Infrared absorption of femtosecond laser doped silicon

CSSC-5
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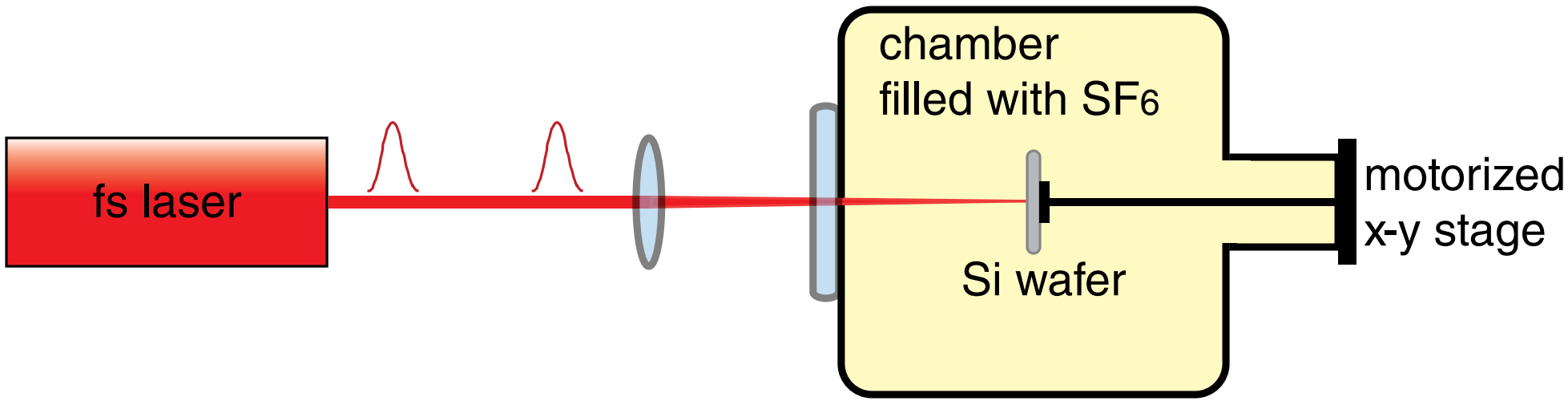
Harvard University

Christian Pruner and Augustinus Asenbaum
University of Salzburg , Salzburg, Austria

“Black Silicon”



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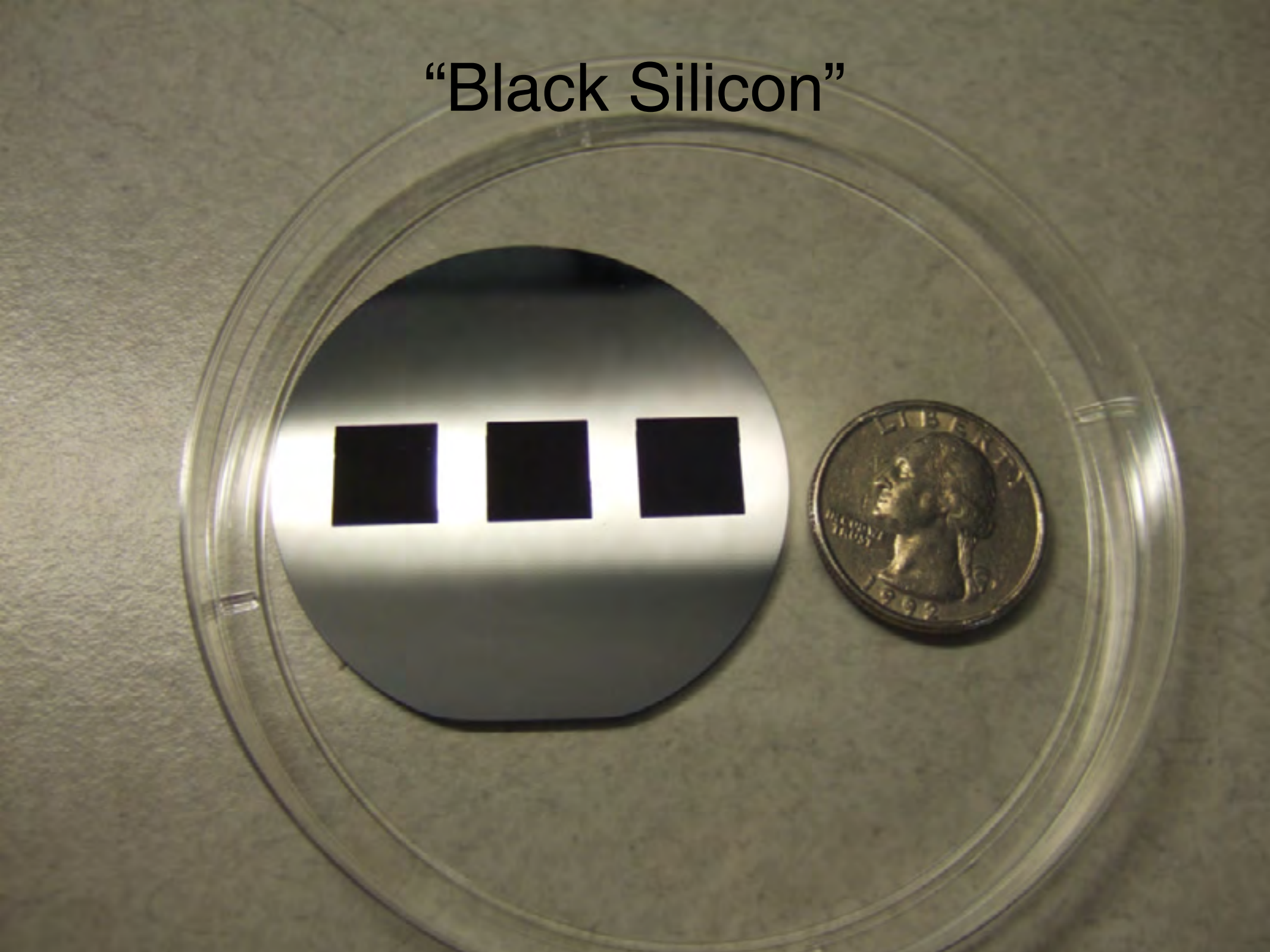

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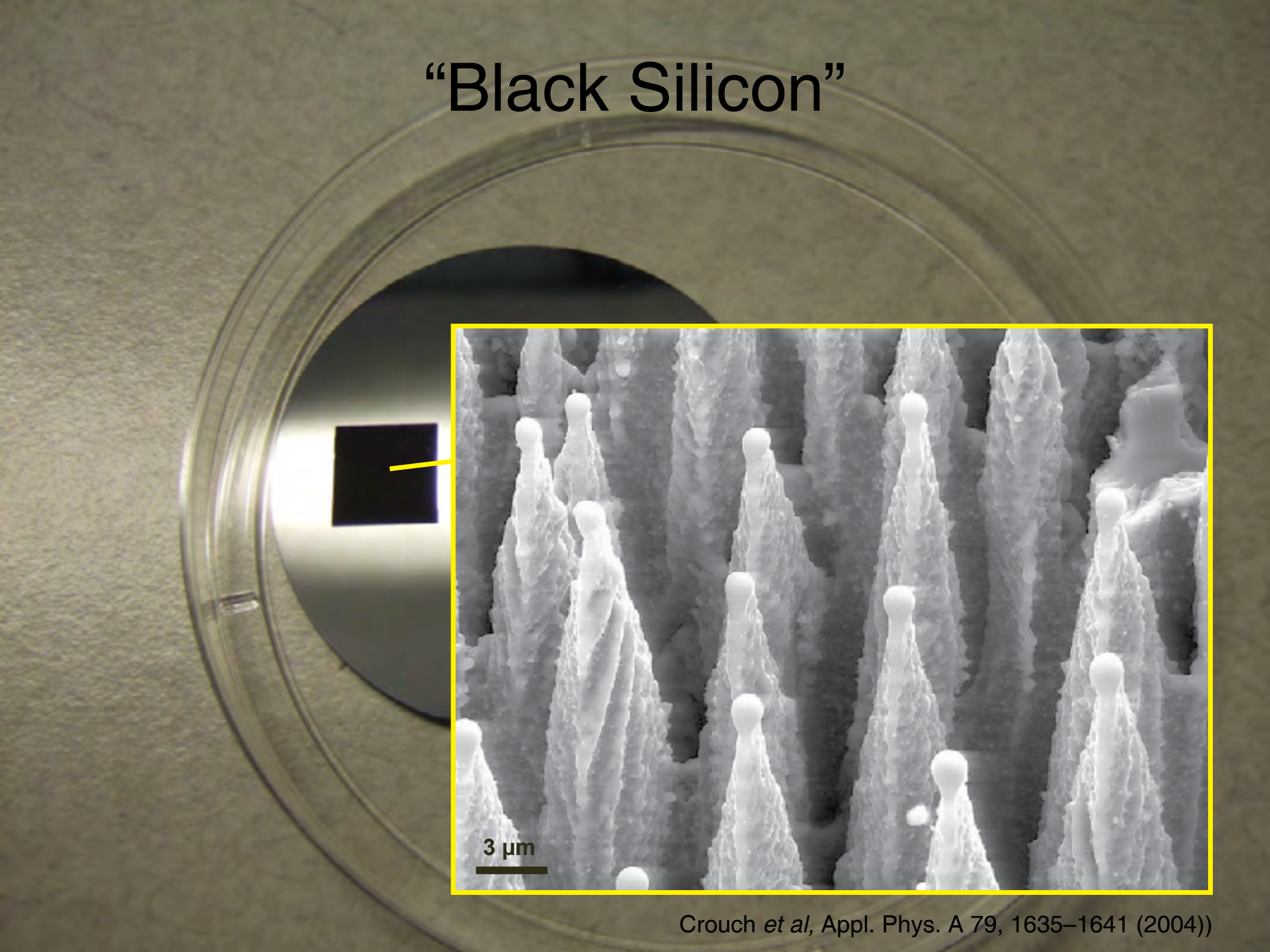

Crouch *et al,* Appl. Phys. A 79, 1635–1641 (2004))

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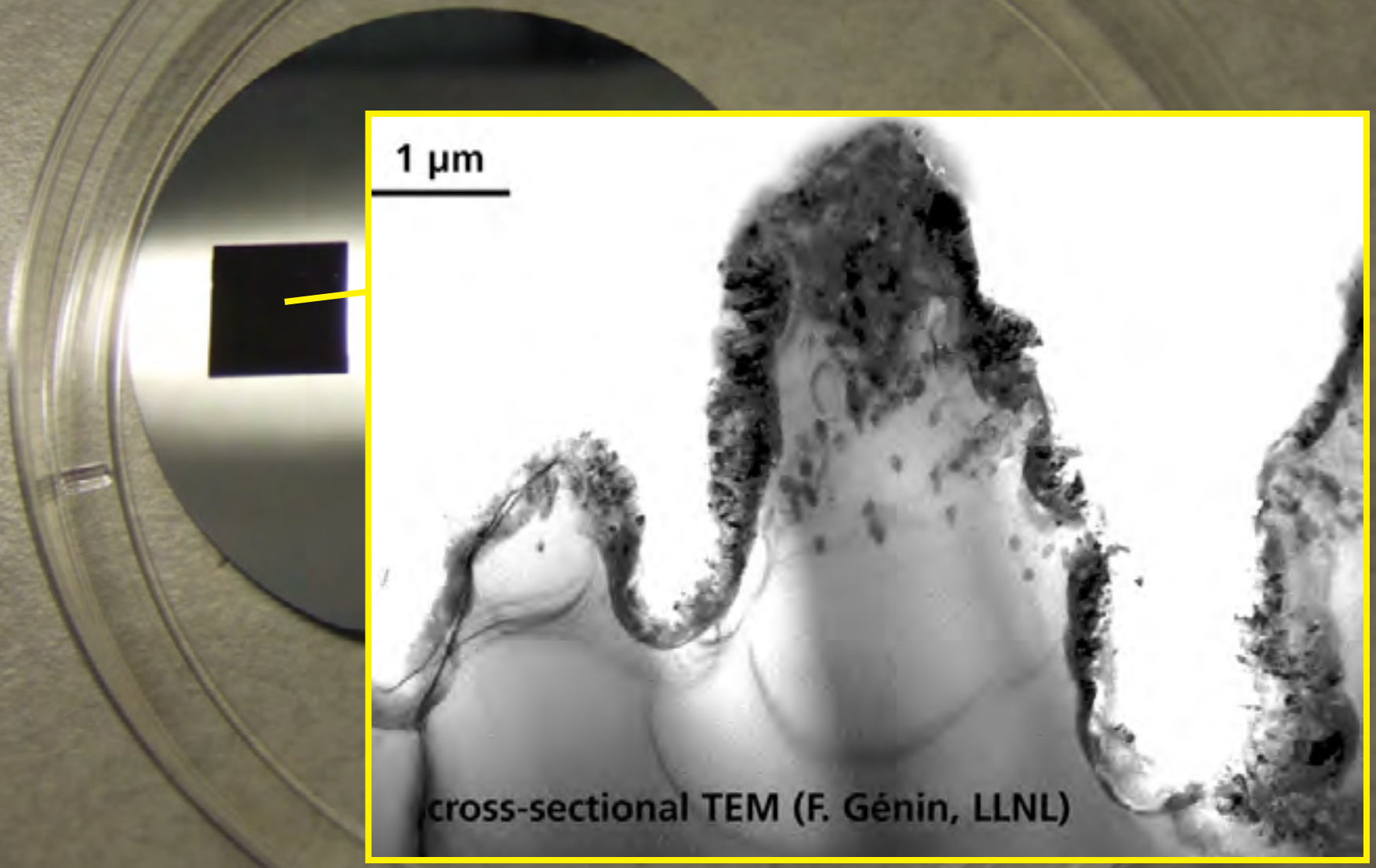

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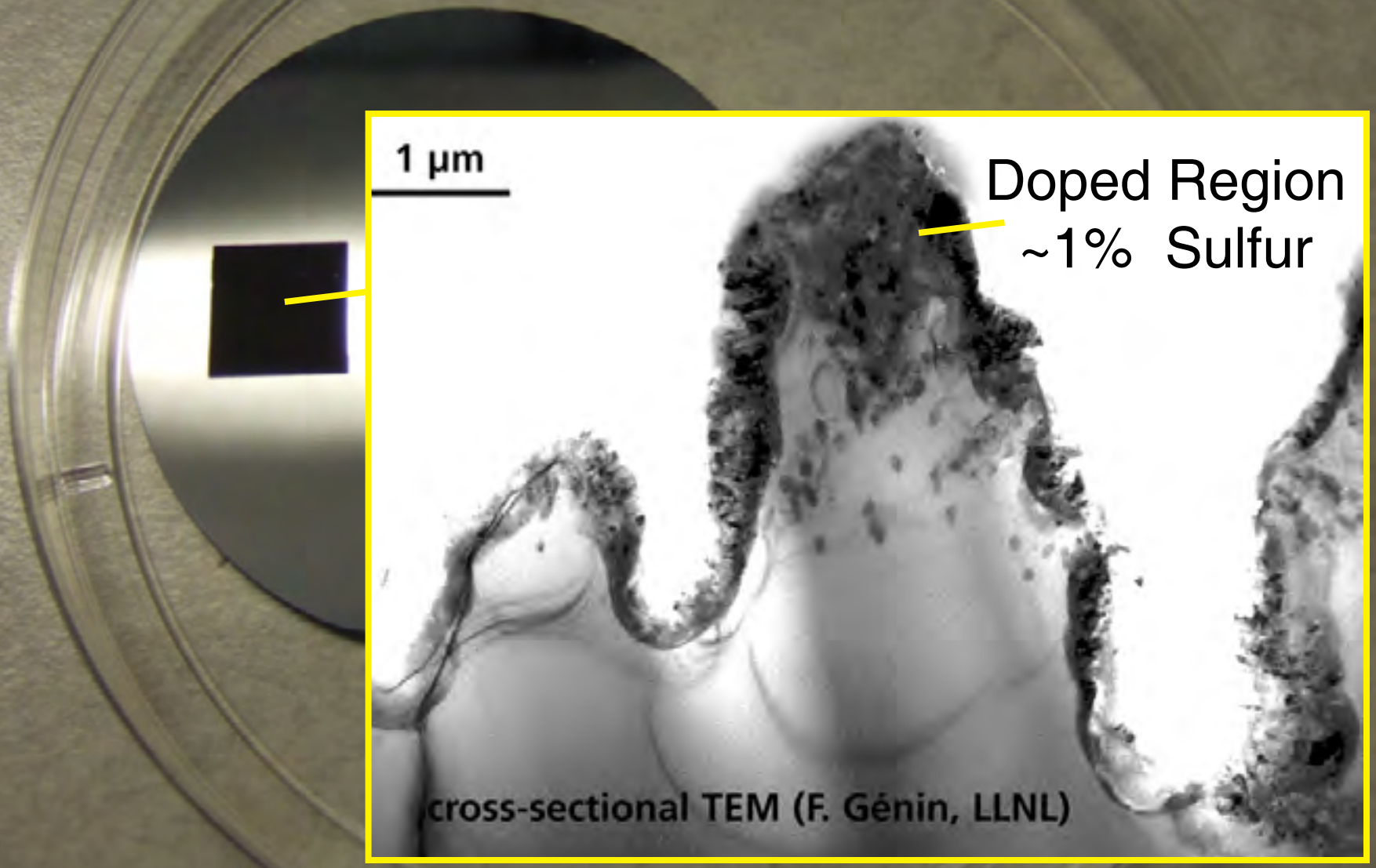
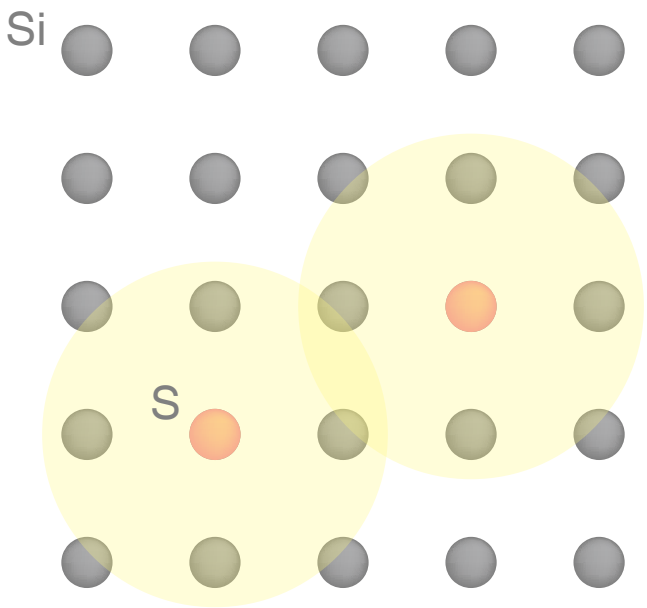


