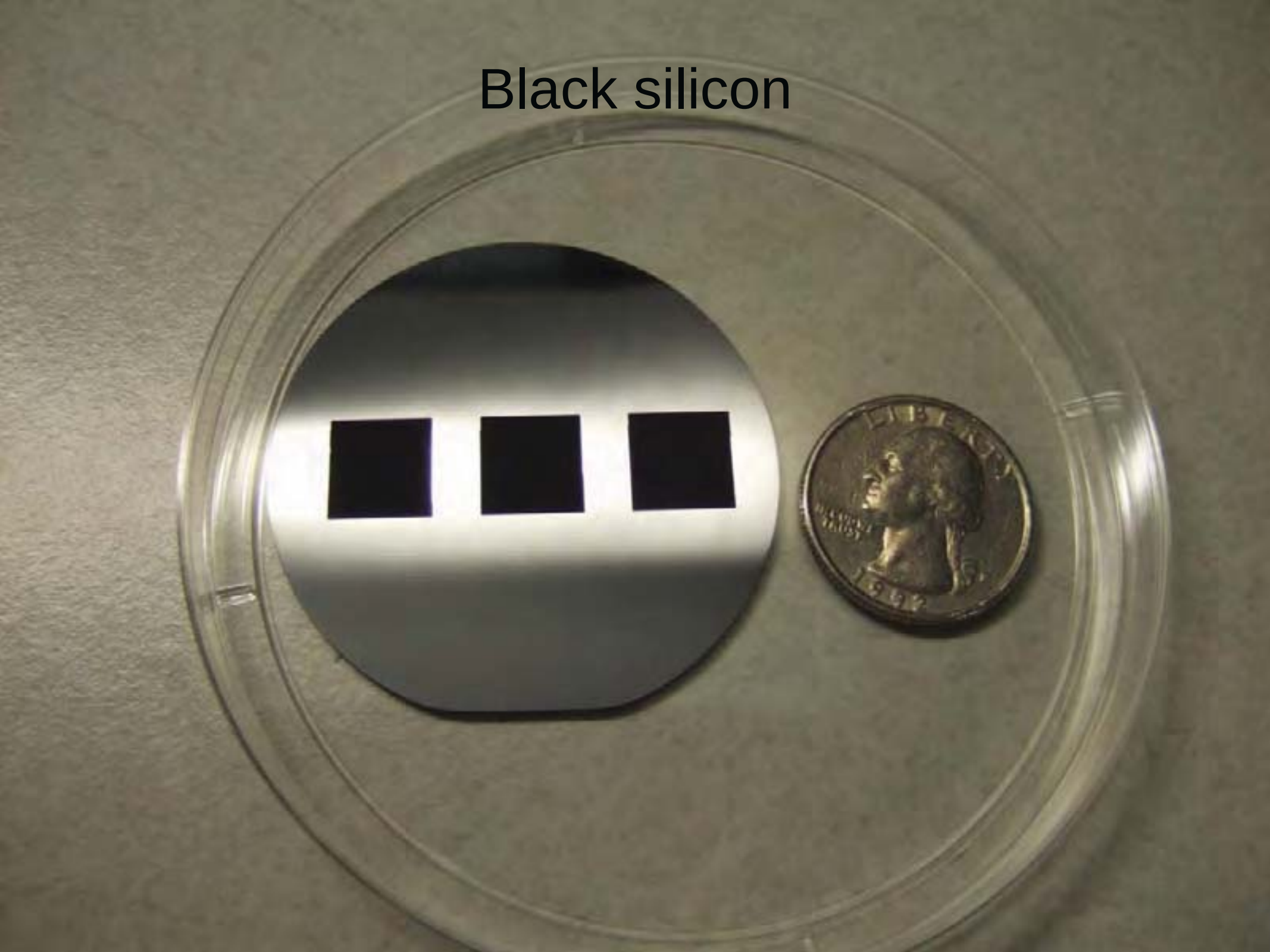
Meng-Ju Sher, Kenneth Hammond, Lysander Christakis and Eric Mazur, Harvard University
Photonics West, CA
2013/02/07

Black silicon

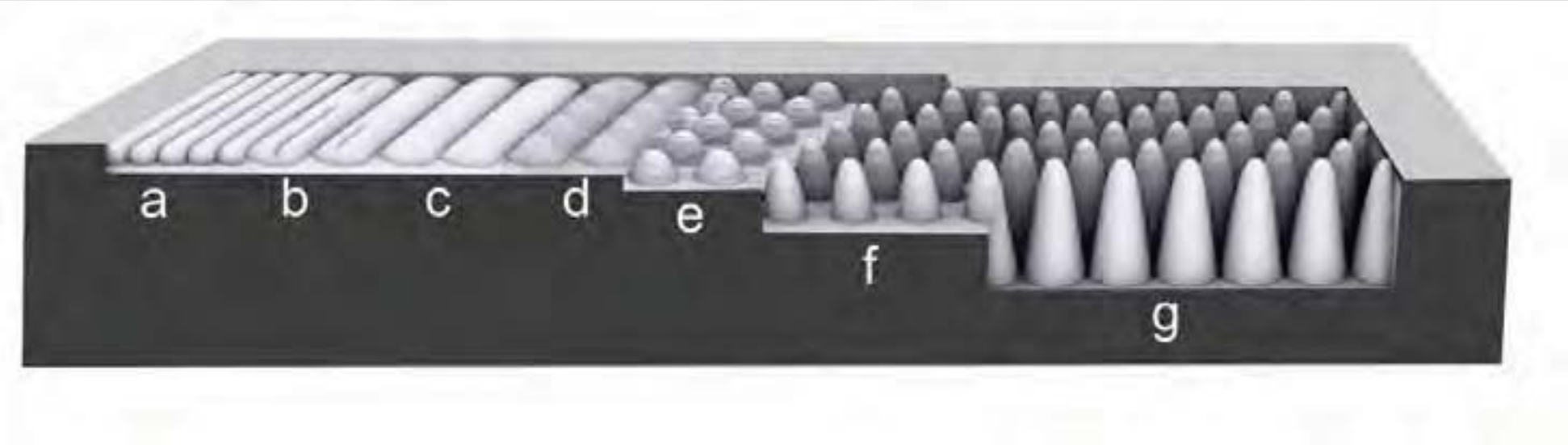



Black silicon
10 µm

Black silicon



Black silicon

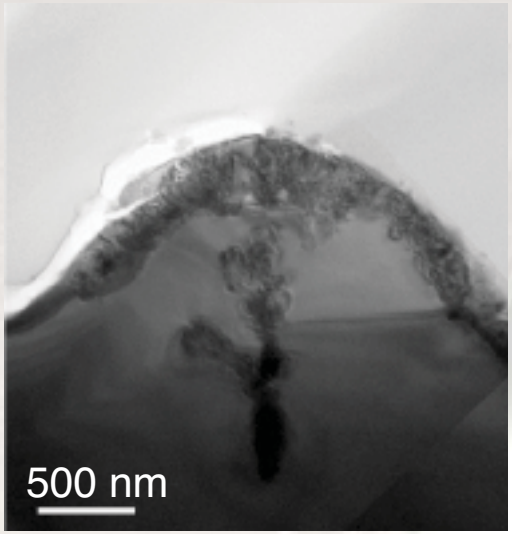


increasing laser dose

Sarnet *et al.*, JAIP Conf. Proc. 1464, 219 (2012)

Black silicon

PV on silicon wafers



laser texturing

one-step laser texturing and doping

defect removal

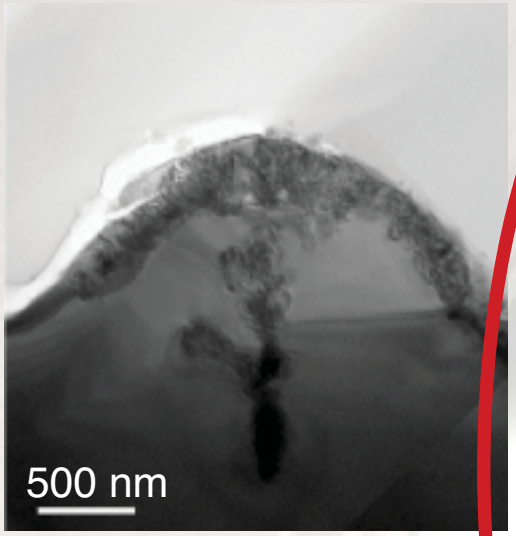
standard PV process

contact deposition

efficiency: 8% 14.2% 4.5%

Kontermann *et* al., Energy Procedia 27, 390 (2012)
Iyengar *et al.,* Sol. Energ. Mat. Sols C. 95, 2745 (2011)
Sarnet *et al.*, JAIP Conf. Proc. 1464, 219 (2012)

Black silicon



laser texturing

one-step laser texturing and doping

thin film, a-Si PV?

standard PV process

contact deposition

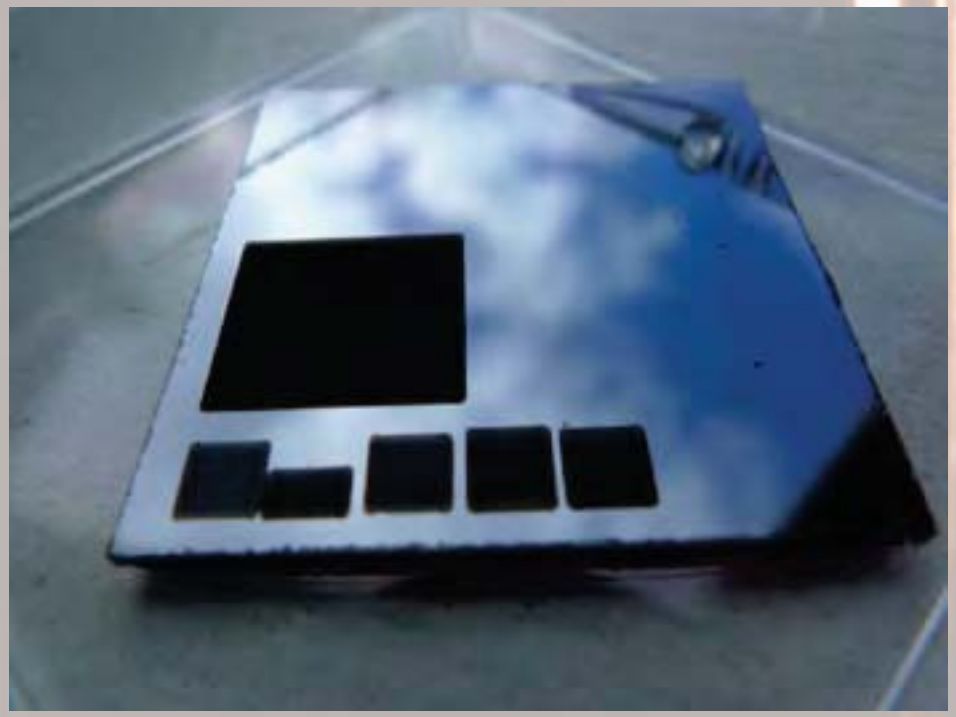
efficiency: ?% 14.2% 4.5%

Kontermann *et* al., Energy Procedia 27, 390 (2012)
Iyengar *et al.,* Sol. Energ. Mat. Sols C. 95, 2745 (2011)
Sarnet *et al.*, JAIP Conf. Proc. 1464, 219 (2012)

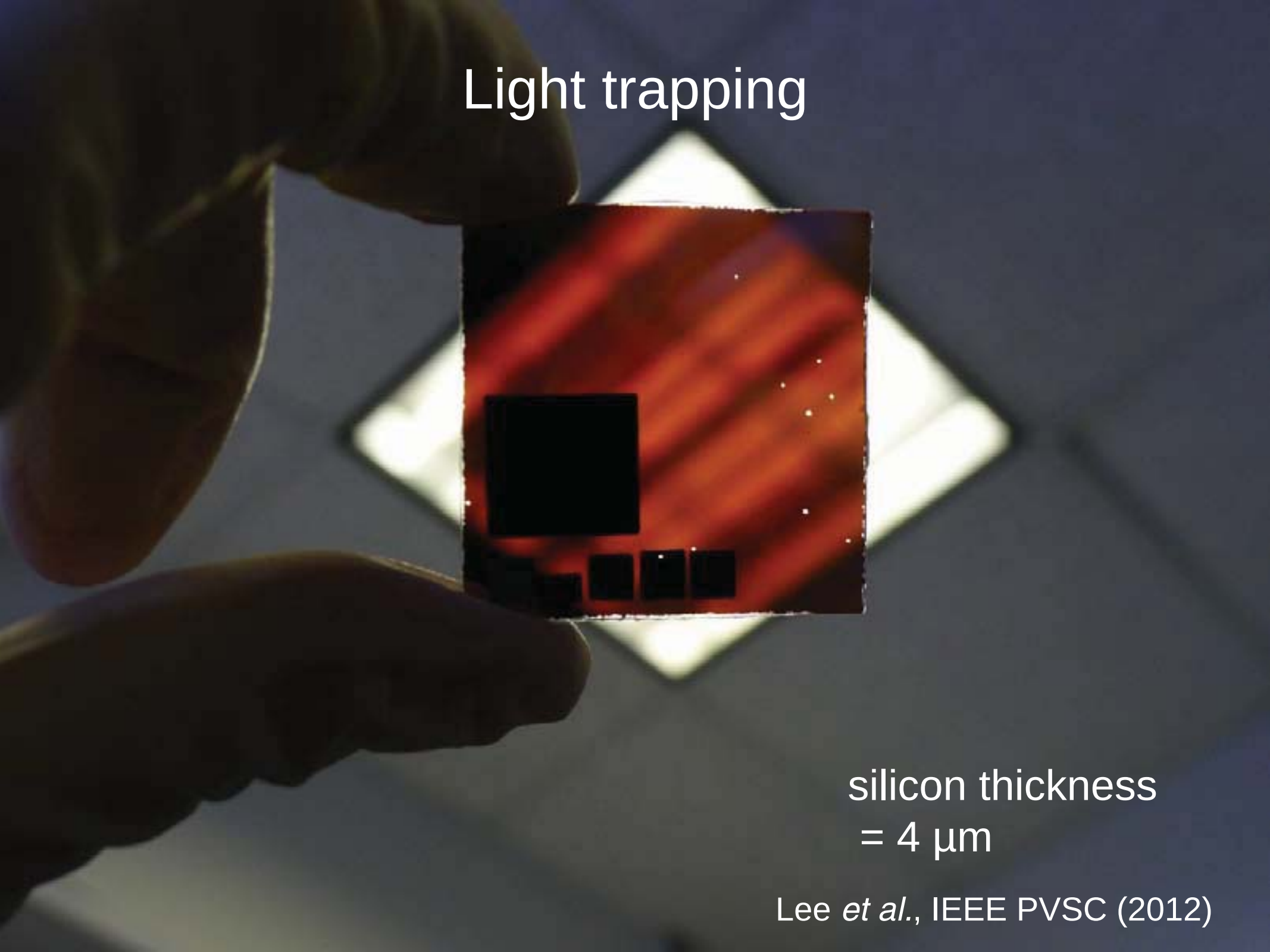
Outline

- light trapping and material properties
- laser-textured a-Si solar cells
- a-Si solar cells on laser-textured substrates