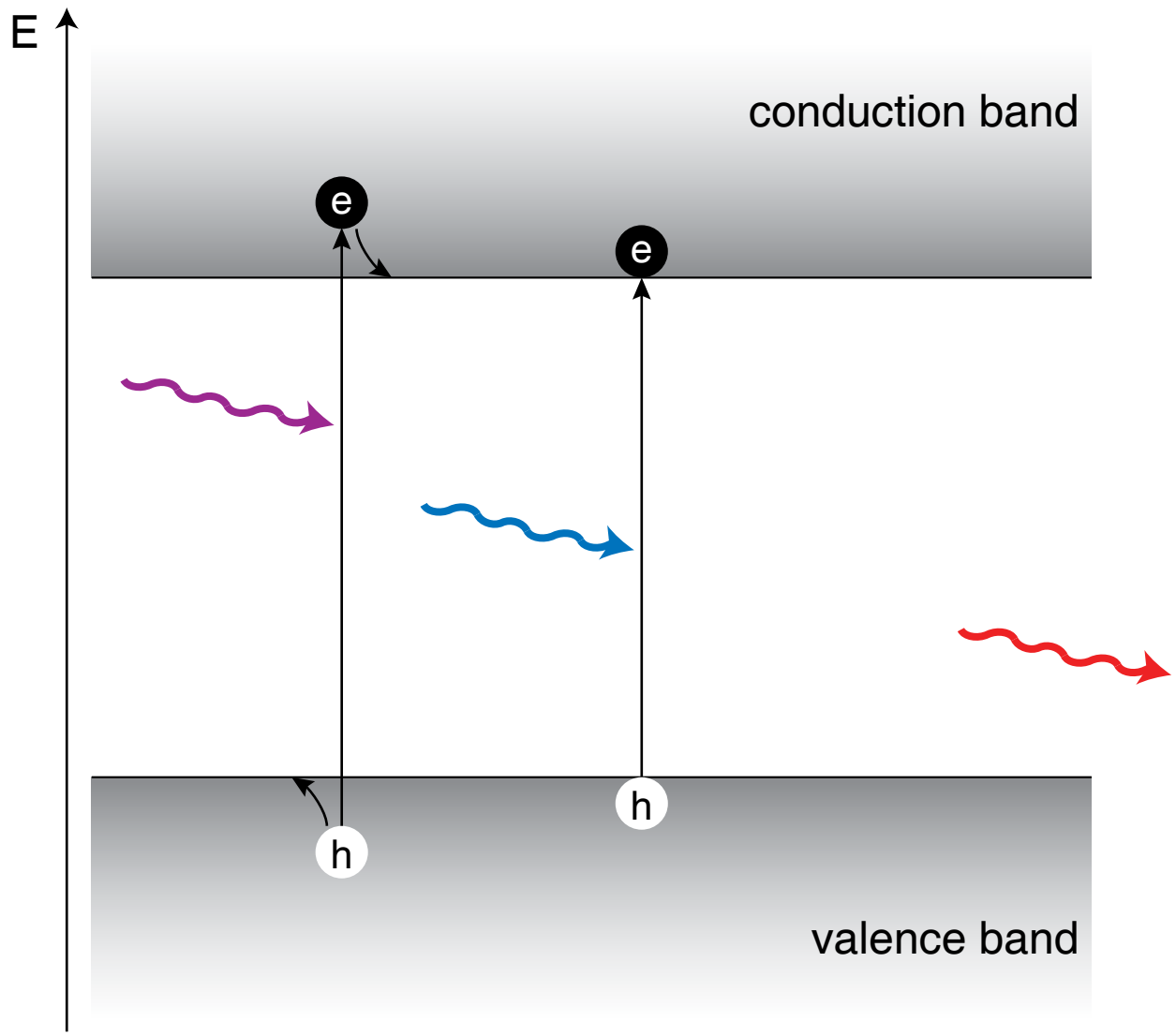
Crouch *et al,* Appl. Phys. A 79, 1635–1641 (2004))

Outline

- fs-laser hyperdoping and texturing
- intermediate band PV
- infrared absorption
- dopant diffusion



Intermediate-band photovoltaics



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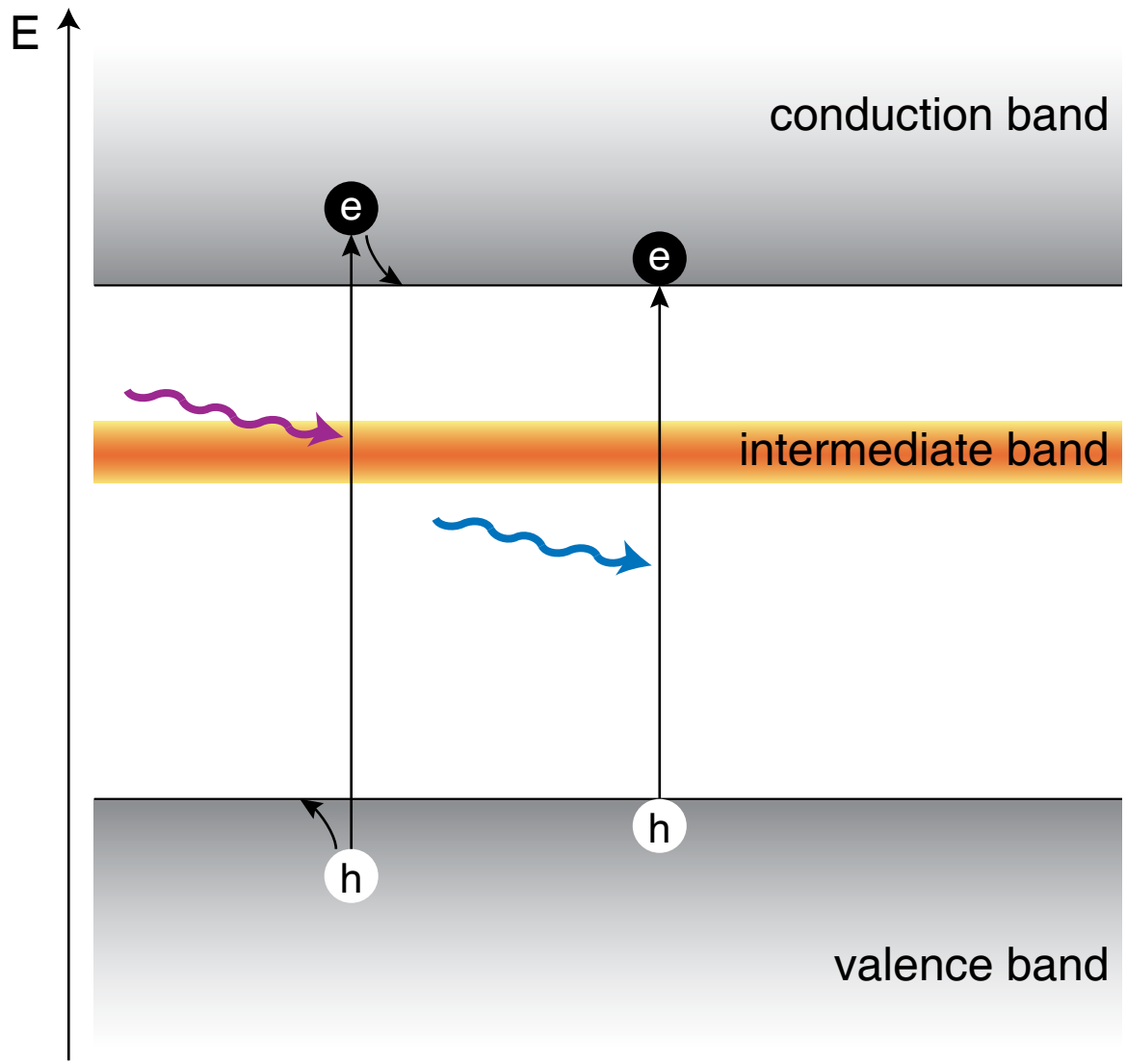
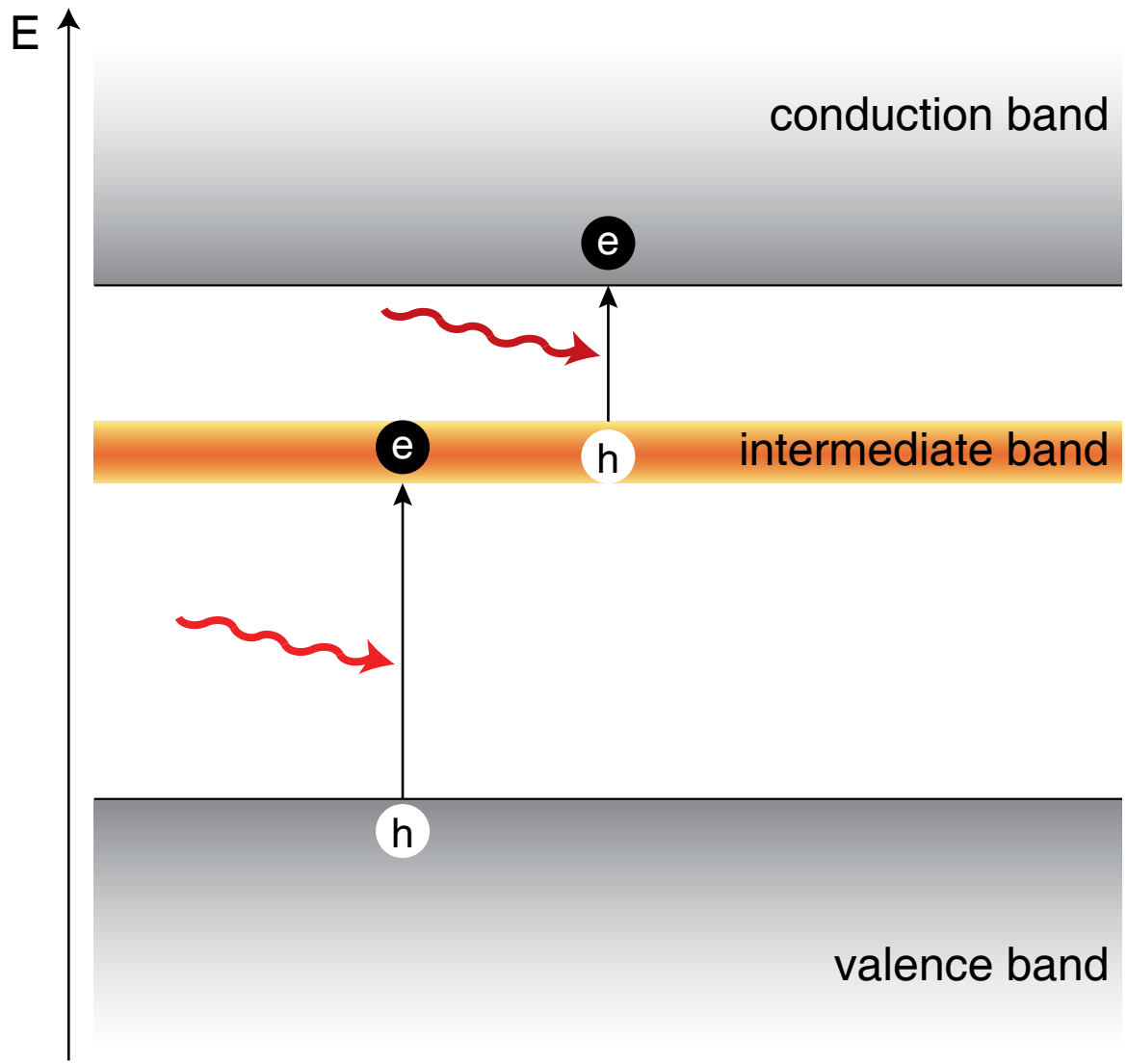


Luque and Marti, Phys. Rev. Lett. 78, 5014 (1997)

Intermediate-band photovoltaics



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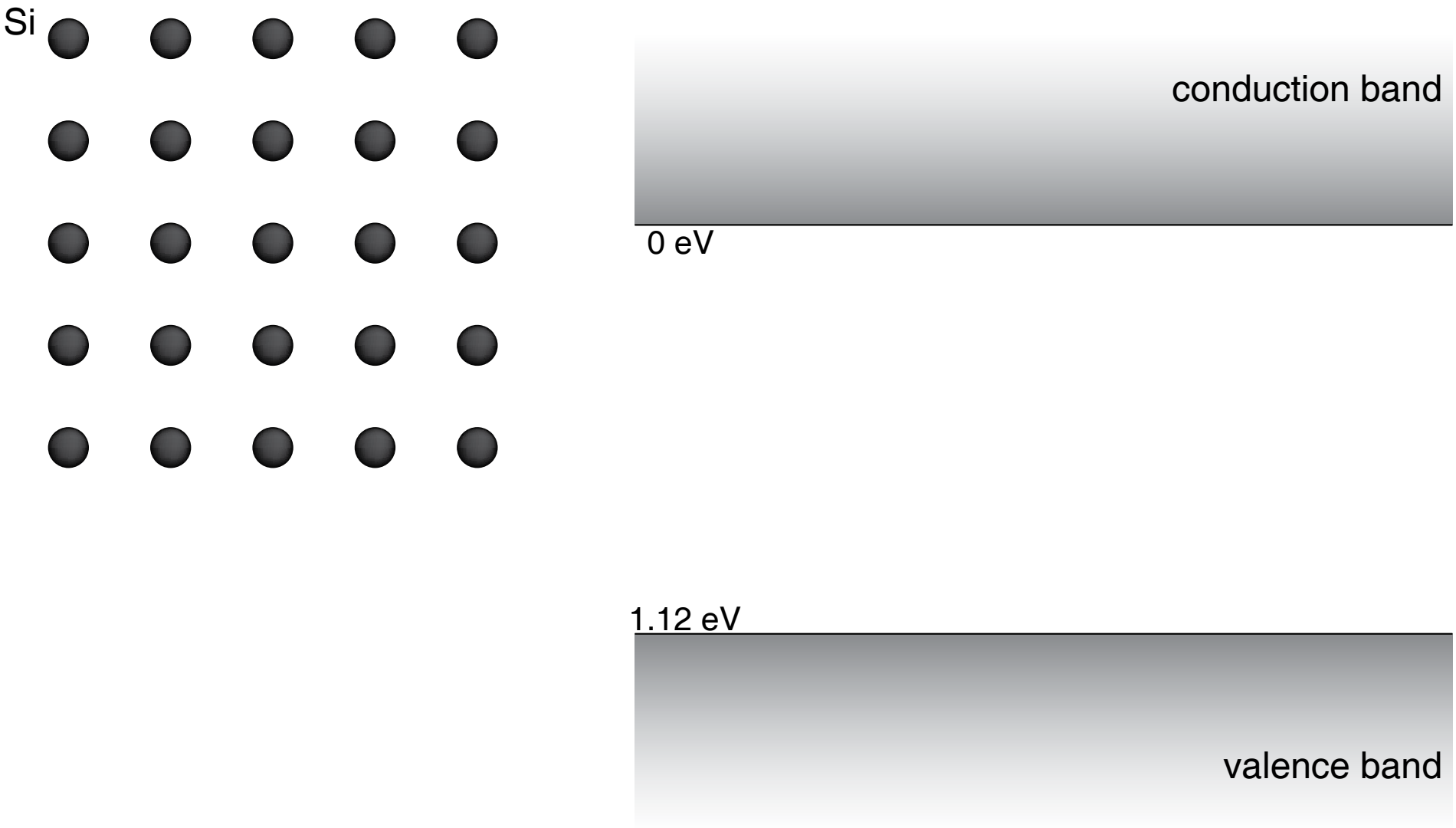

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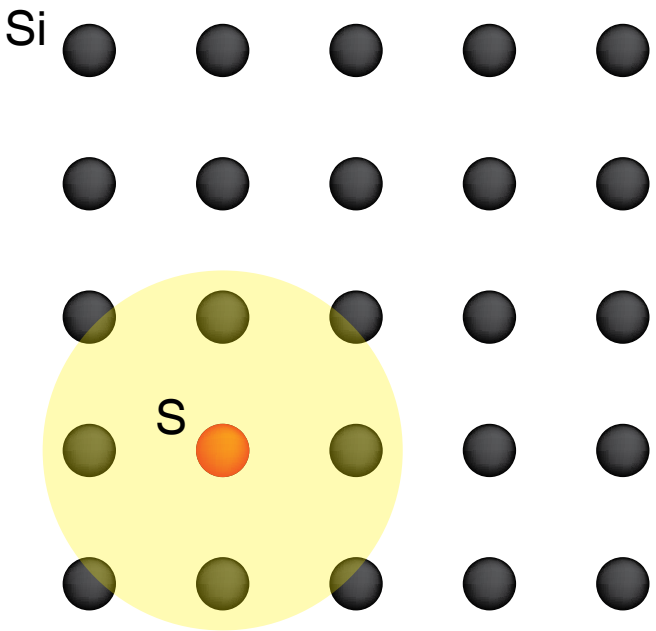

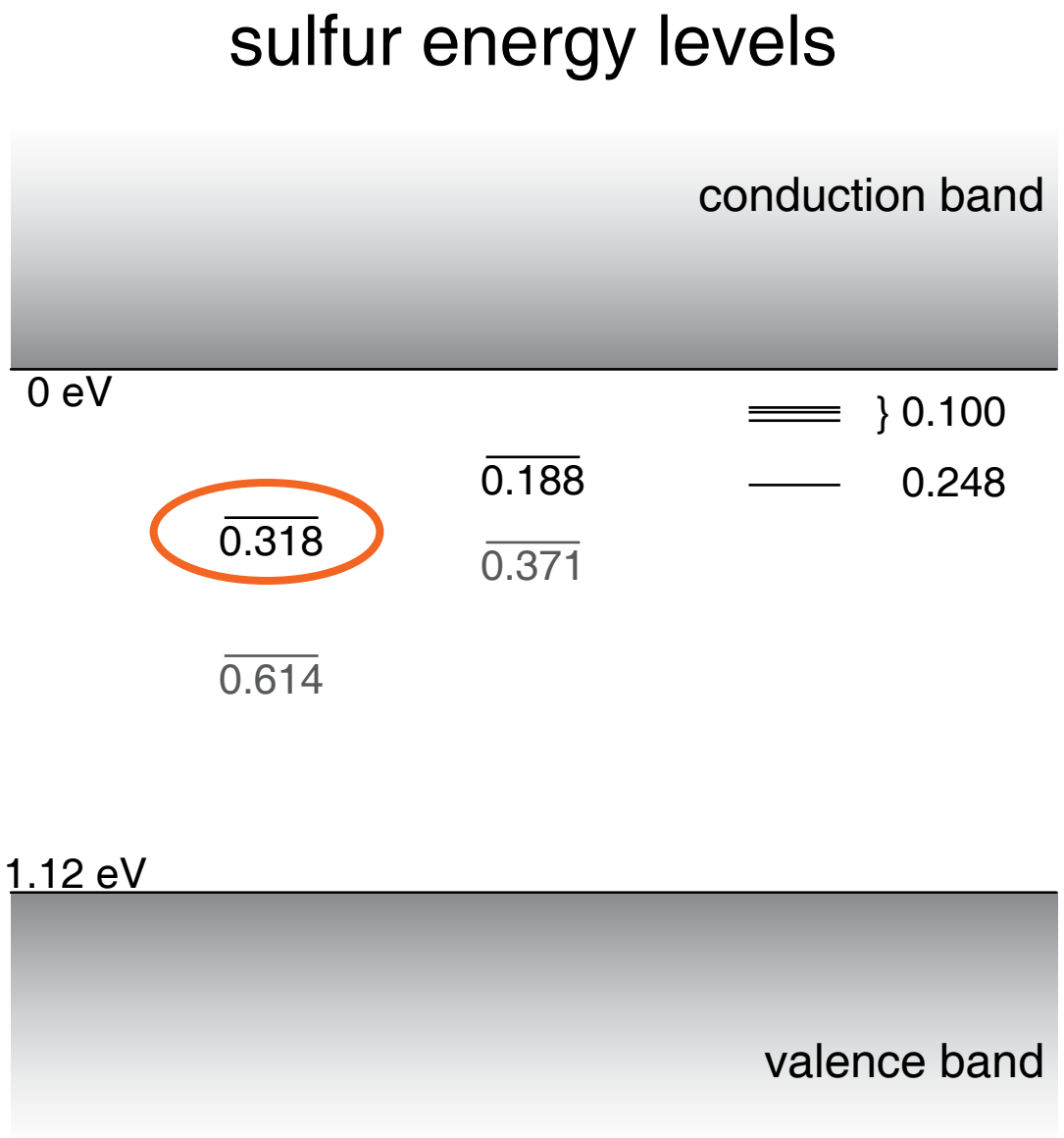

Janzén *et al,* Phys. Rev. B 29, 1907 (1984)

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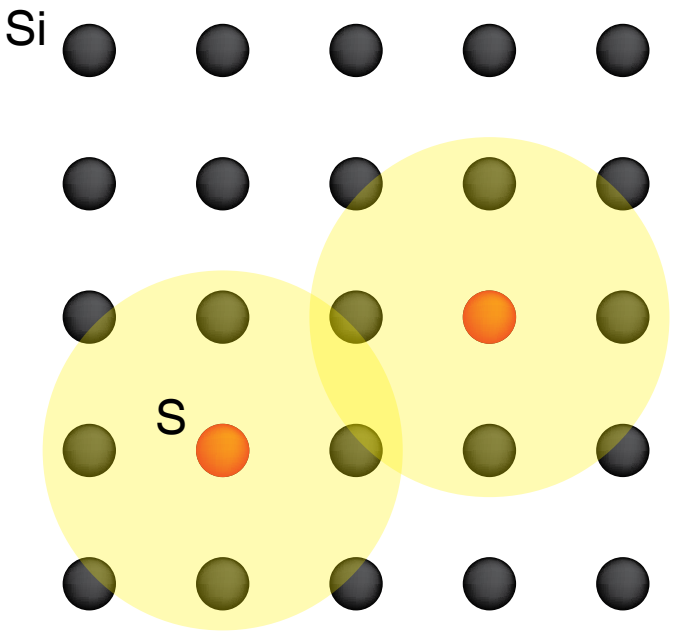
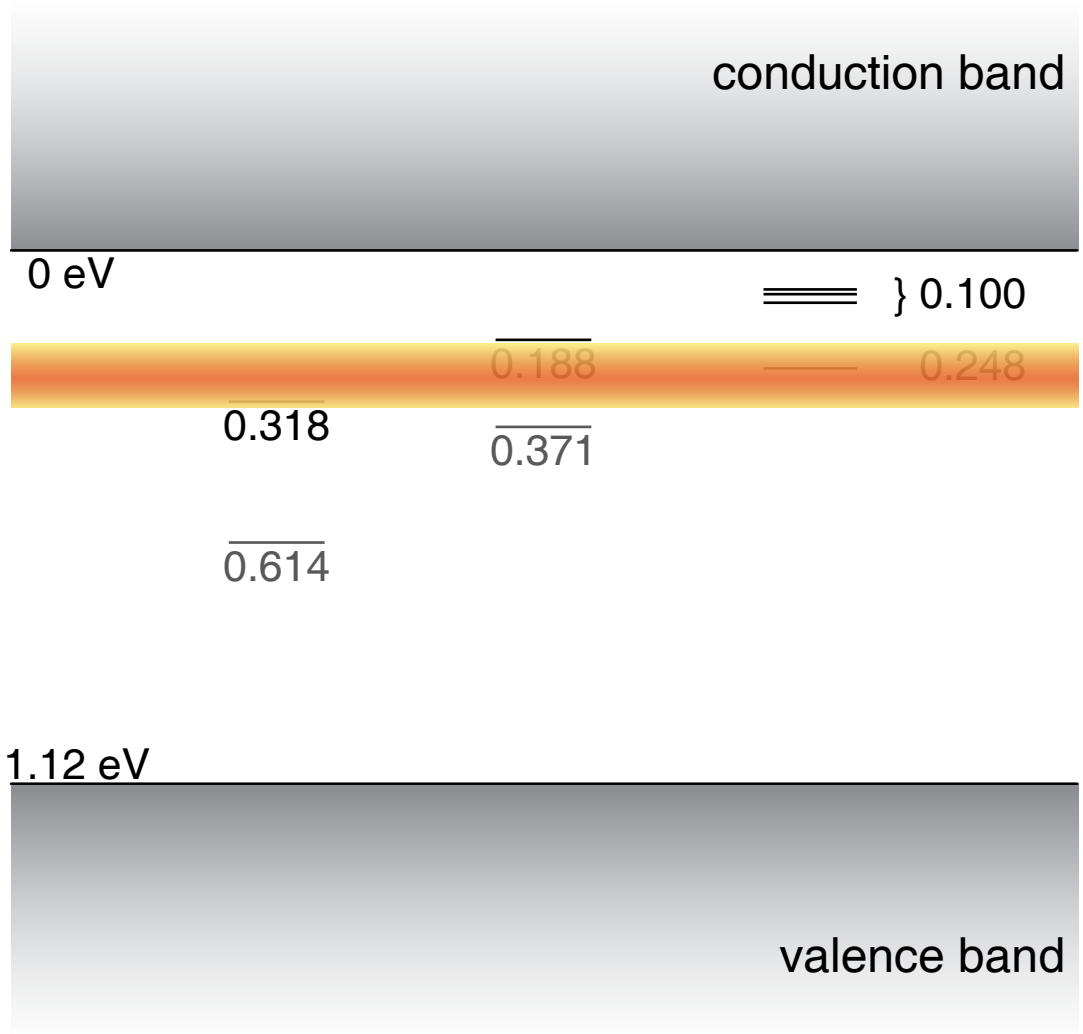


metal-insulator transition



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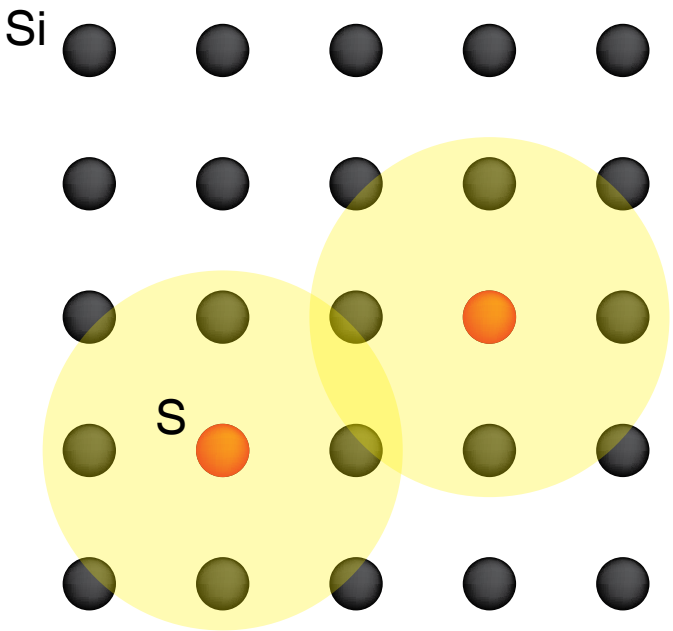
Intermediate-band photovoltaics



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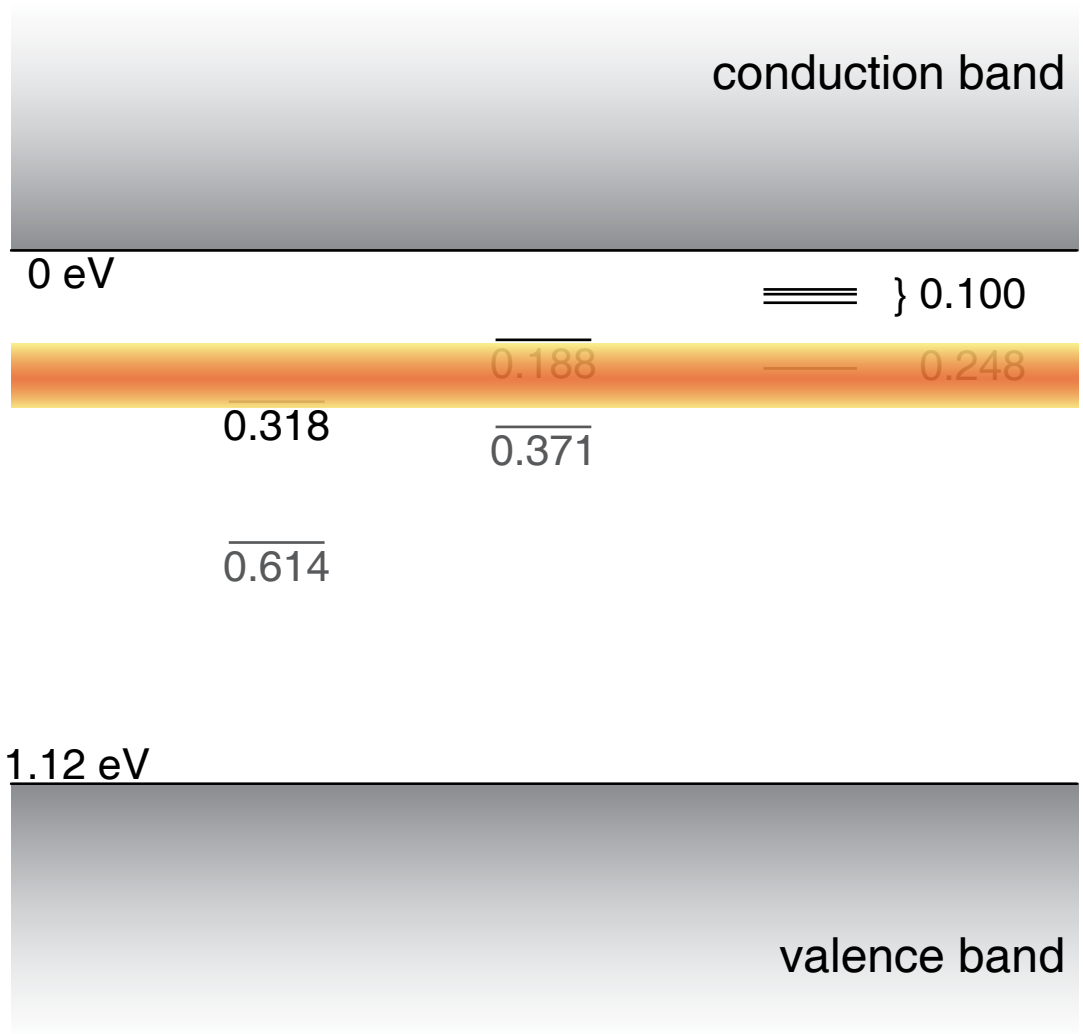
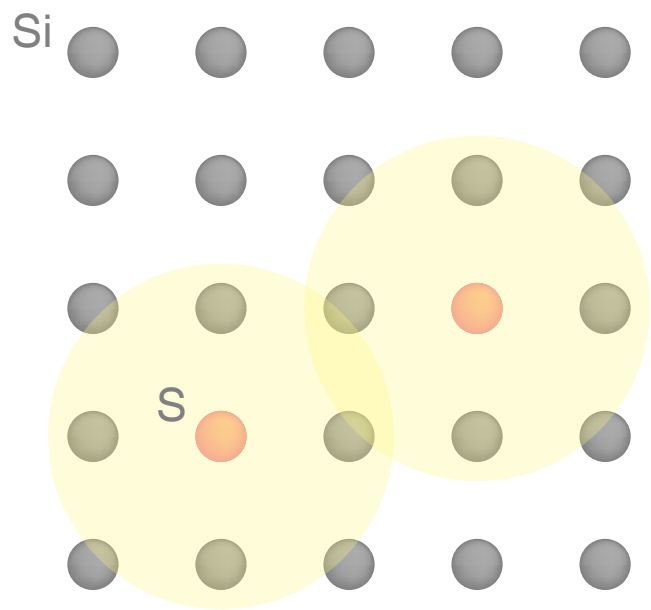


deep level
high concentration

Janzén *et al,* Phys. Rev. B 29, 1907 (1984)

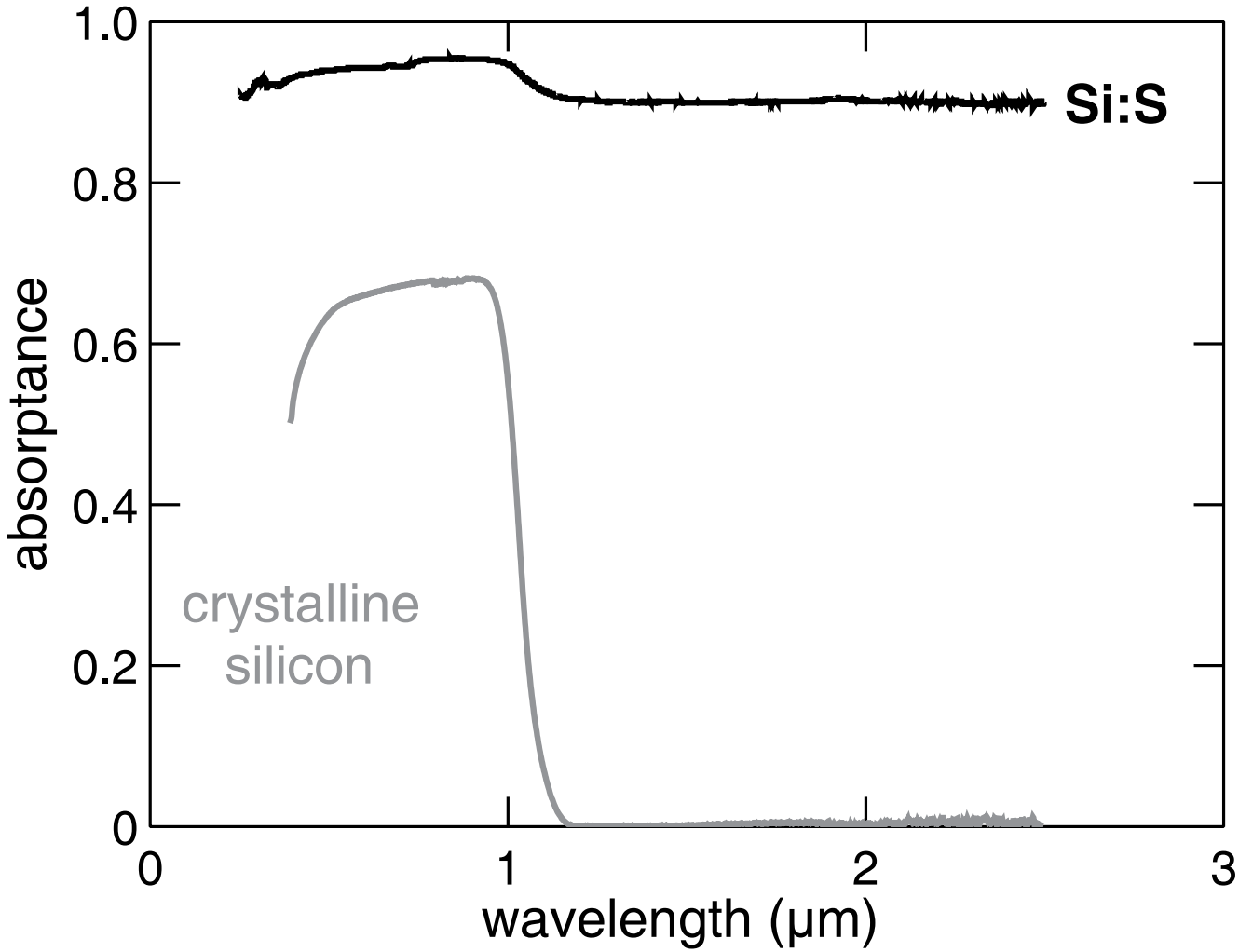
Outline

- fs-laser hyperdoping and texturing
- intermediate band PV
- infrared absorption
- dopant diffusion