silicon thickness
= 4 µm



Light trapping

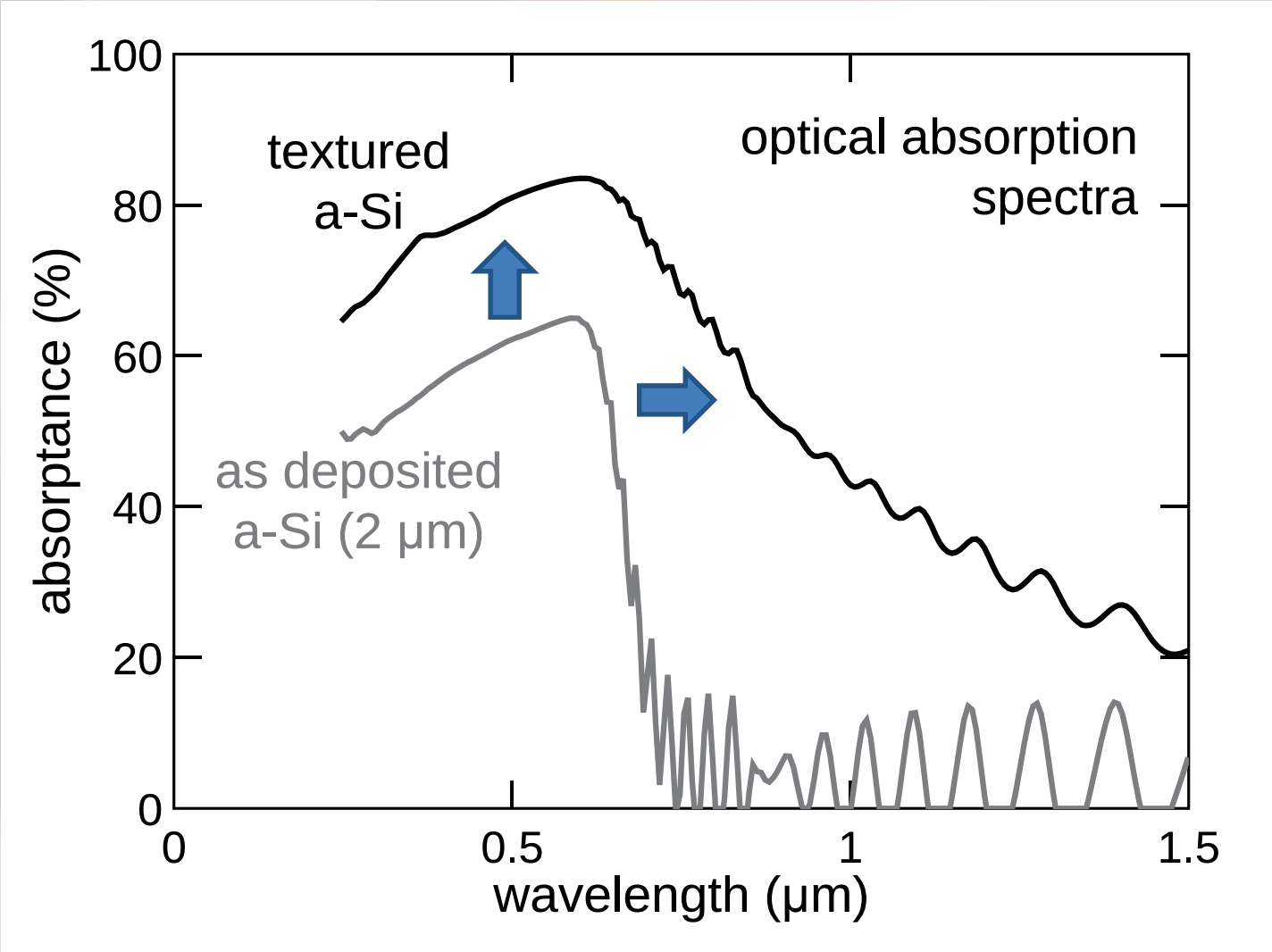


silicon thickness
= 4 µm

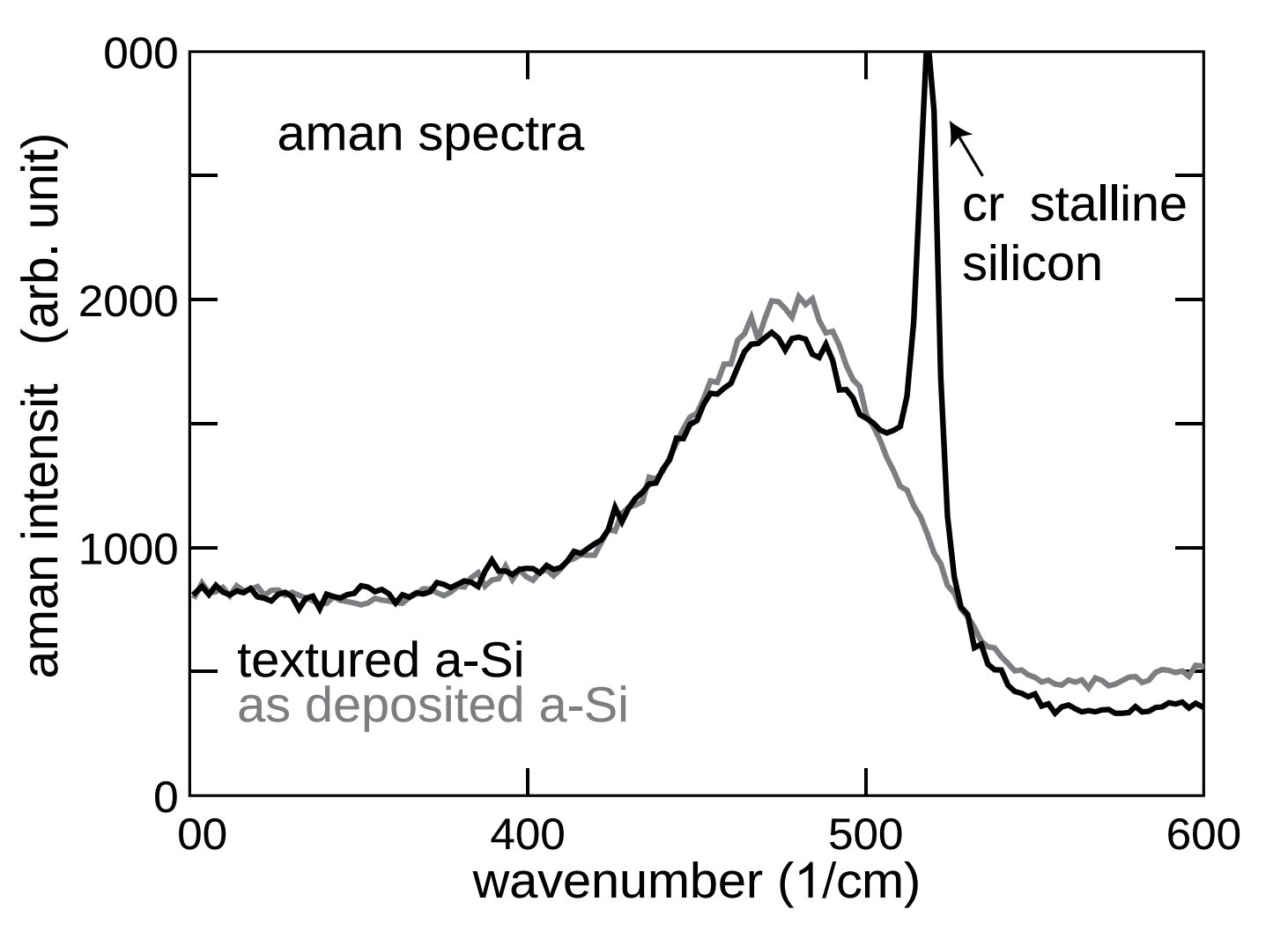
Lee *et al.*, IEEE PVSC (2012)