IR absorption

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



Sheehy *et al,* Materials Science and Engineering B 137 (2007)

IR absorption

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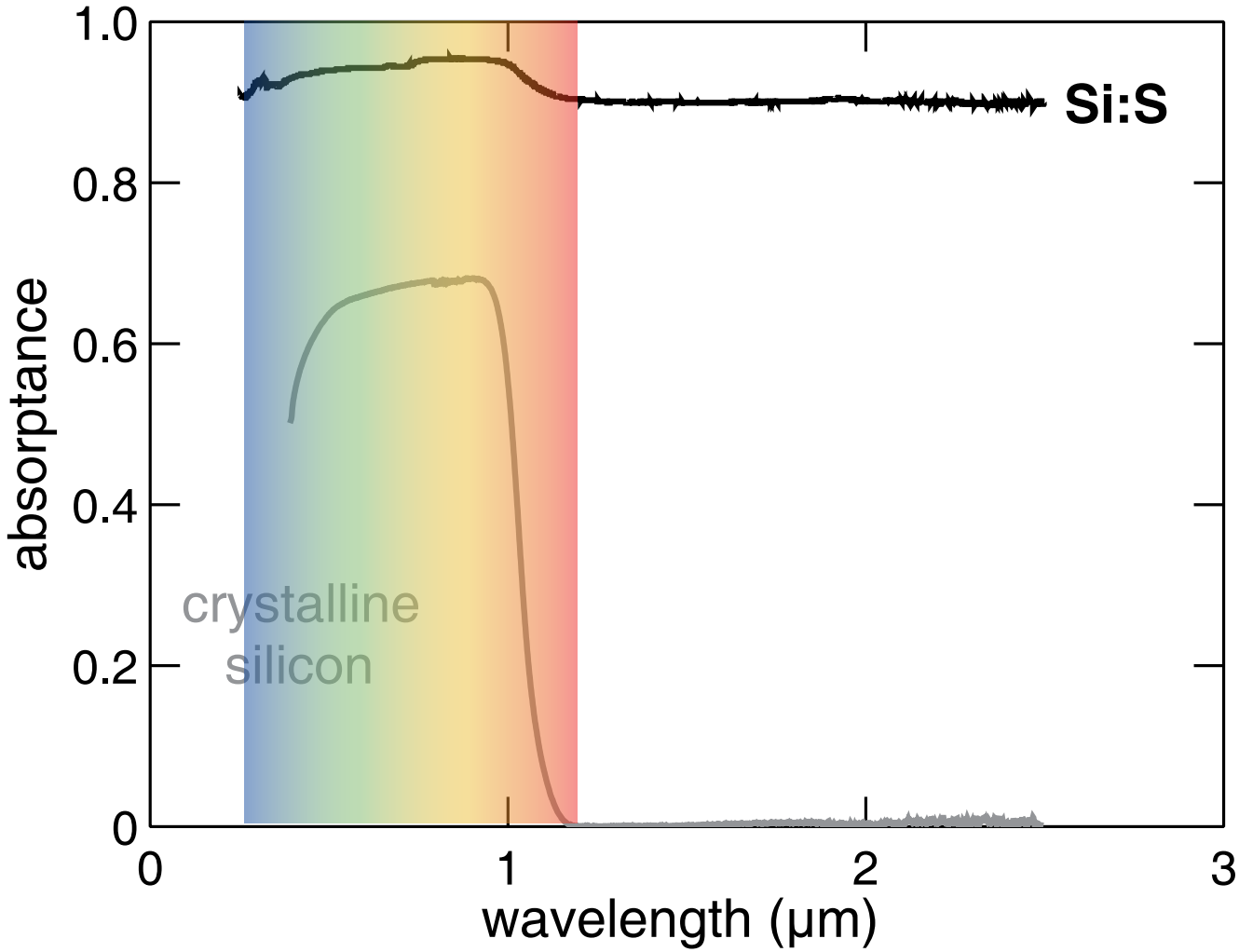

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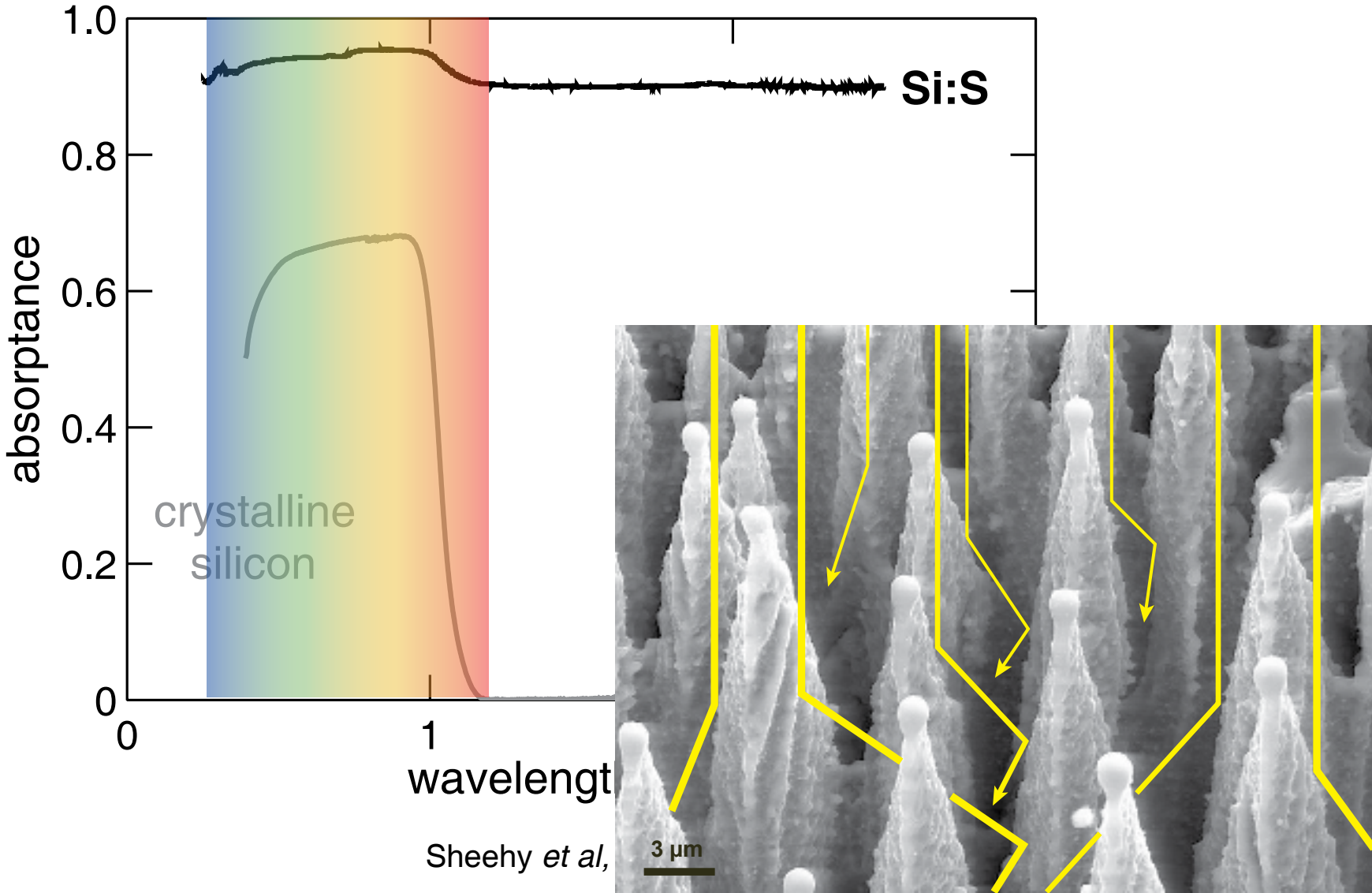

Sheehy *et al,*

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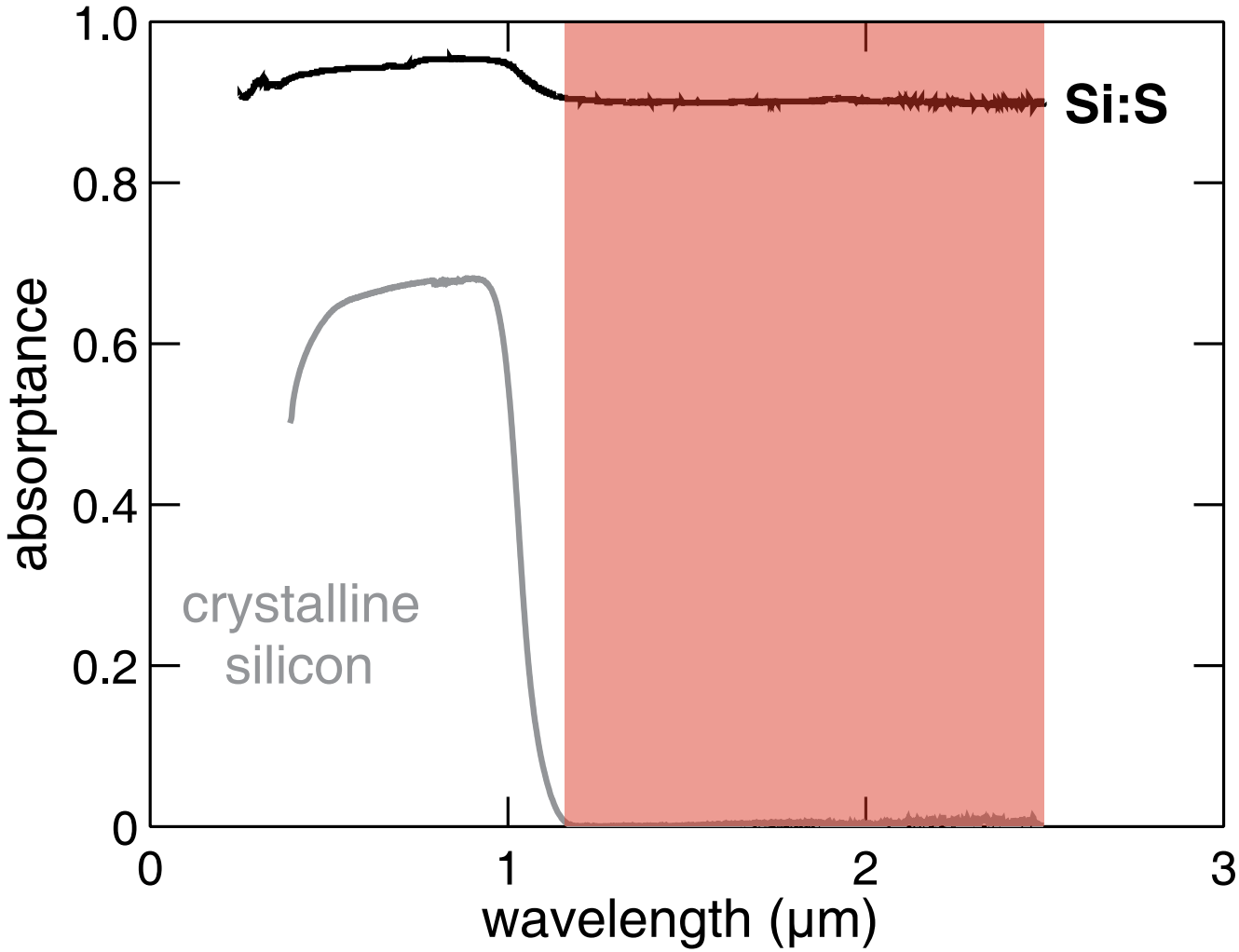

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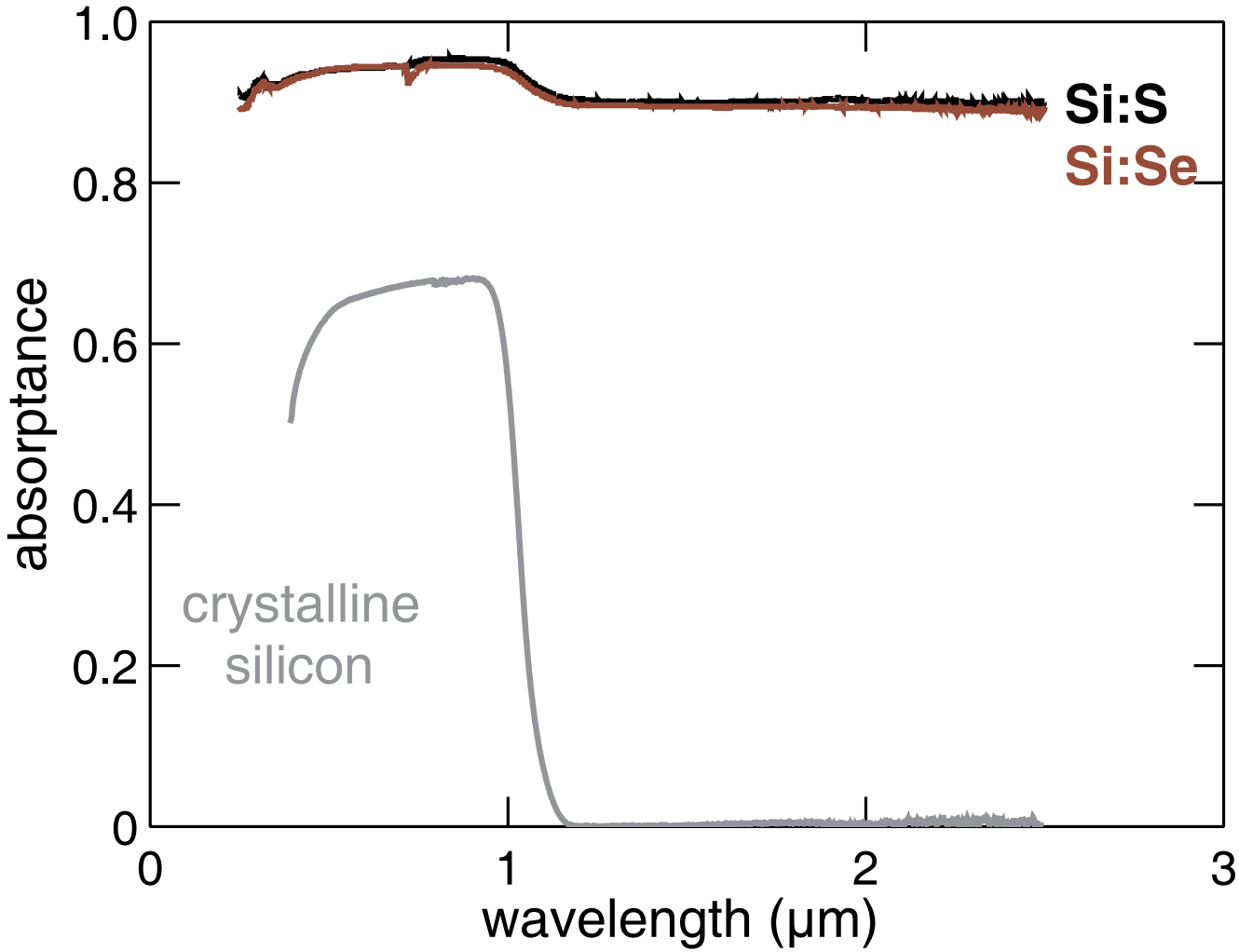