Light trapping

$$A = 1 - T_{int} - R_{int}$$



Crystallinity



Outline

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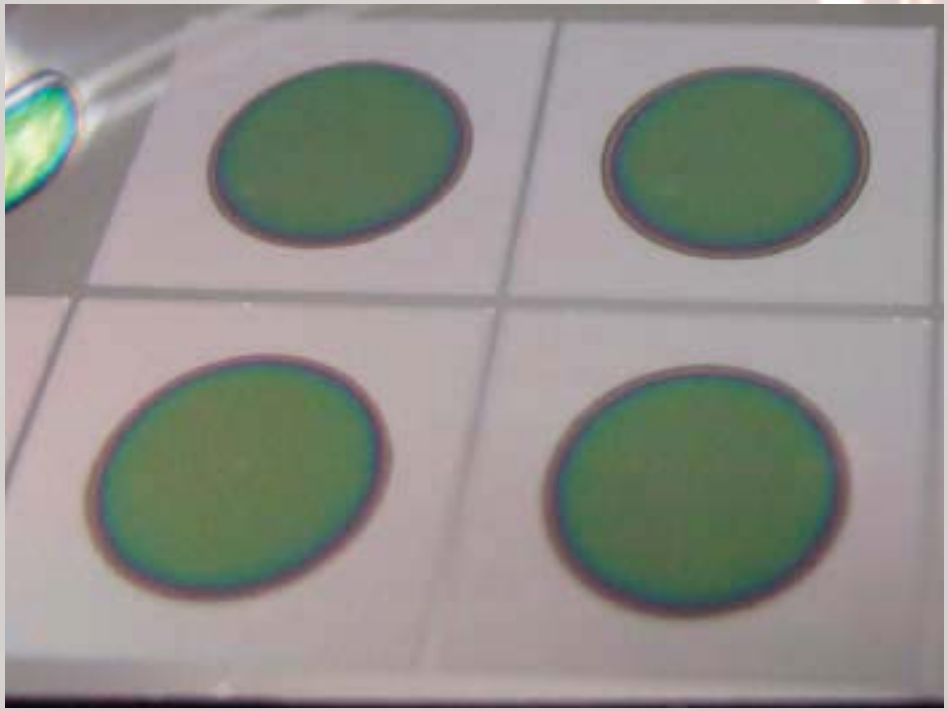
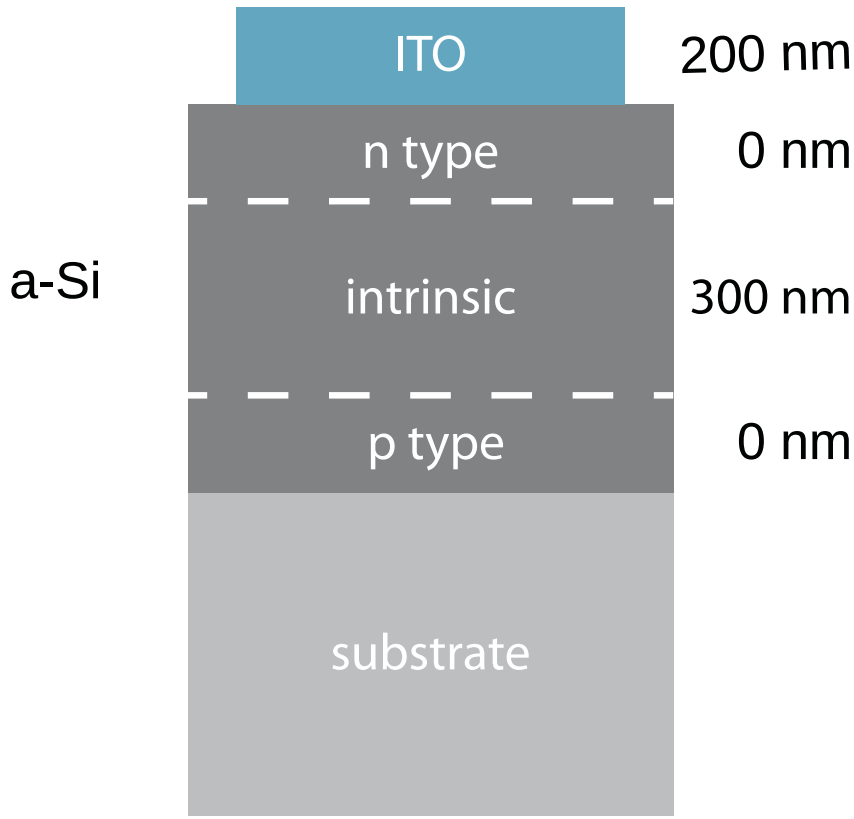
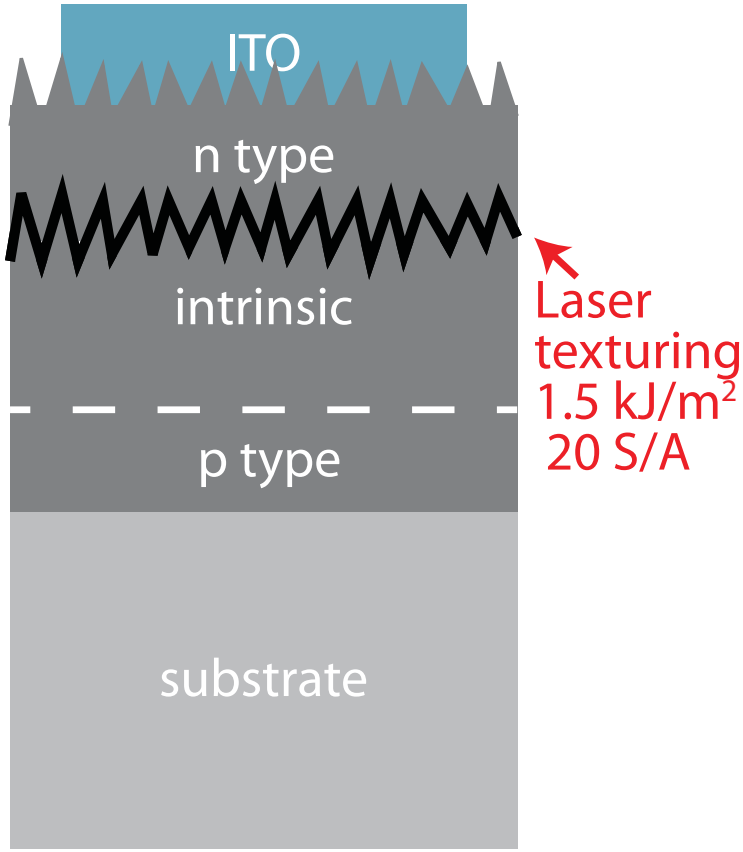
- laser-textured a-Si solar cells
- a-Si solar cells on laser-textured substrates



Laser-textured a-Si solar cells

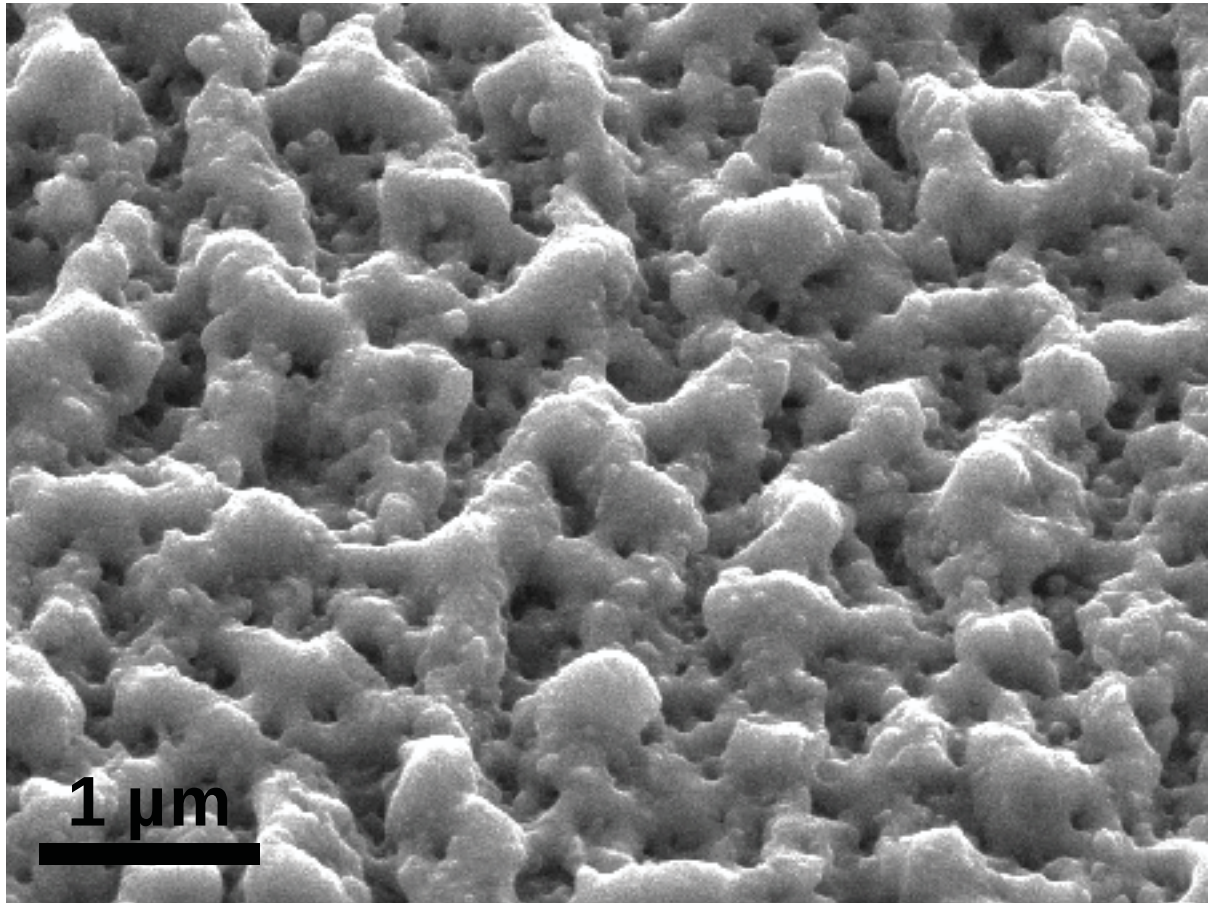


reference cell

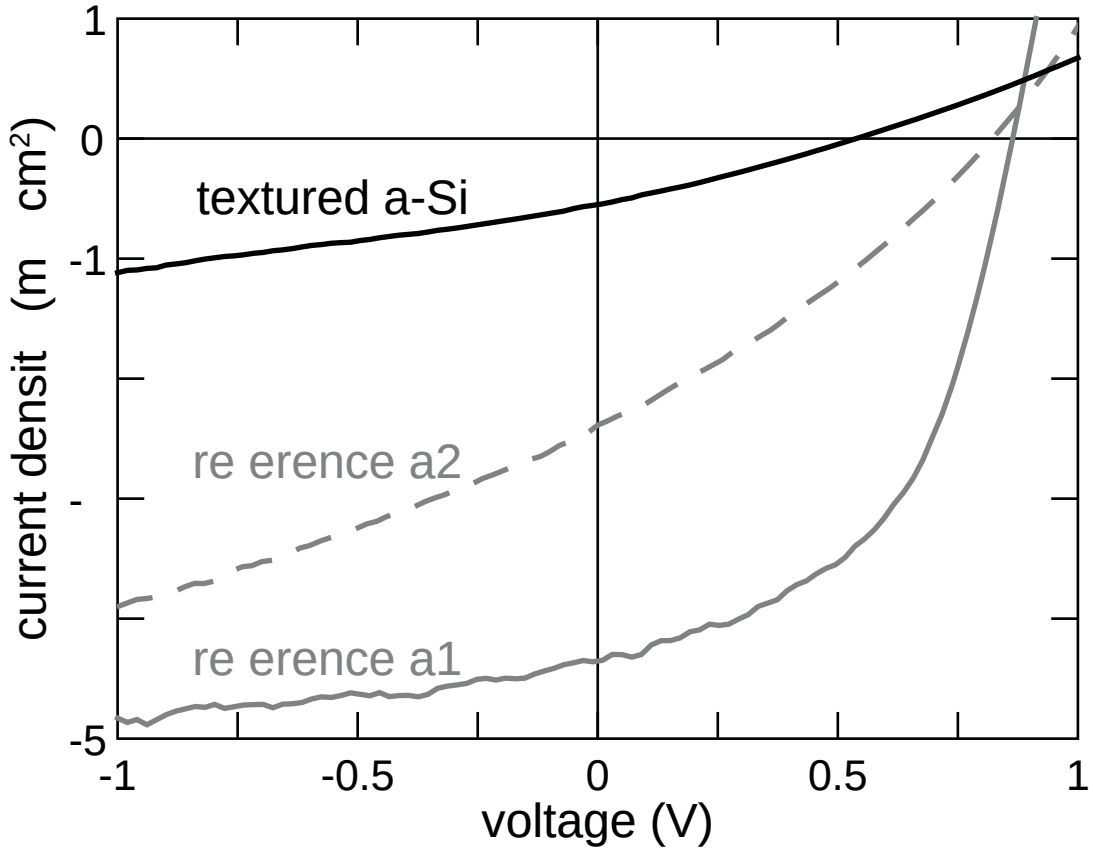


textured a-Si

Laser-textured a-Si solar cells



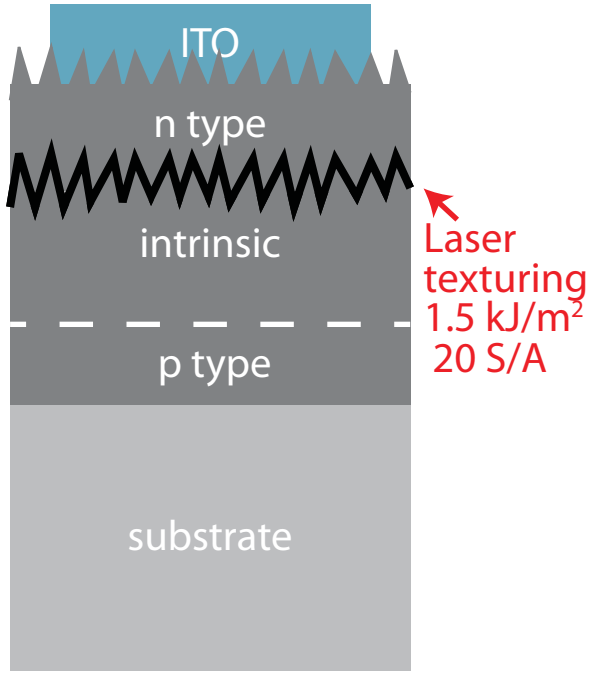
Laser-textured a-Si solar cells

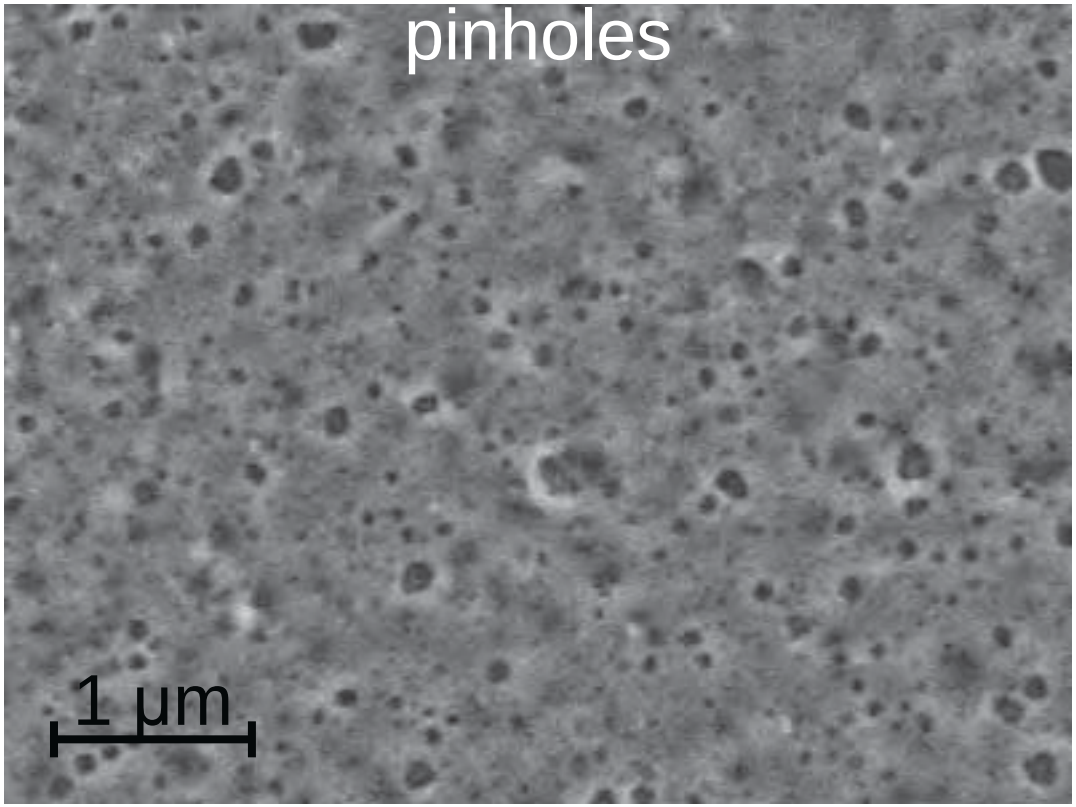


Sample	Efficiency (%)	J_{SC} (mA/cm^2)	V_{OC} (V)	Fill factor
Ref. a1 (300 nm)	1.89	4.37	0.86	0.50
Ref. a2 (2 µm)	0.60	2.39	0.82	0.31
Textured a-Si	0.08	0.55	0.54	0.28