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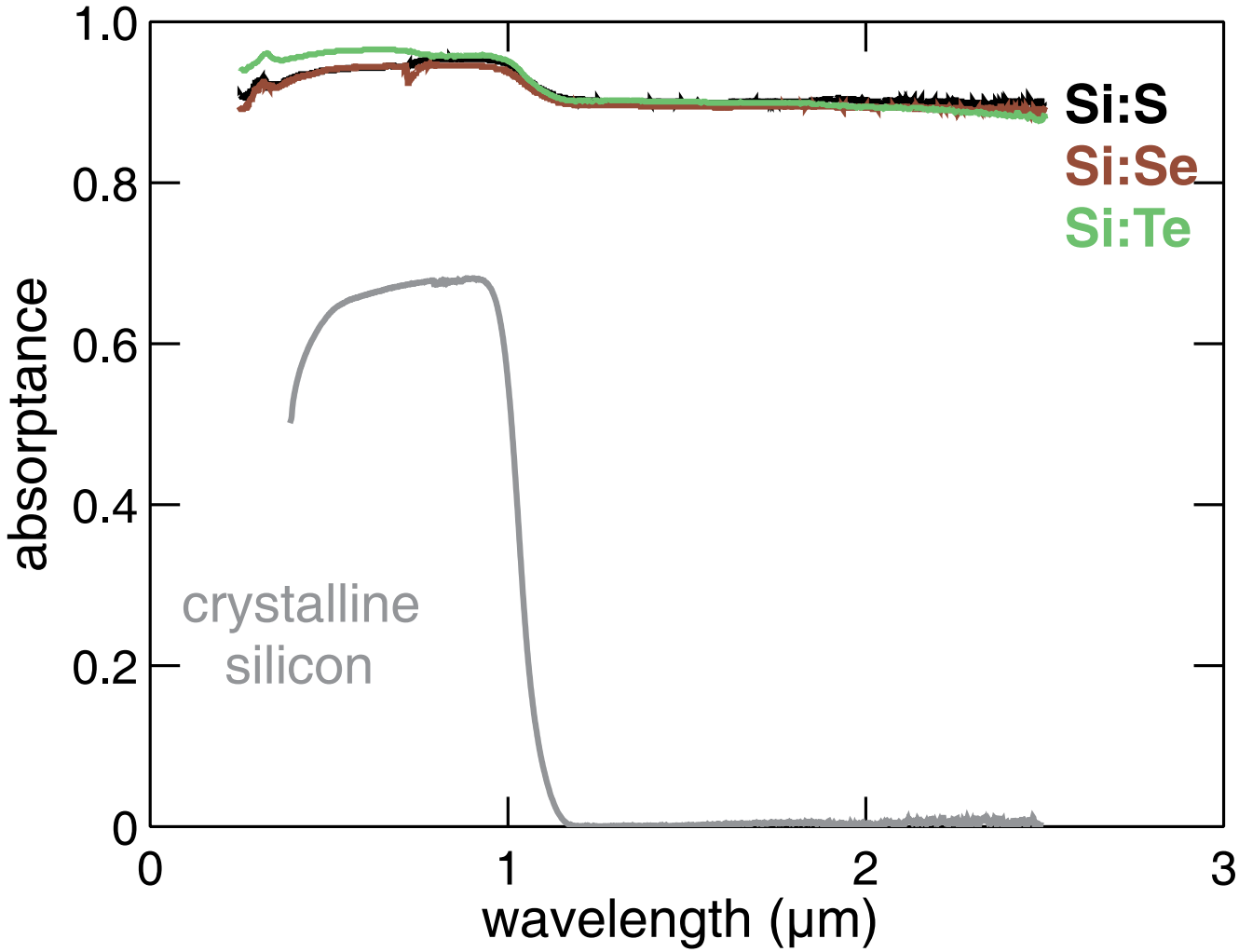
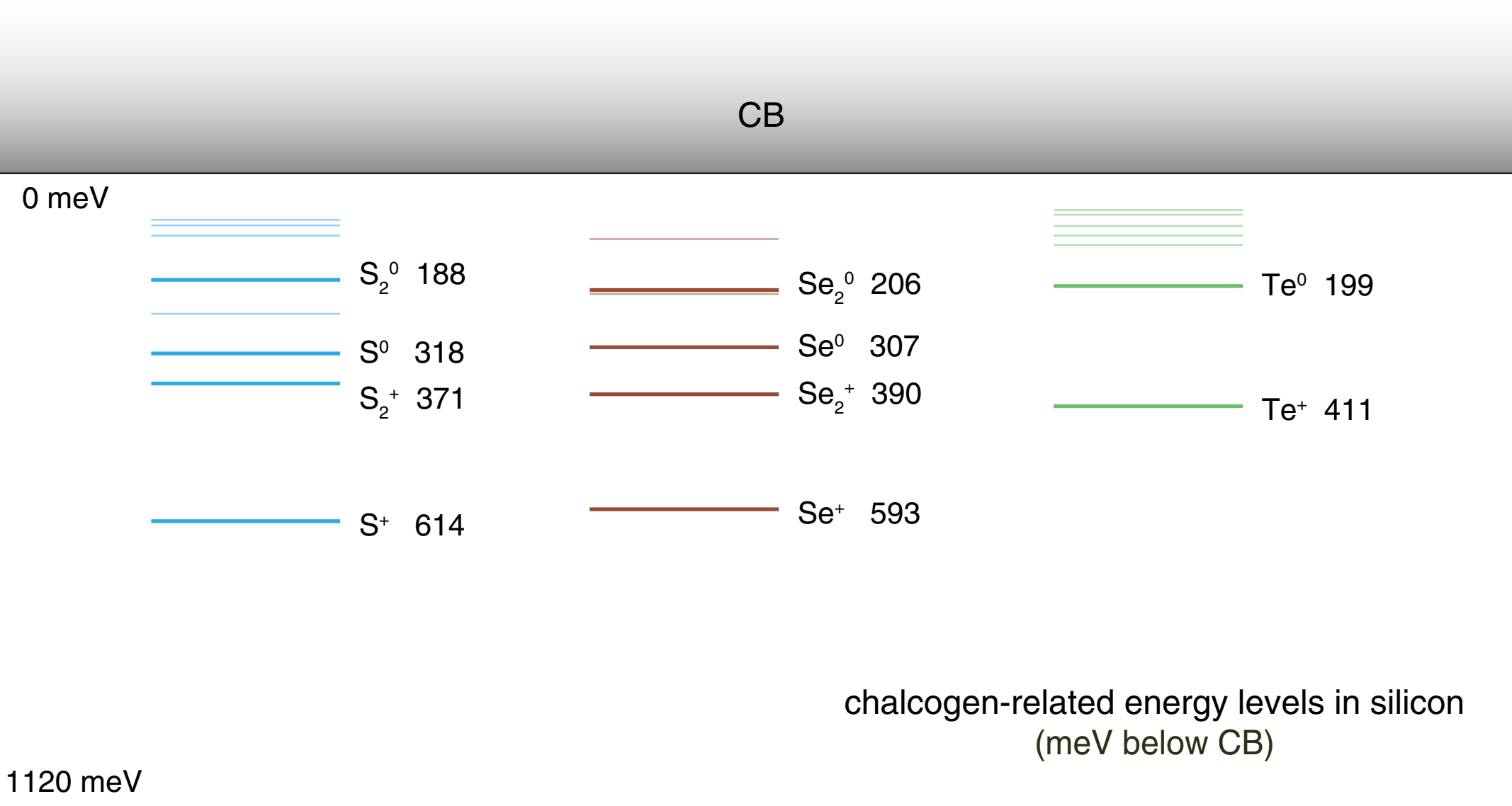


Sheehy *et al,* Materials Science and Engineering B 137 (2007)

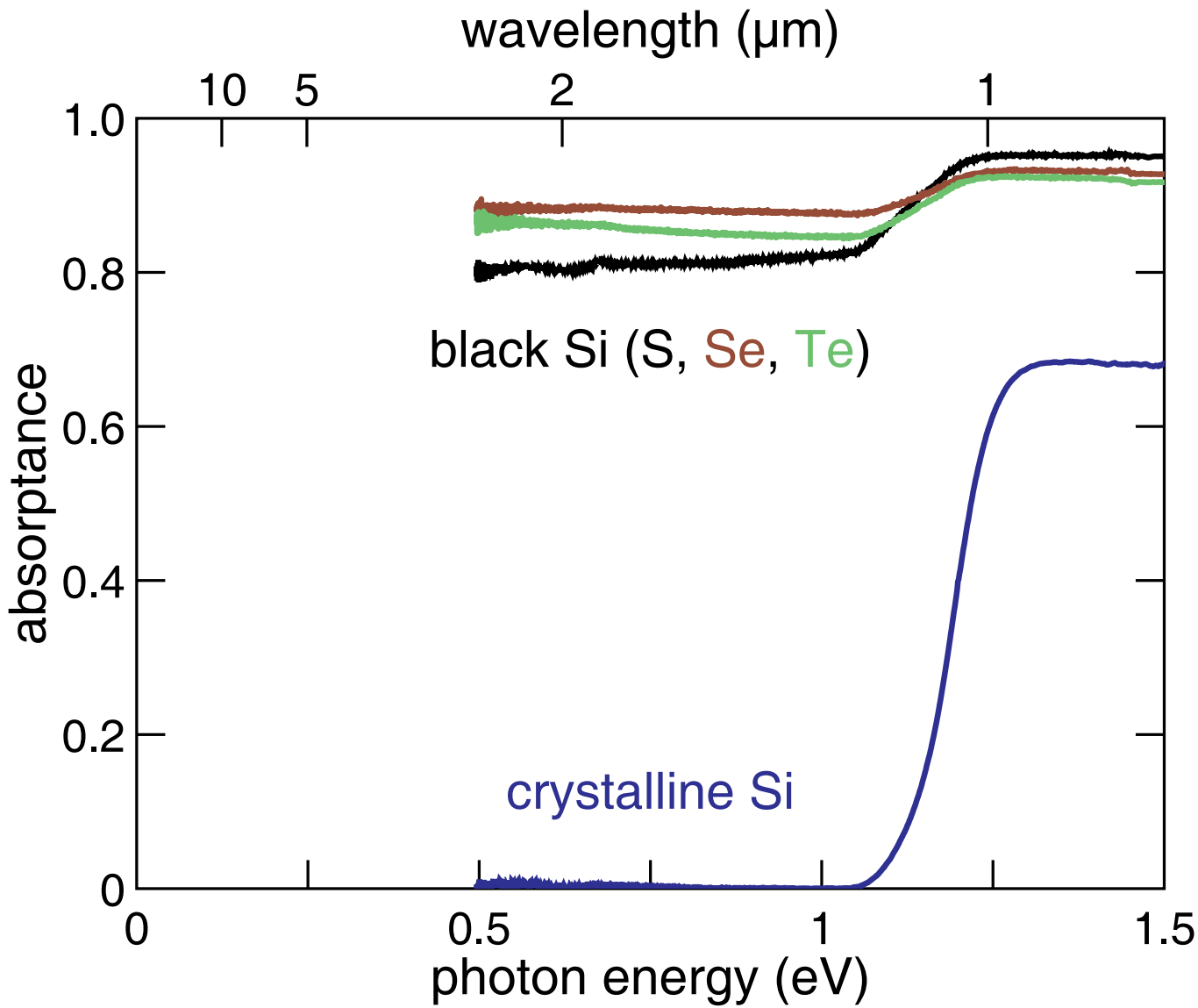
Mid-IR absorption



chalcogen-related energy levels in silicon
(meV below CB)

Janzén *et al,* Phys. Rev. B 29, 1907 (1984)

Mid-IR absorption



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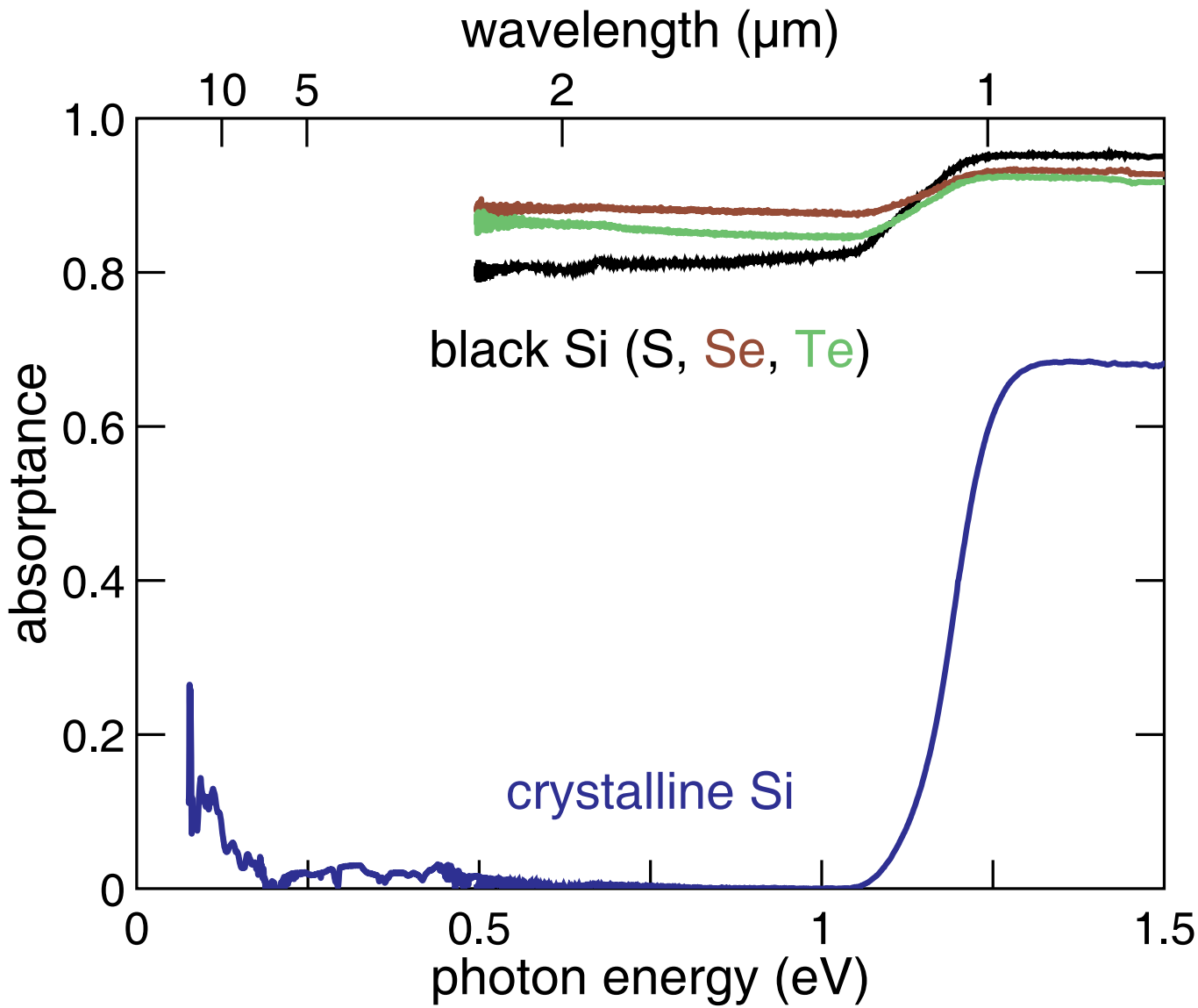
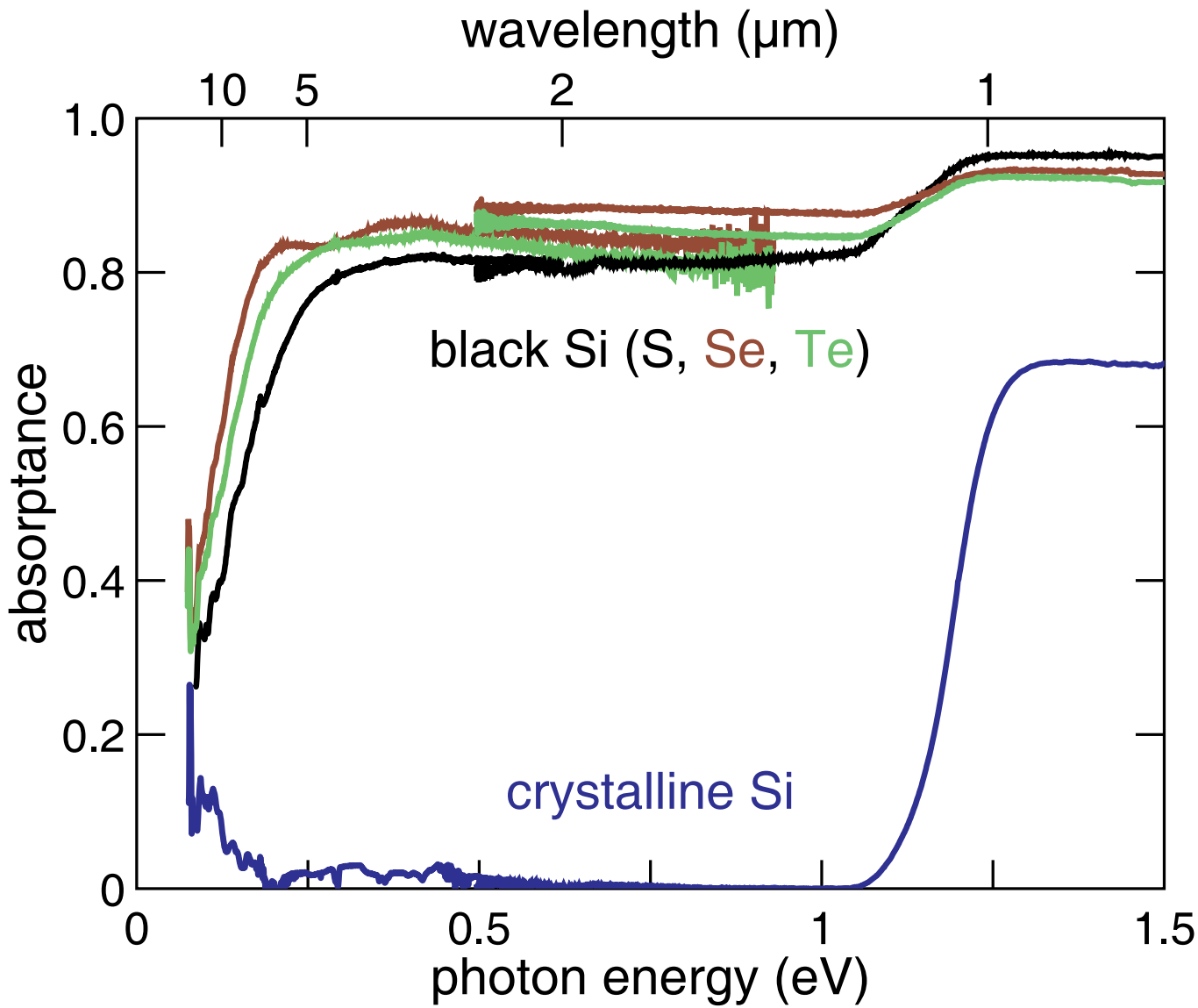


Mid-IR absorption



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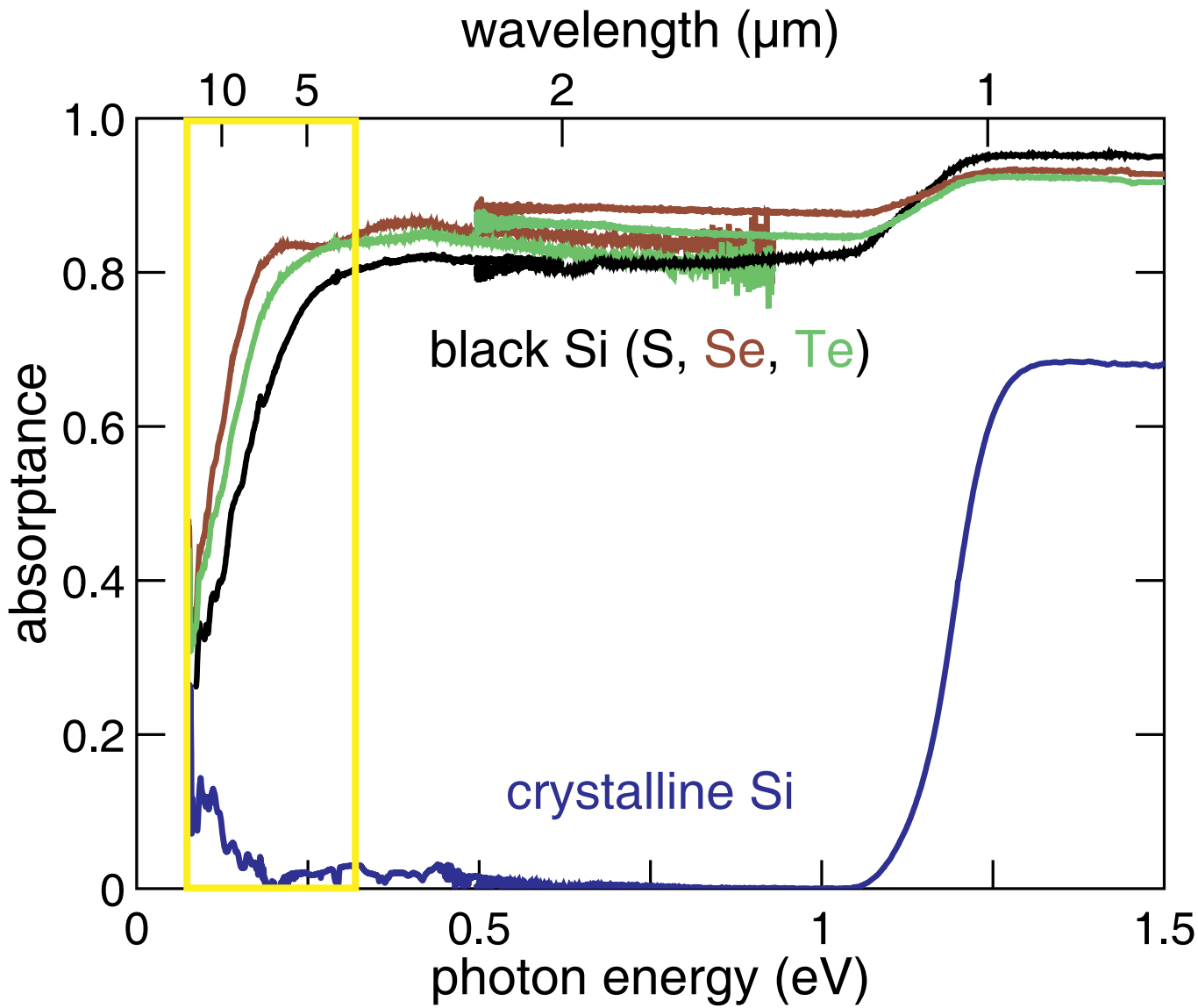