Laser-textured a-Si solar cells

over or under texture





reason for low efficiency:
over or under texture
pinhole formation
other defects

Outline

- light trapping and material properties
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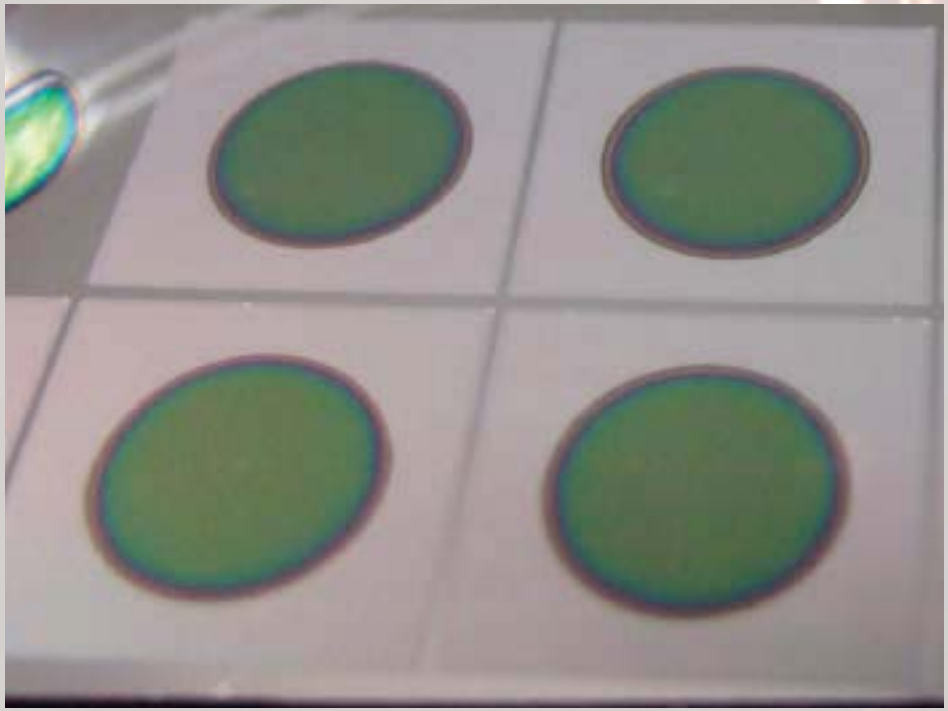
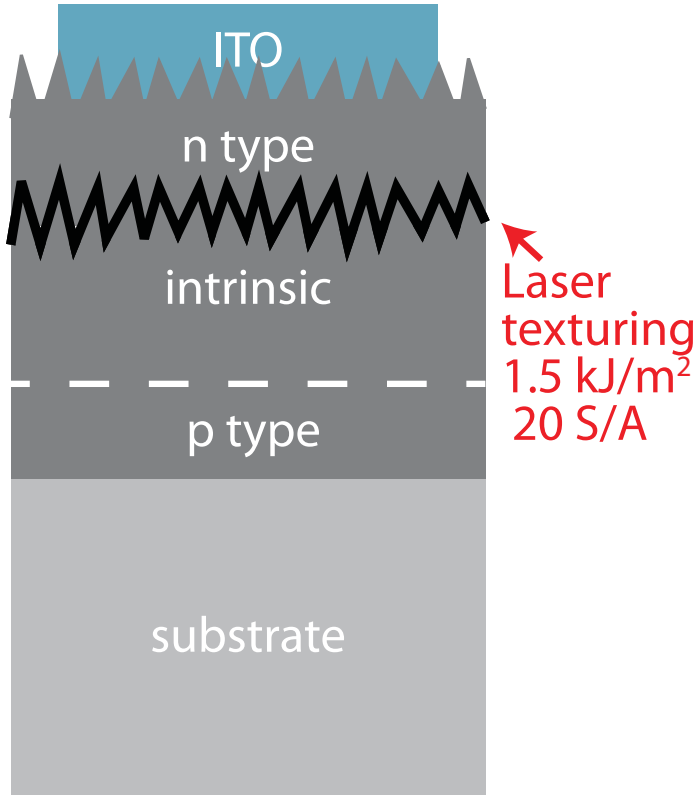
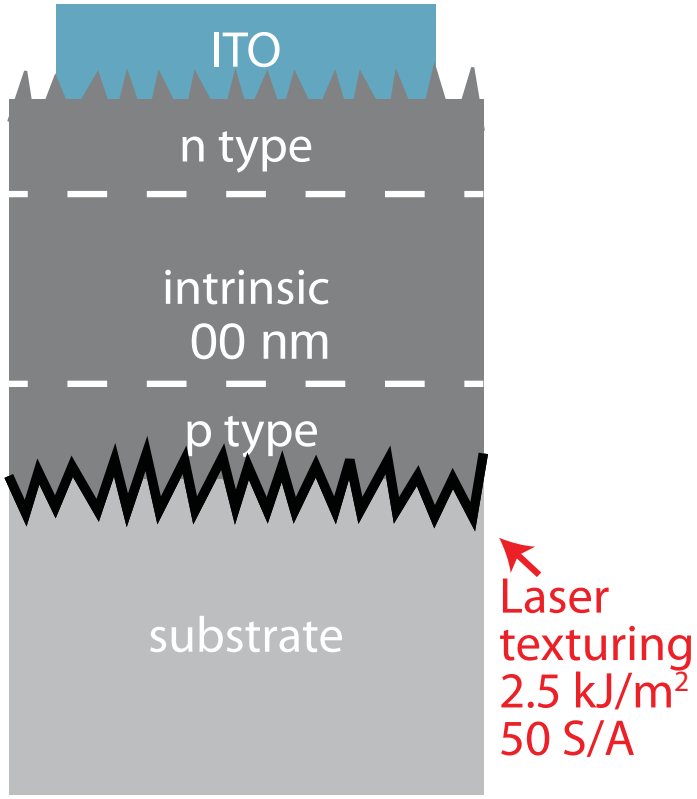
- a-Si solar cells on laser-textured substrates