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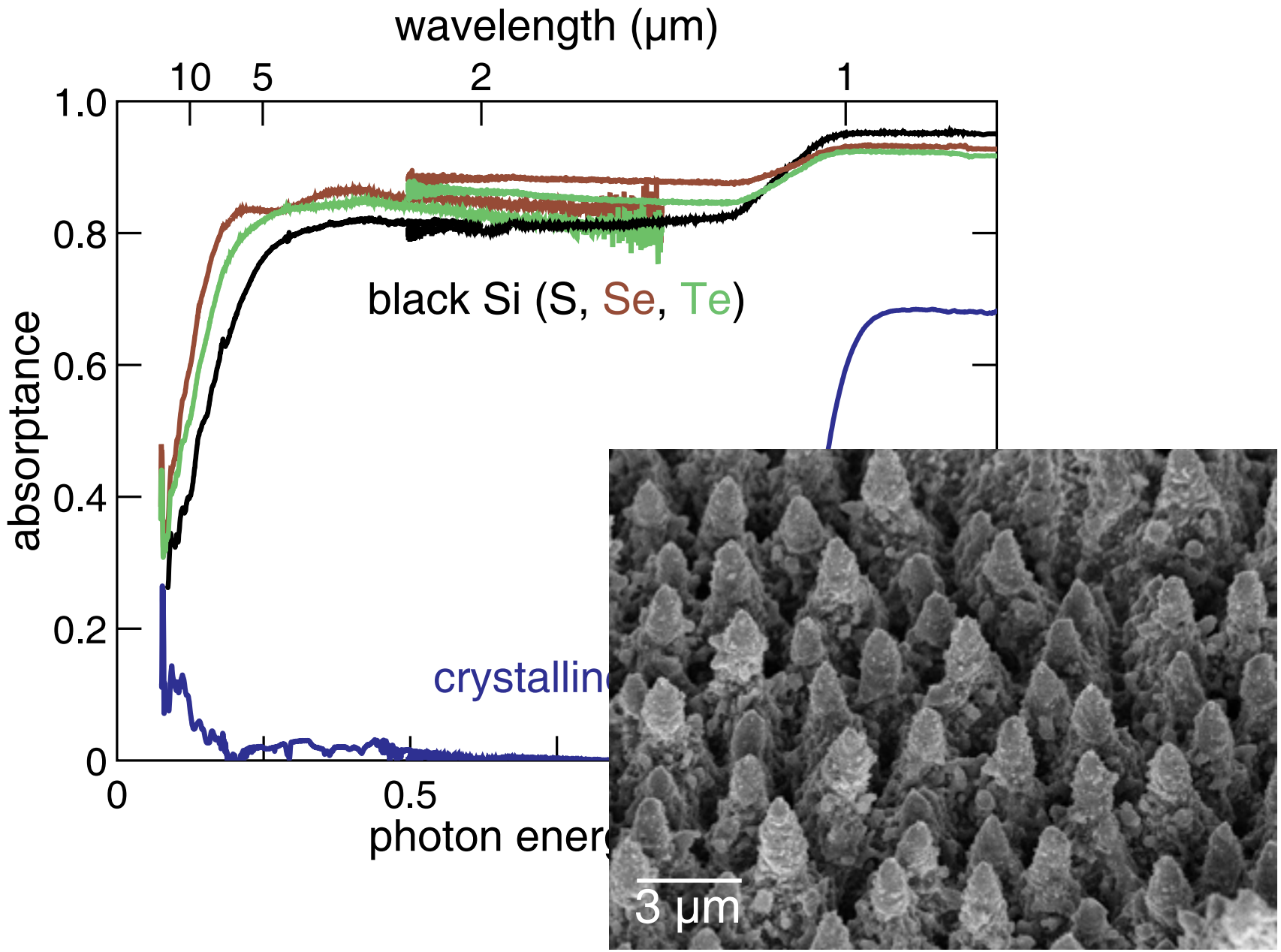

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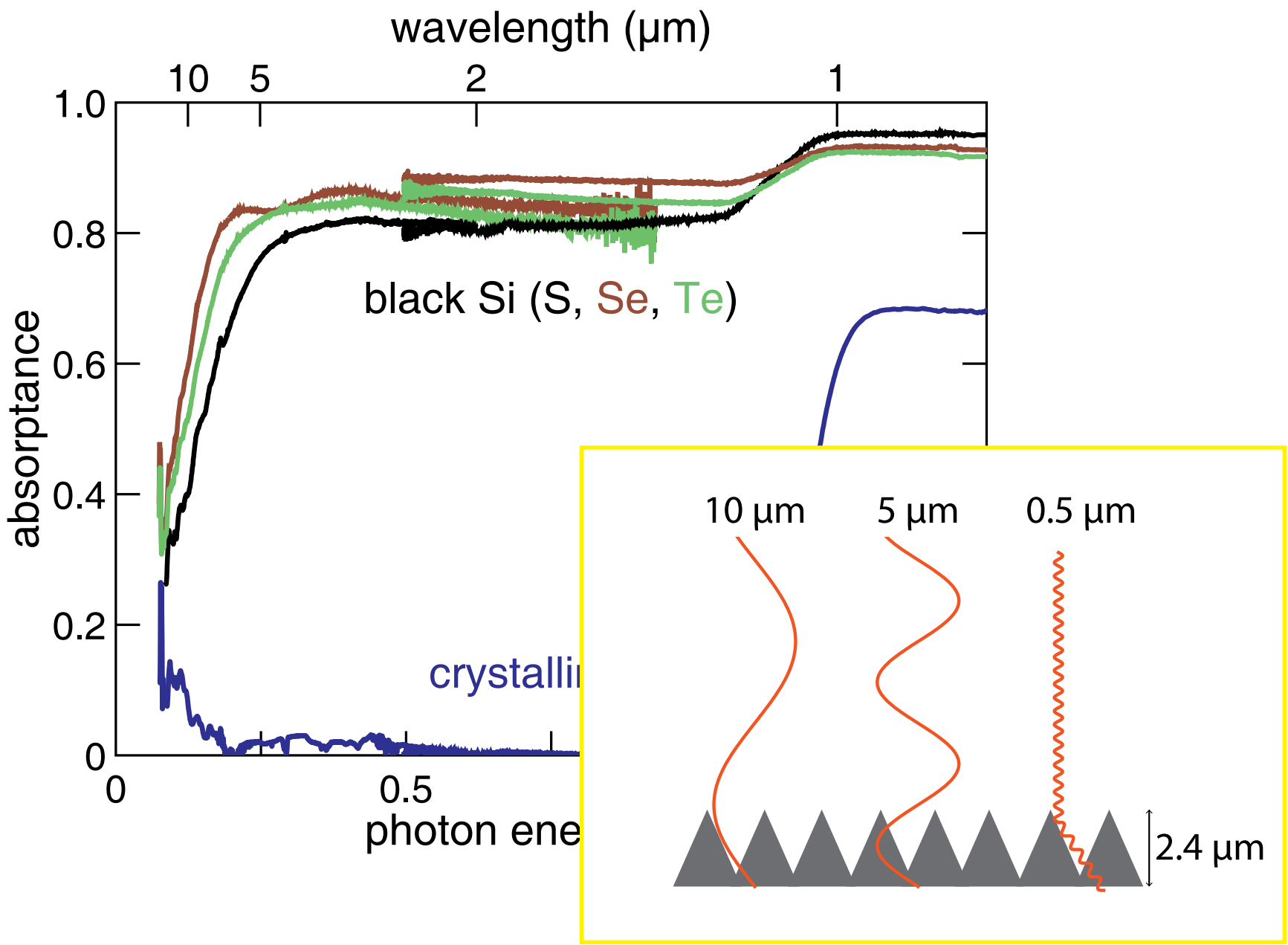
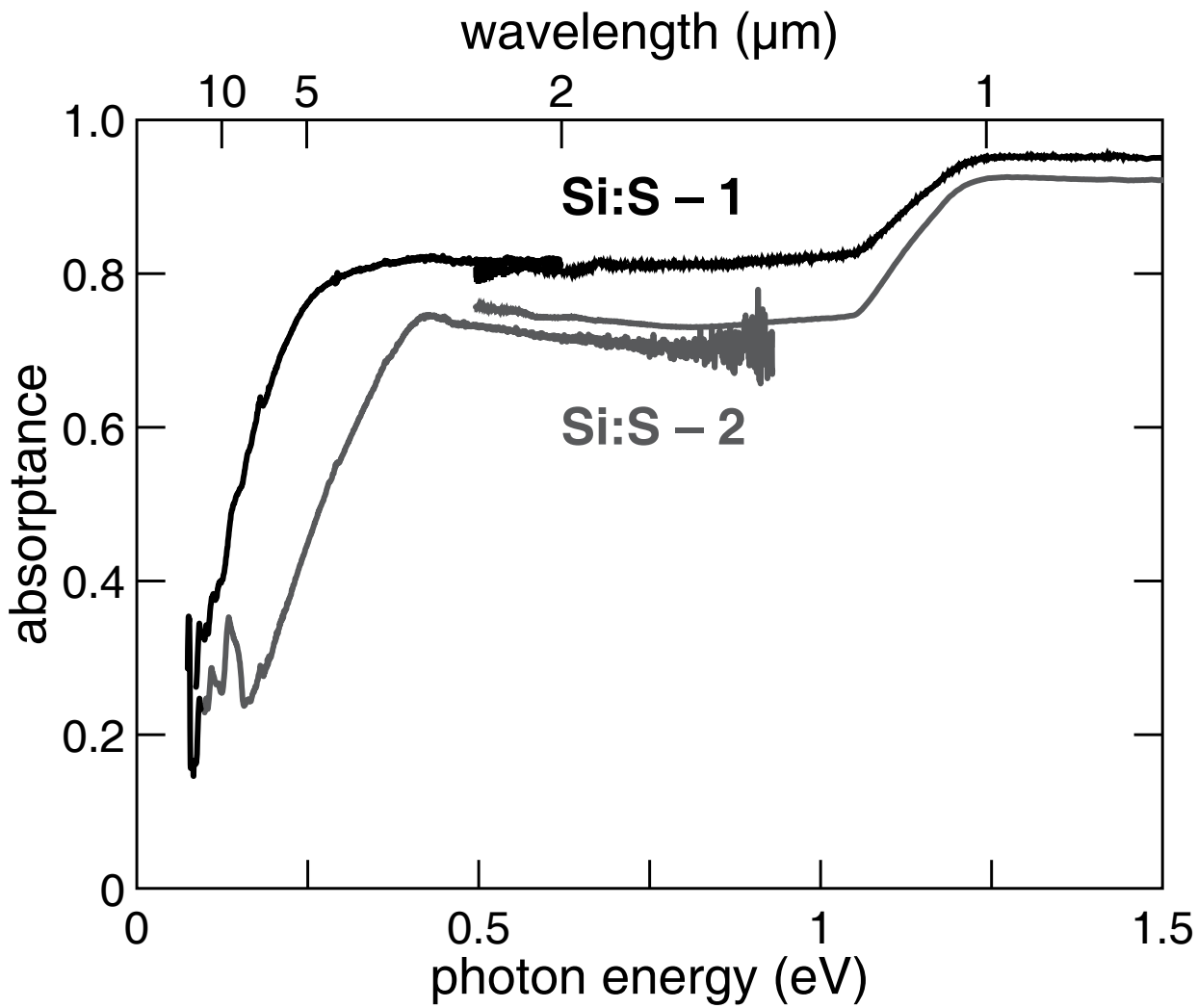
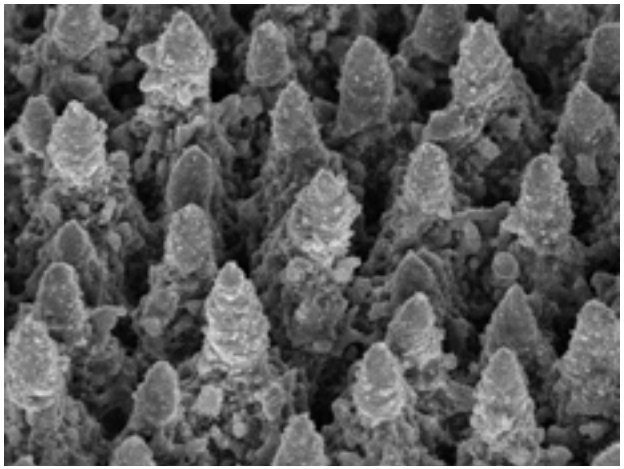


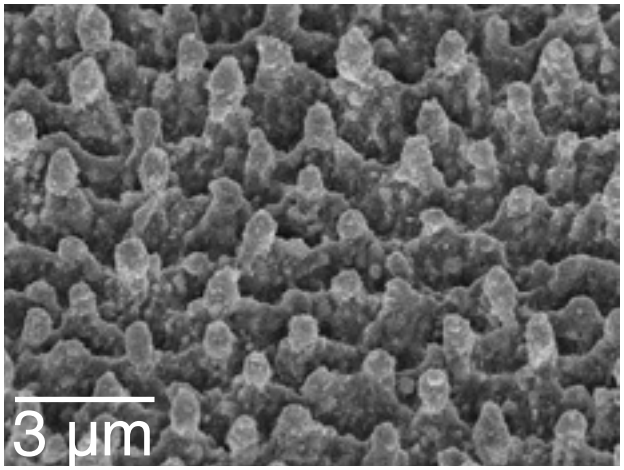
Mid-IR absorption



Si:S – 1

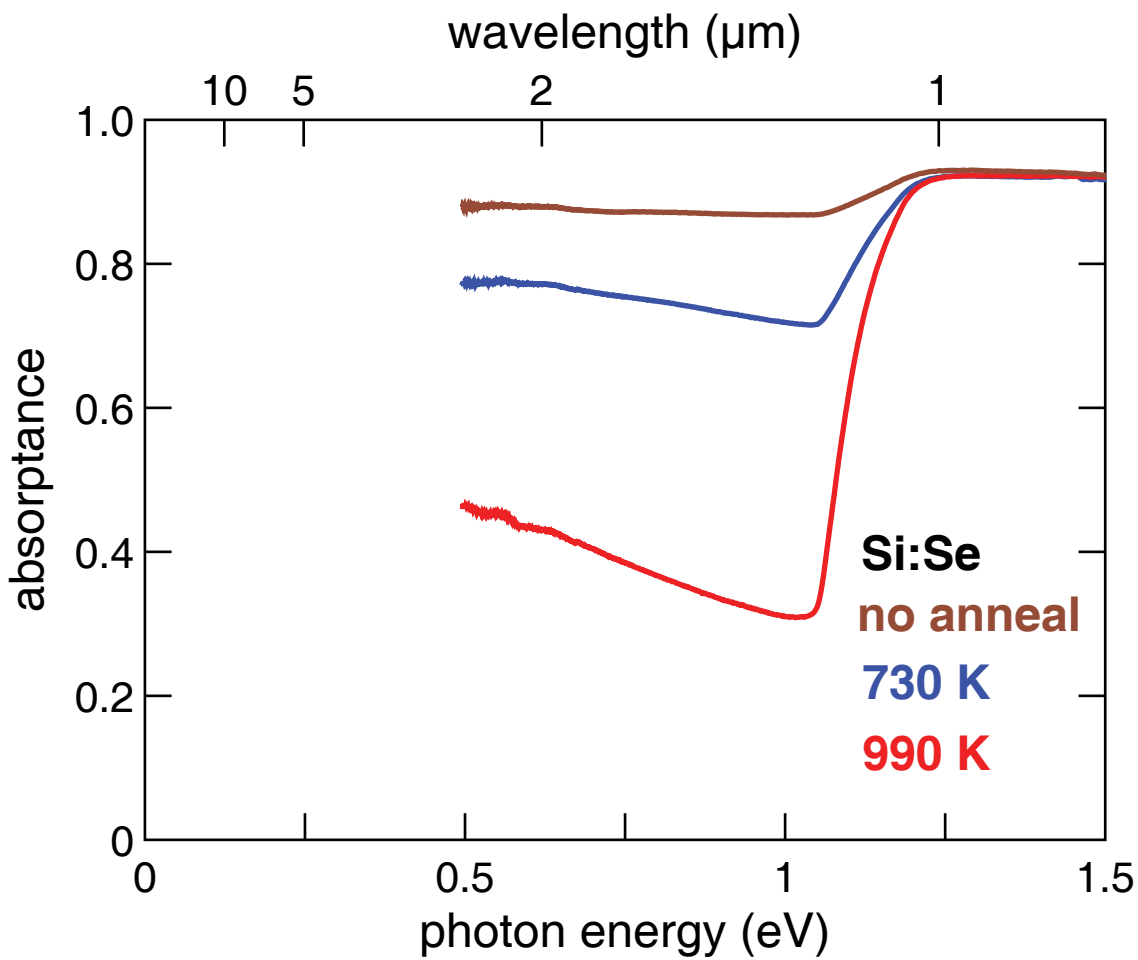


Si:S – 2

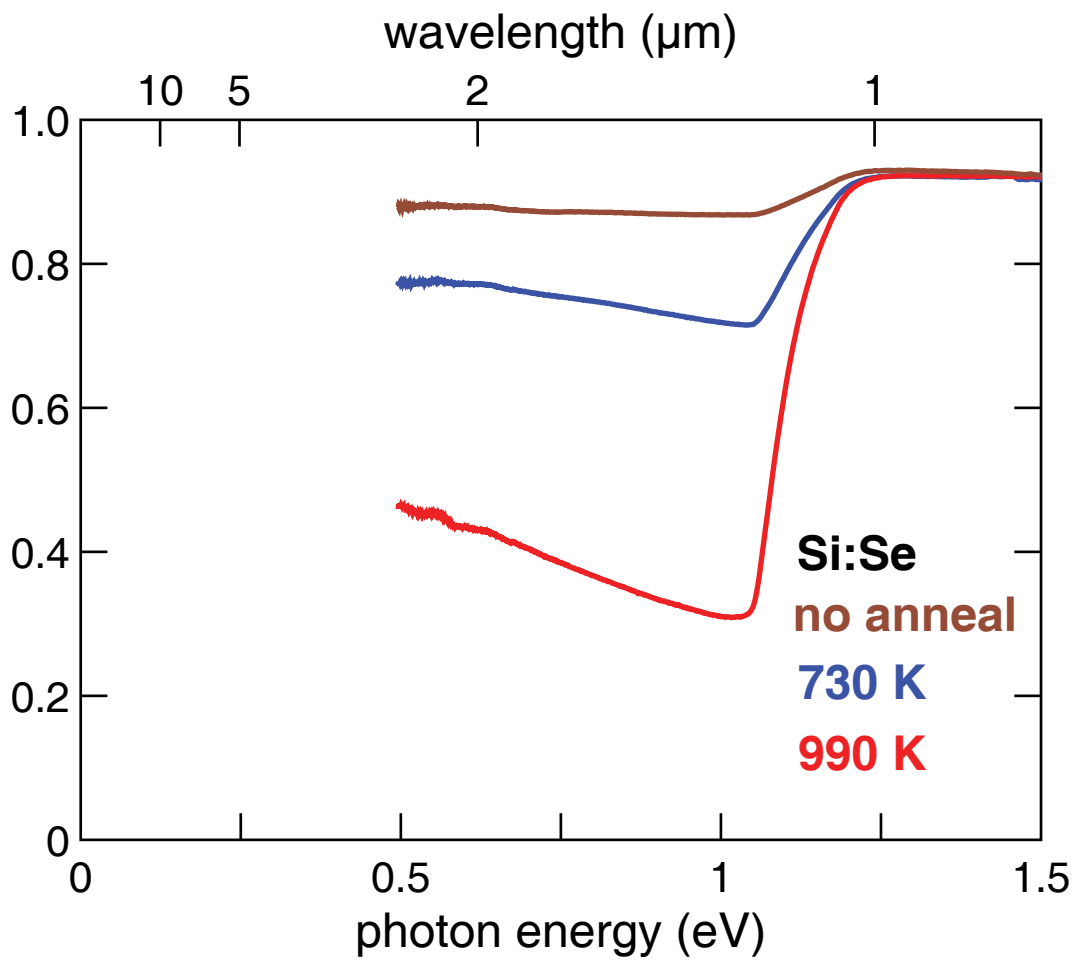


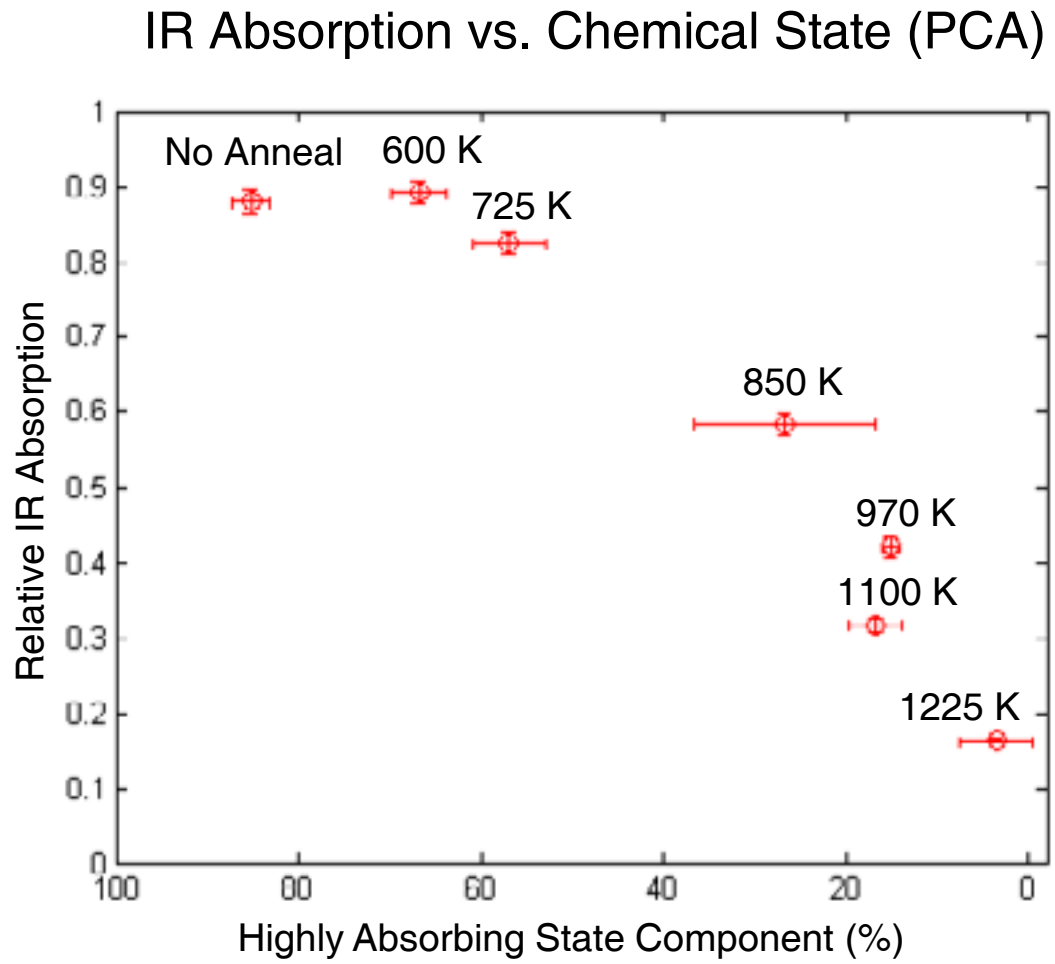
changing surface roughness

Dopant diffusion



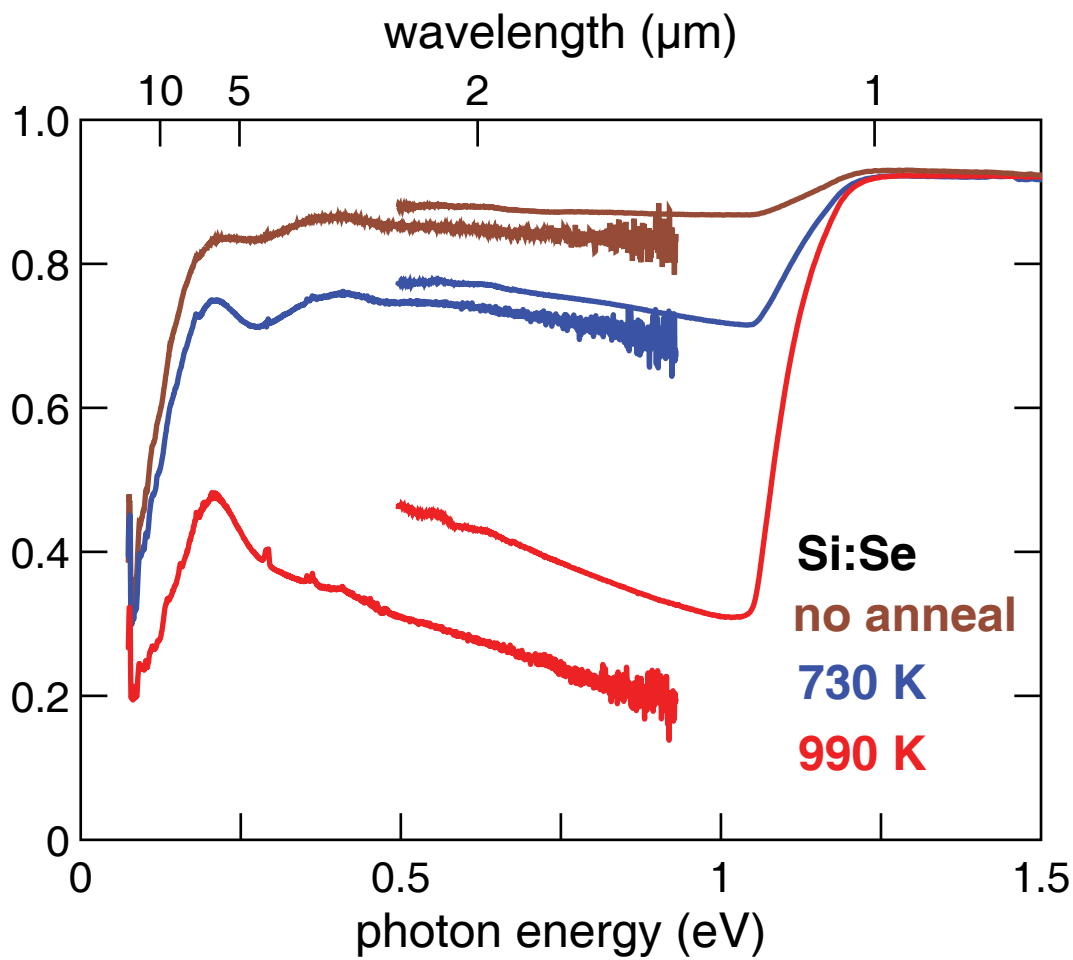
Dopant diffusion

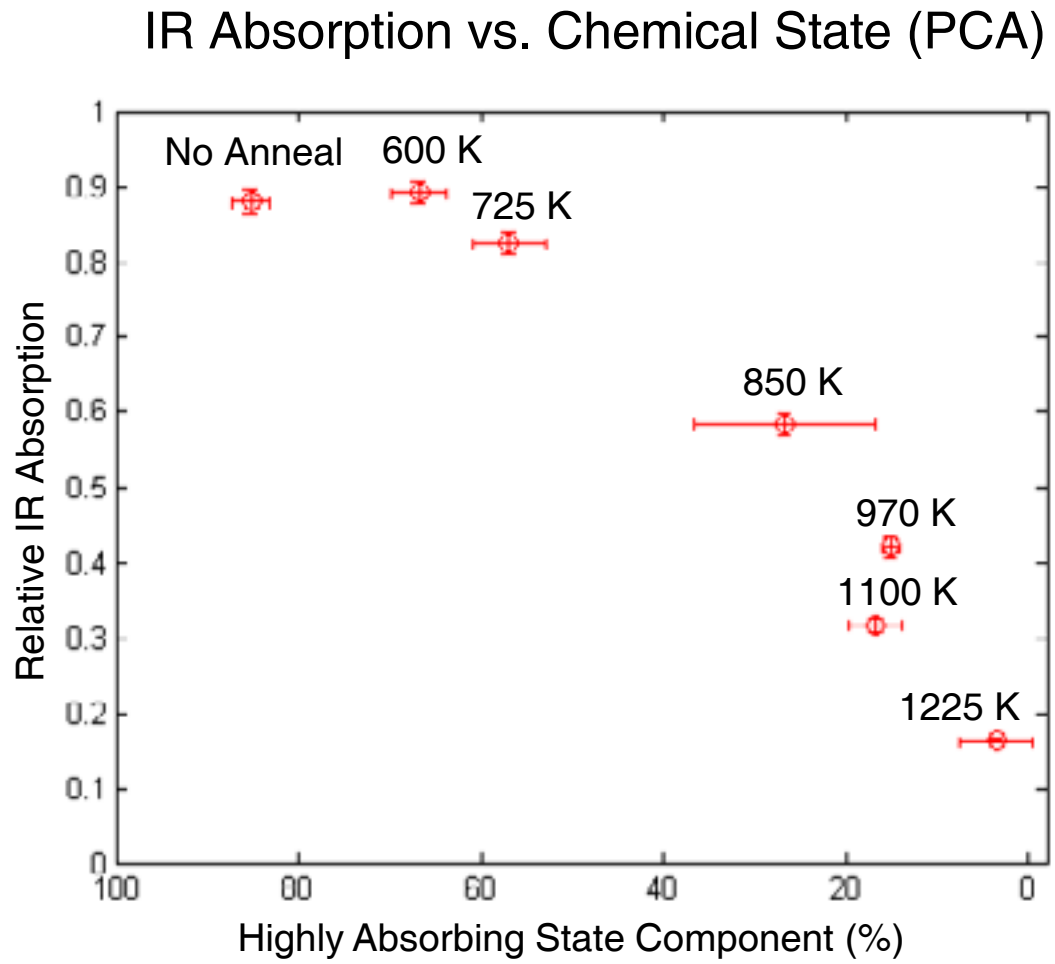




B. Newman, *et. al.*, EU-PVSEC, Hamburg, Germany (2009)

Dopant diffusion





B. Newman, *et. al.*, EU-PVSEC, Hamburg, Germany (2009)

Summary

- fs-laser hyperdoping and texturing
  - light trapping surface
  - non-equilibrium concentration of dopant in Si
- potential application for IBPV
- IR absorption
  - broadband absorption > 2.5 μm
  - surface morphology
  - dopant diffusion/precipitation

3 μm

Thanks!


DUKE
MOLSON EX
Harvard University
Center for
Nanoscale
Systems
NSF
MZR
GROUP

Thanks!

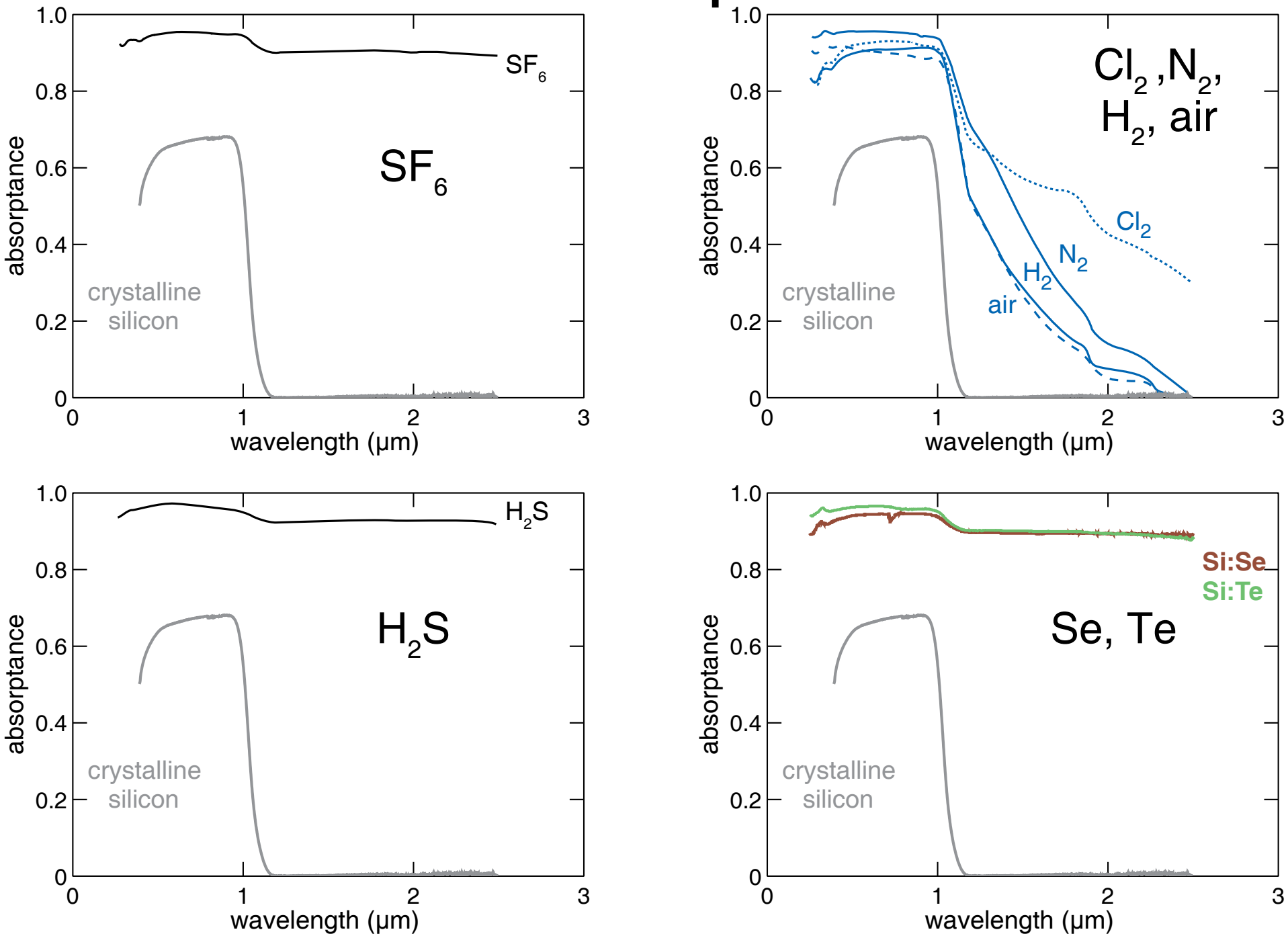
Questions?