a-Si solar cells on laser-textured substrates

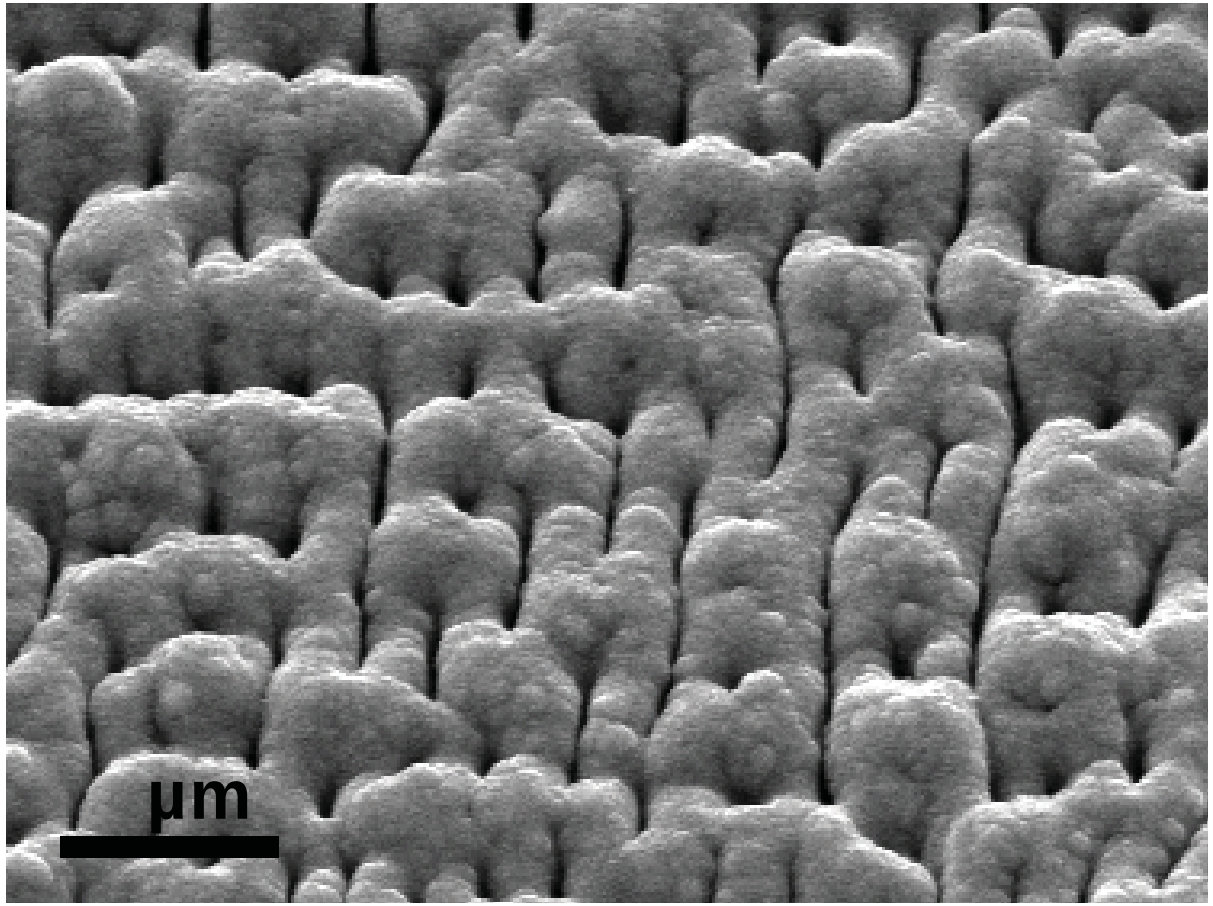


textured a-Si

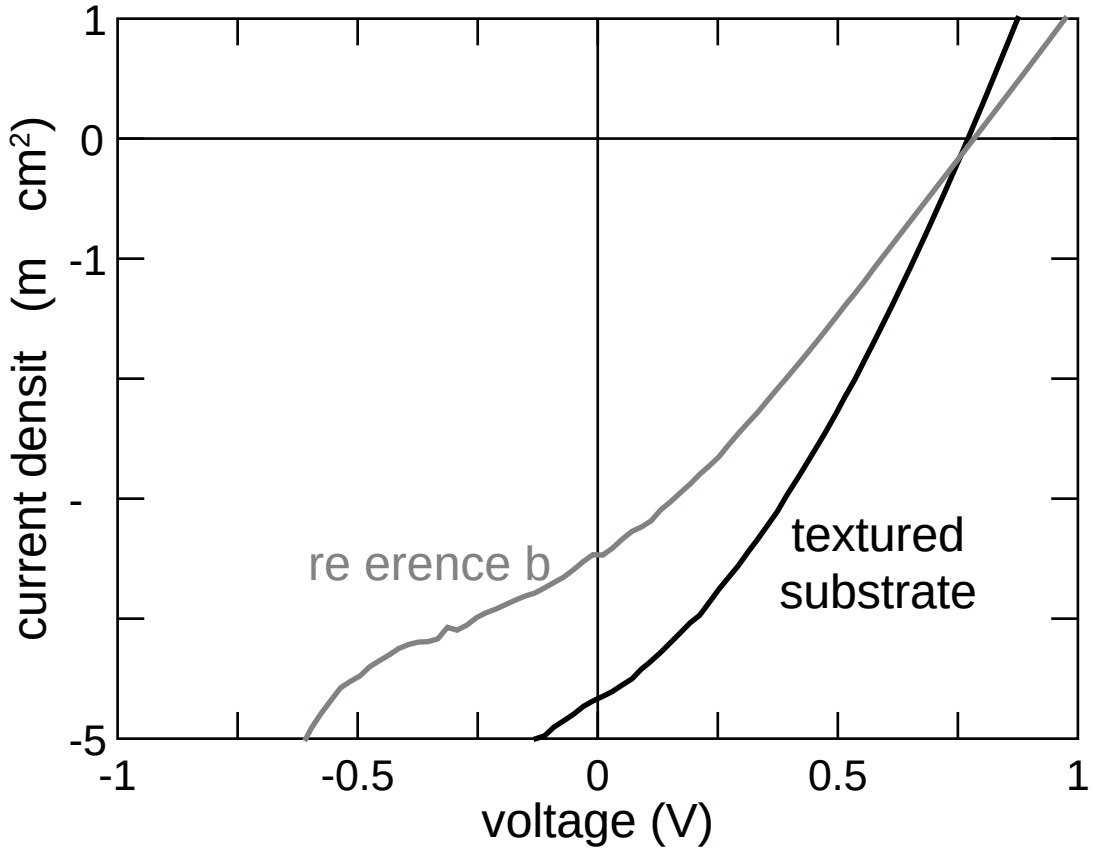


textured substrate

a-Si solar cells on laser-textured substrates

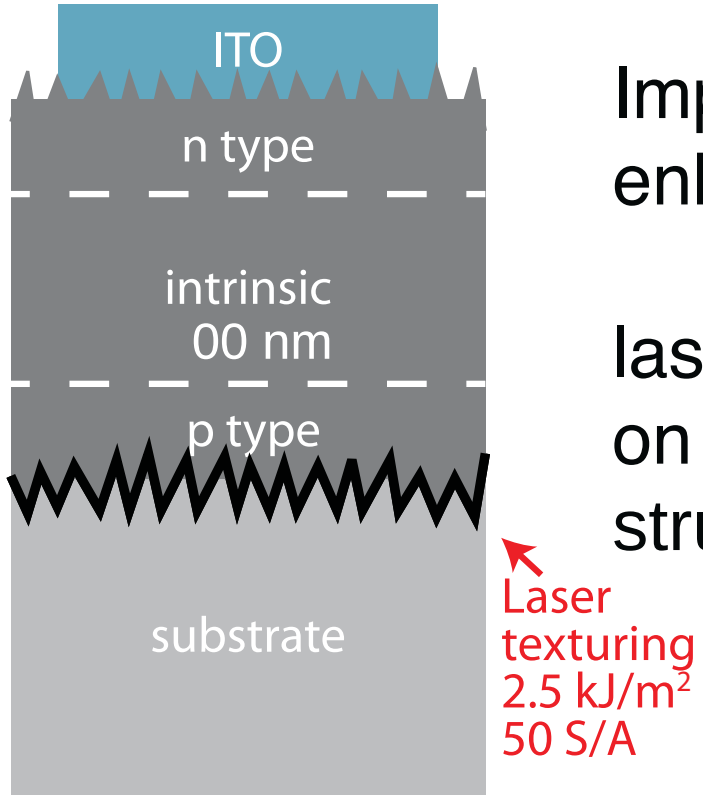


a-Si solar cells on laser-textured substrates



Sample	Efficiency (%)	J_{SC} (mA/cm^2)	V_{OC} (V)	Fill factor
Reference b (300 nm)	0.78	3.46	0.78	0.29
Textured sub-strate (b)	1.18	4.68	0.78	0.32

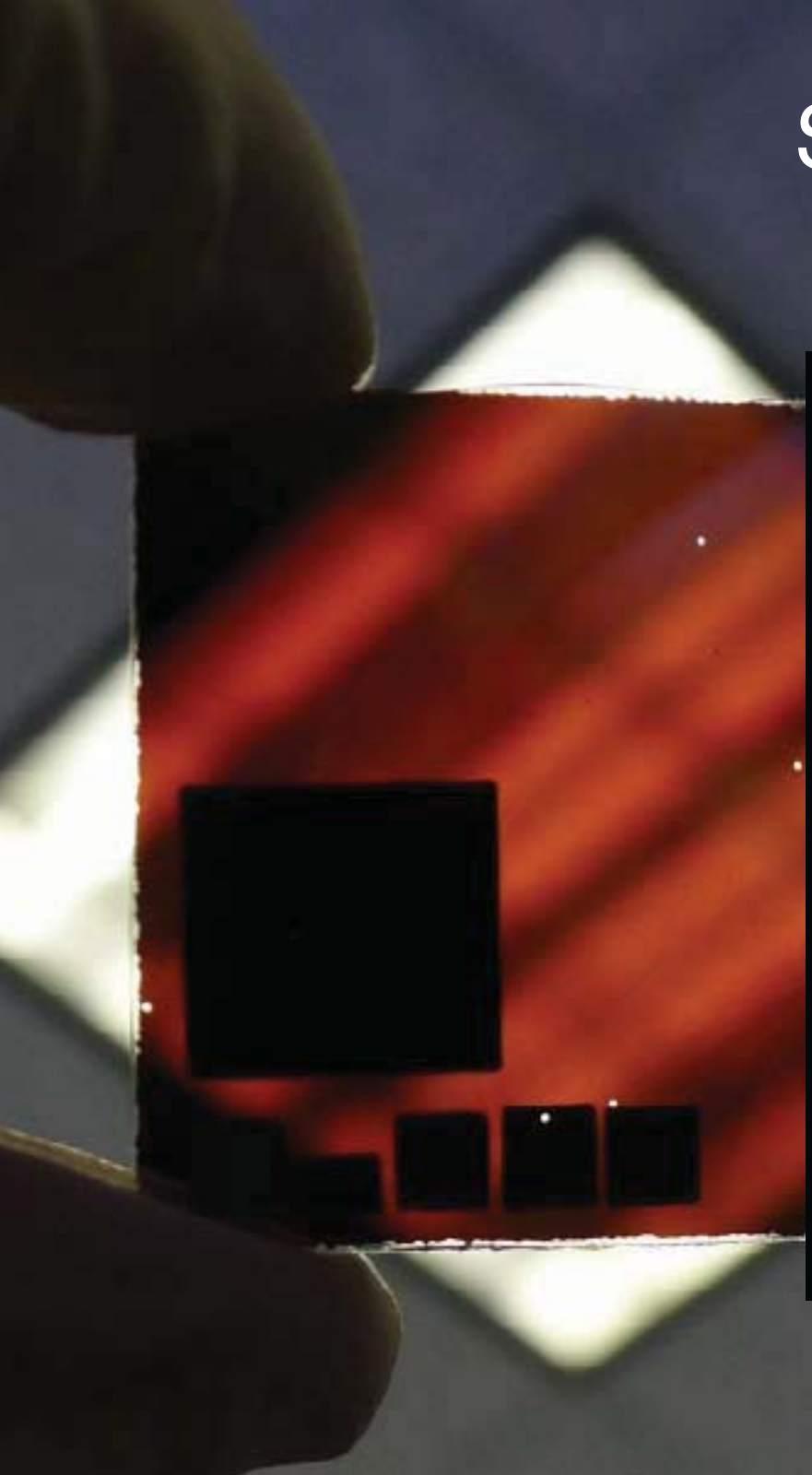
a-Si solar cells on laser-textured substrates



Improved efficiency due to enhanced light absorption

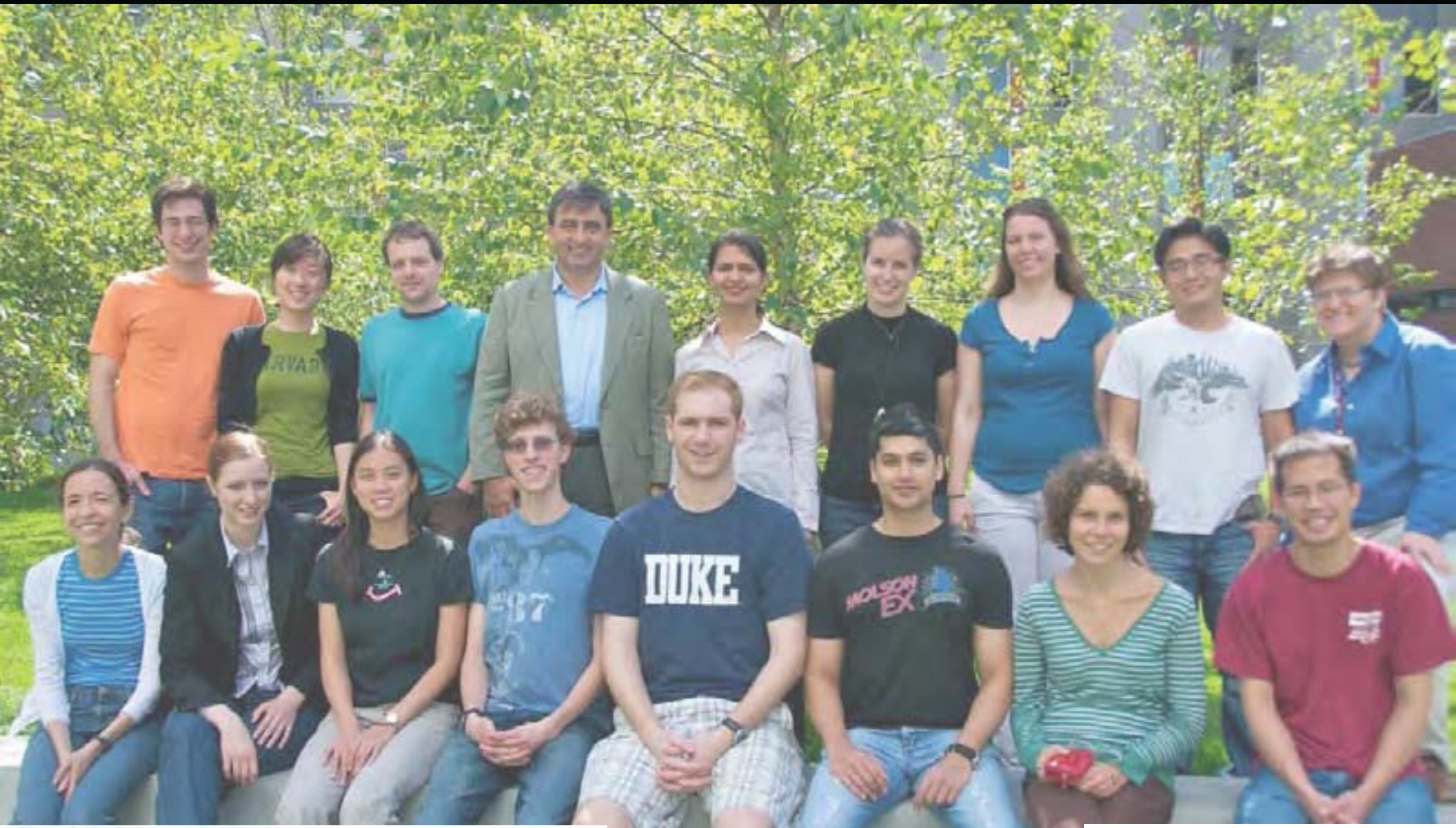
laser texturing:
on a wide variety of substrates
structure size $\propto \lambda$

Summary



- femtosecond laser texturing
  light trapping microstructures
- laser-textured a-Si solar cells
  laser induced damage
  limited efficiency improvement
- a-Si solar cells on laser-textured substrates
  enhanced absorption,
  photocurrent
  improved efficiency

Thanks!



Harvard University
Center for Nanoscale Systems

MAZUR GROUP