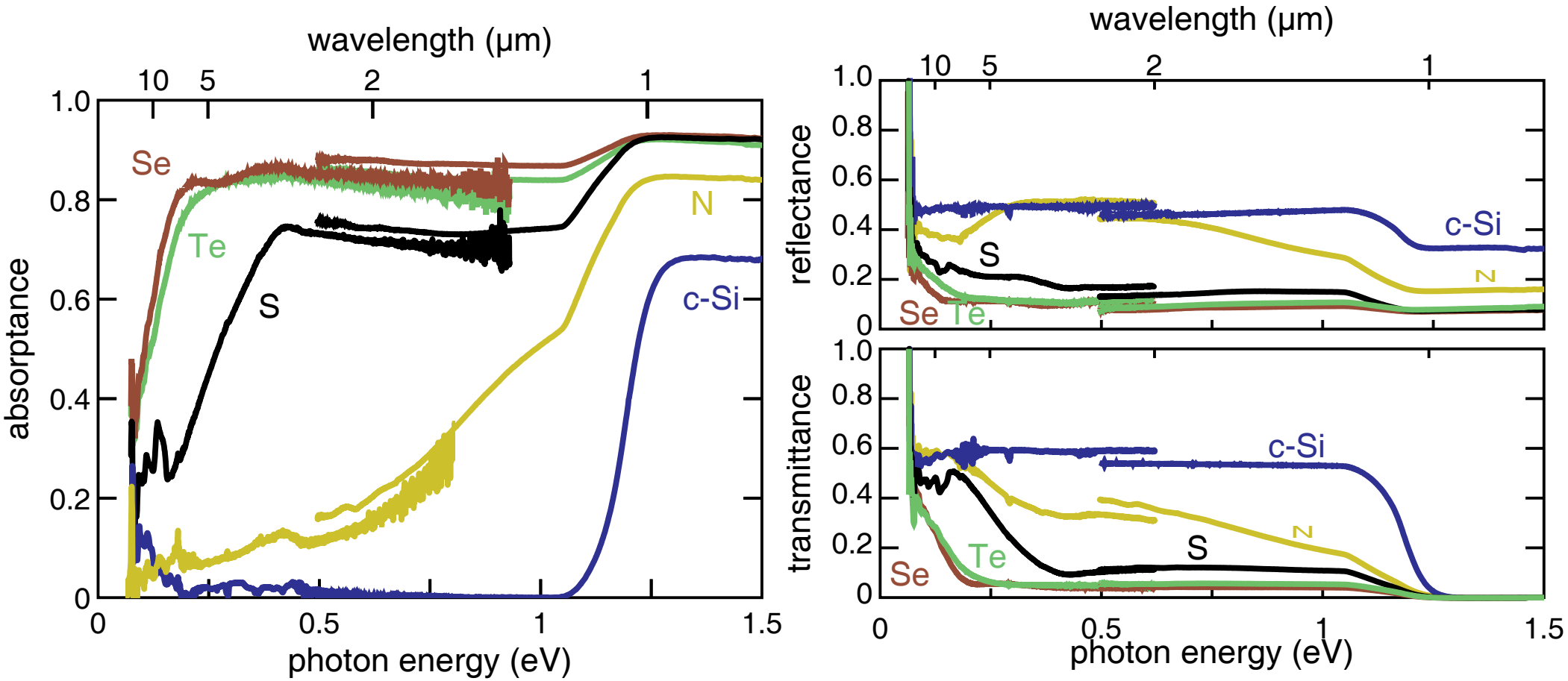
sher@physics.harvard.edu
http://mazur-www.harvard.edu/

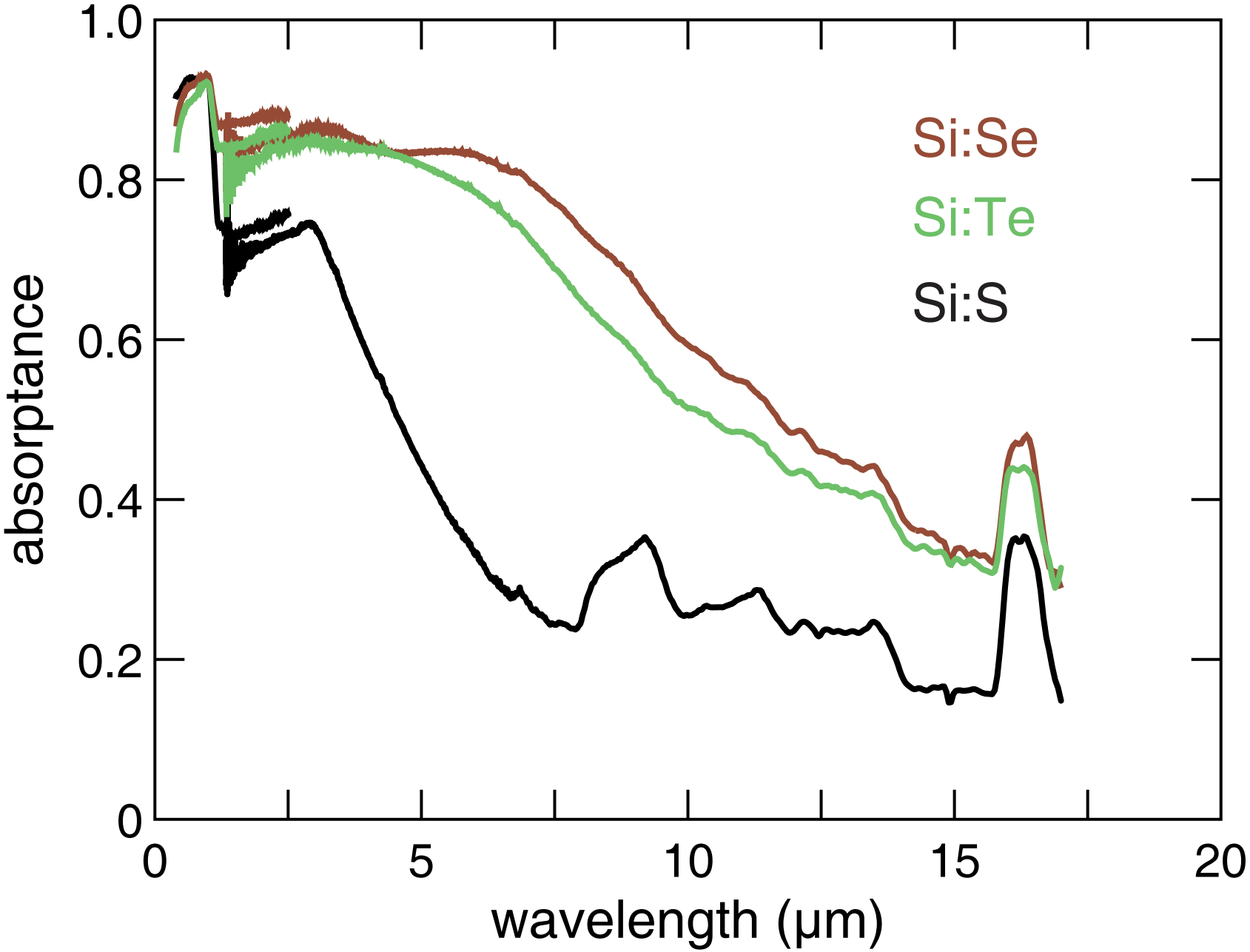
Harvard University
Center for Nanoscale Systems

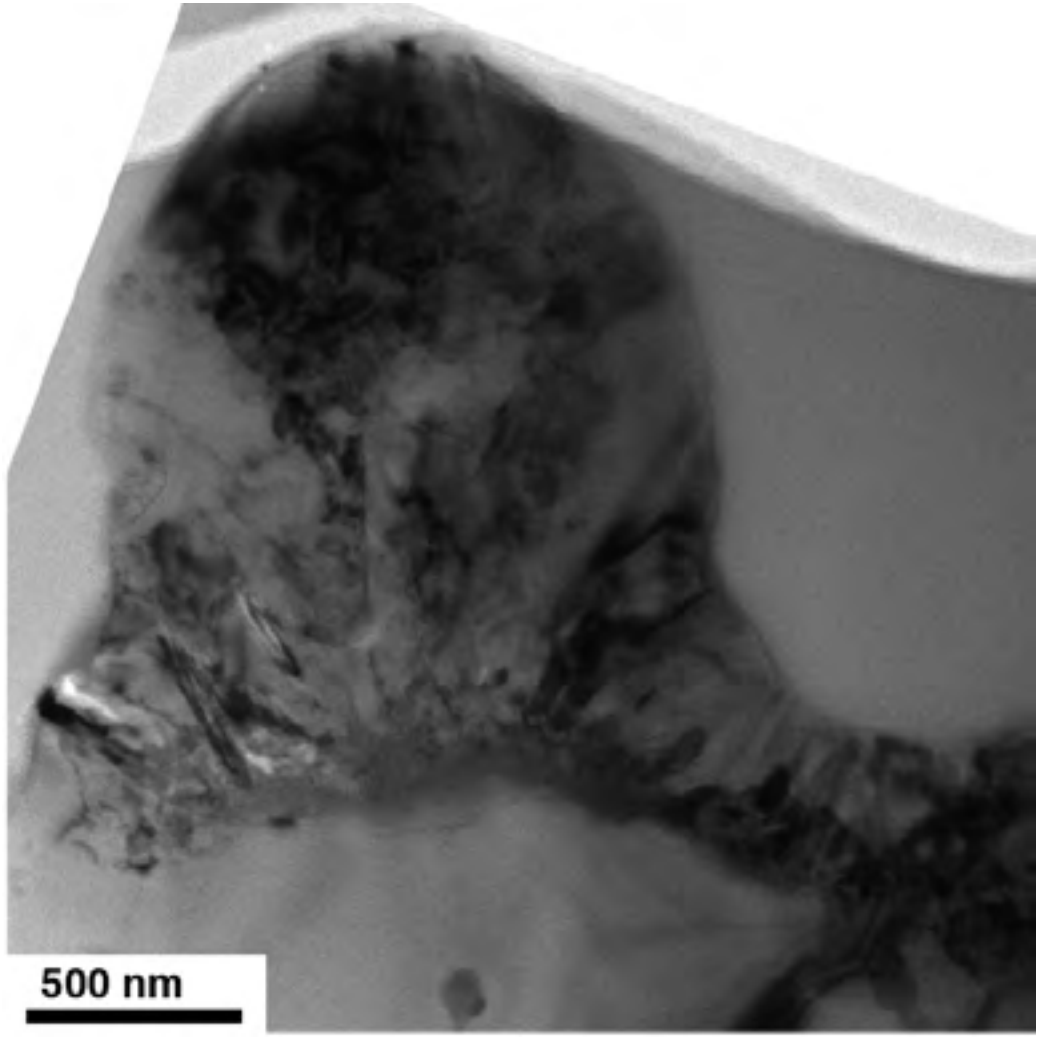
MAZUR GROUP

IR absorption



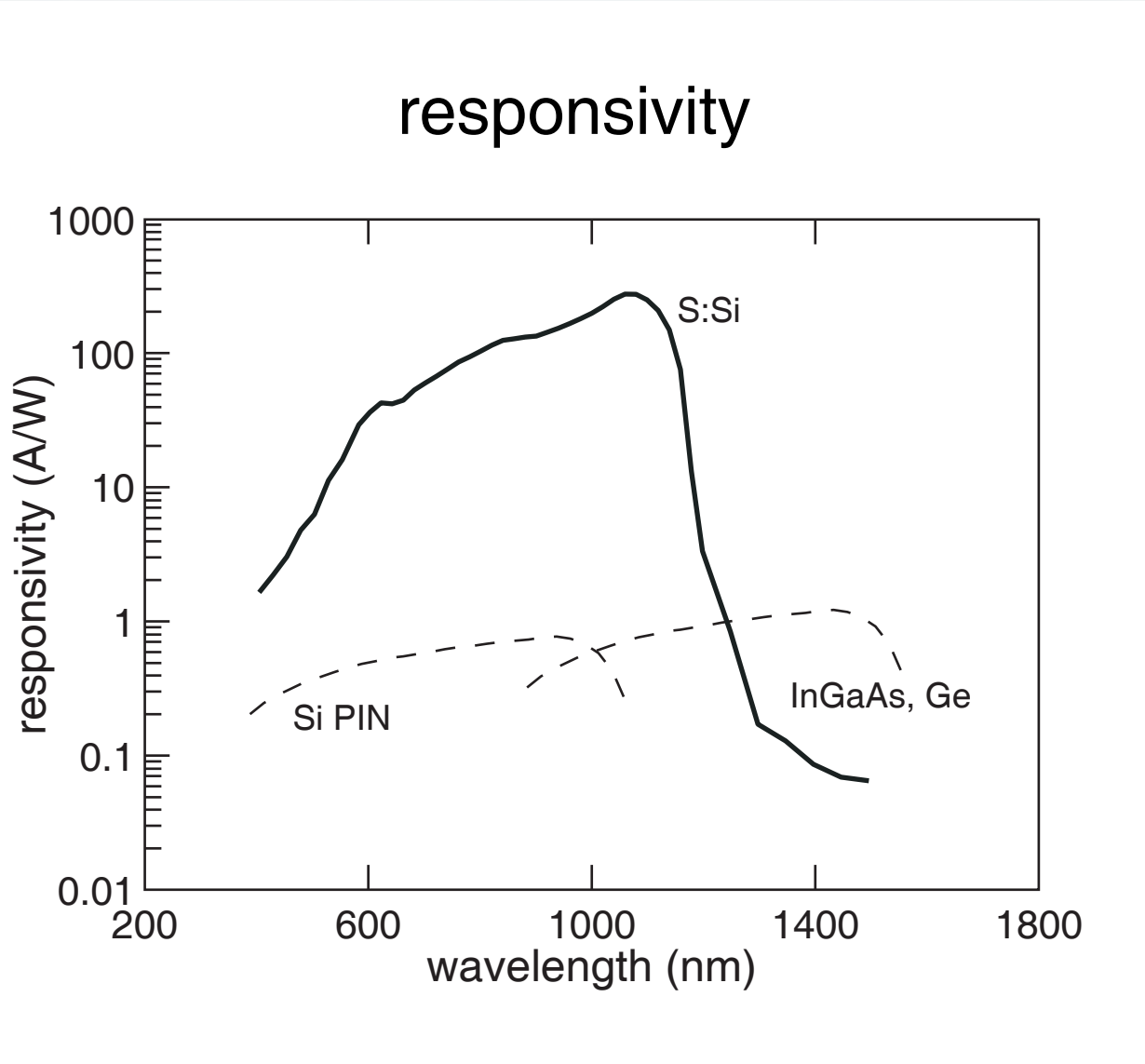

wavelength (μm)
10
5
2
1
absorptance
Se
Te
S
N
c-Si
photon energy (eV)
0
0.5
1
1.5
reflectance
transmittance

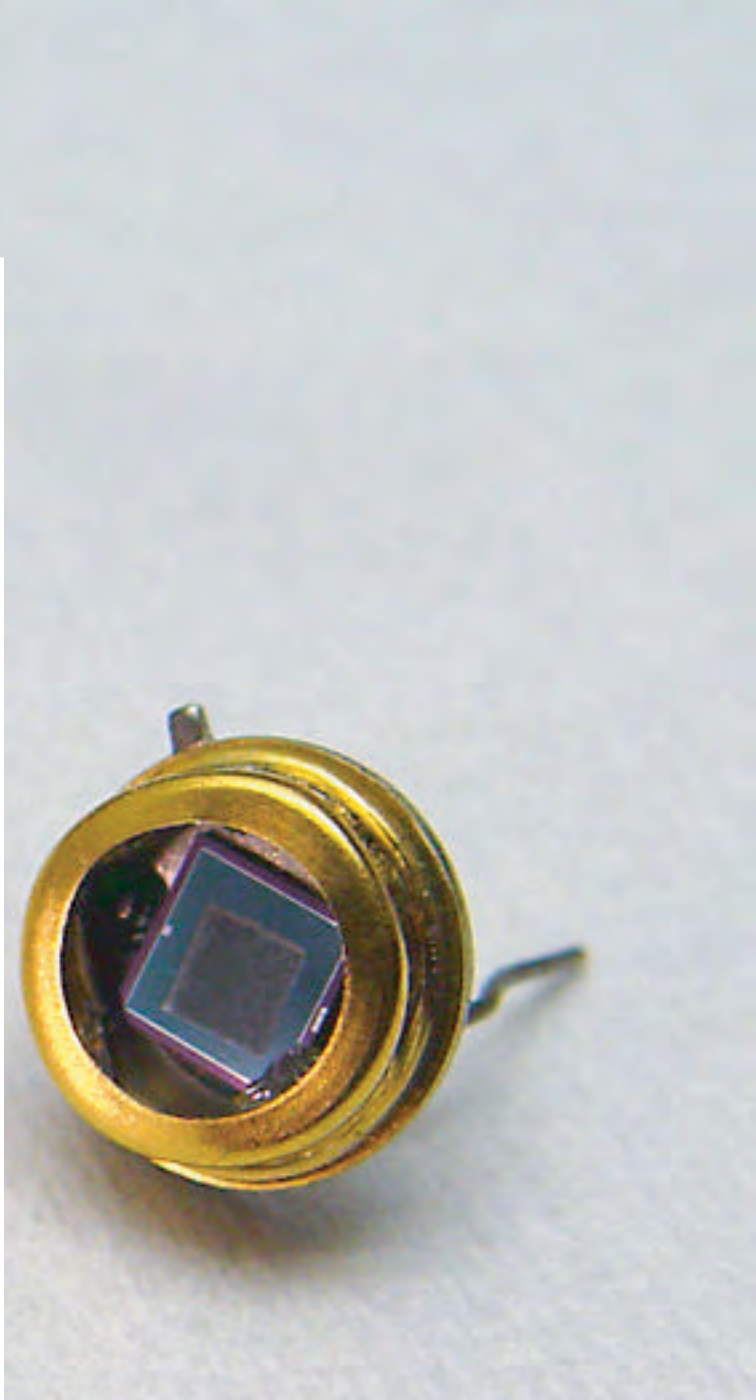

1.0
0.8
0.6
0.4
0.2
0
absorptance
0
5
10
15
20
wavelength (μm)
Si:Se
Si:Te
Si:S



TEM Si:Se

Smith *et al.* accepted for publication





Carey *et al.* Opt. Lett., 30, 1773-1775 (2005)