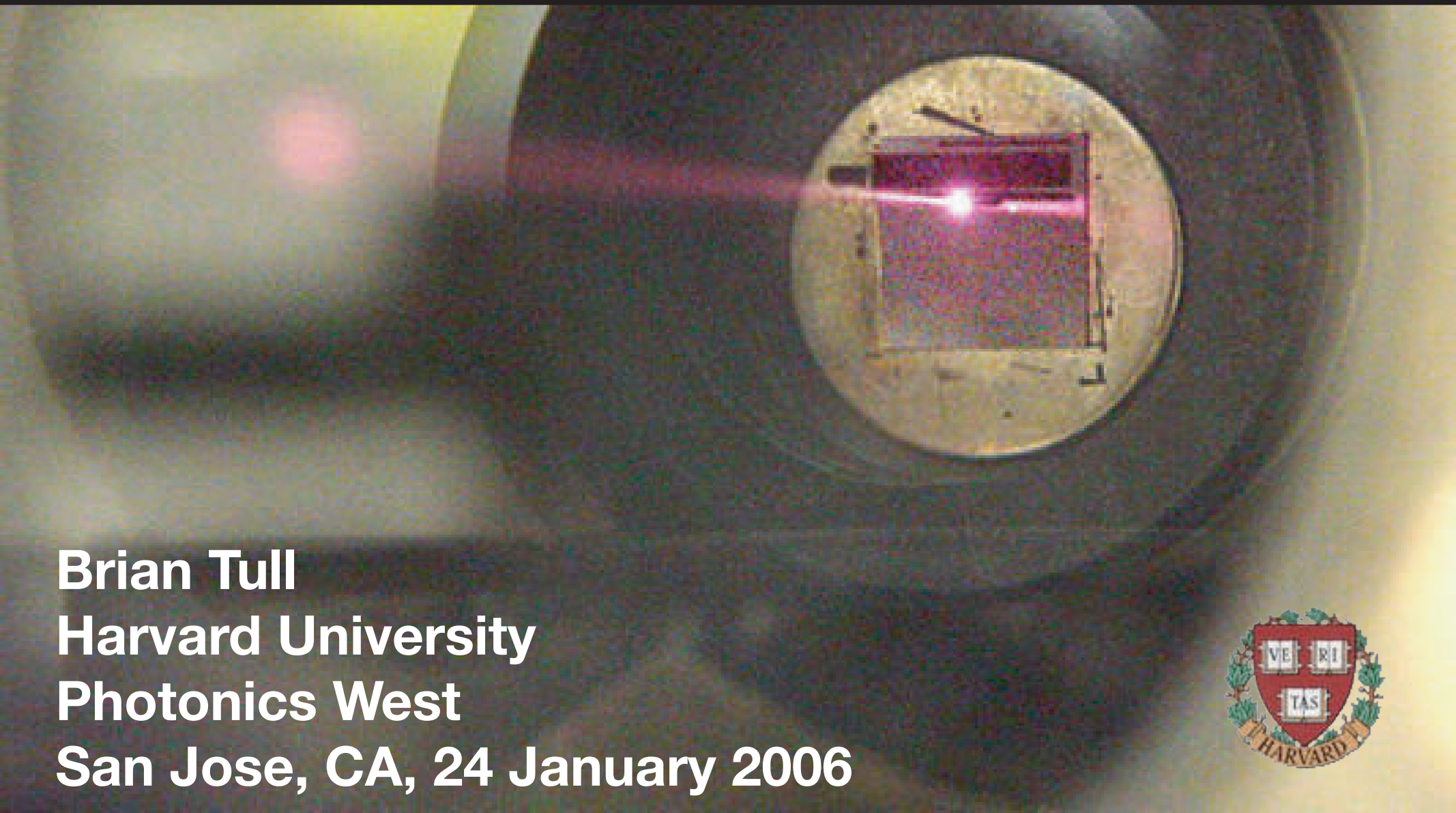
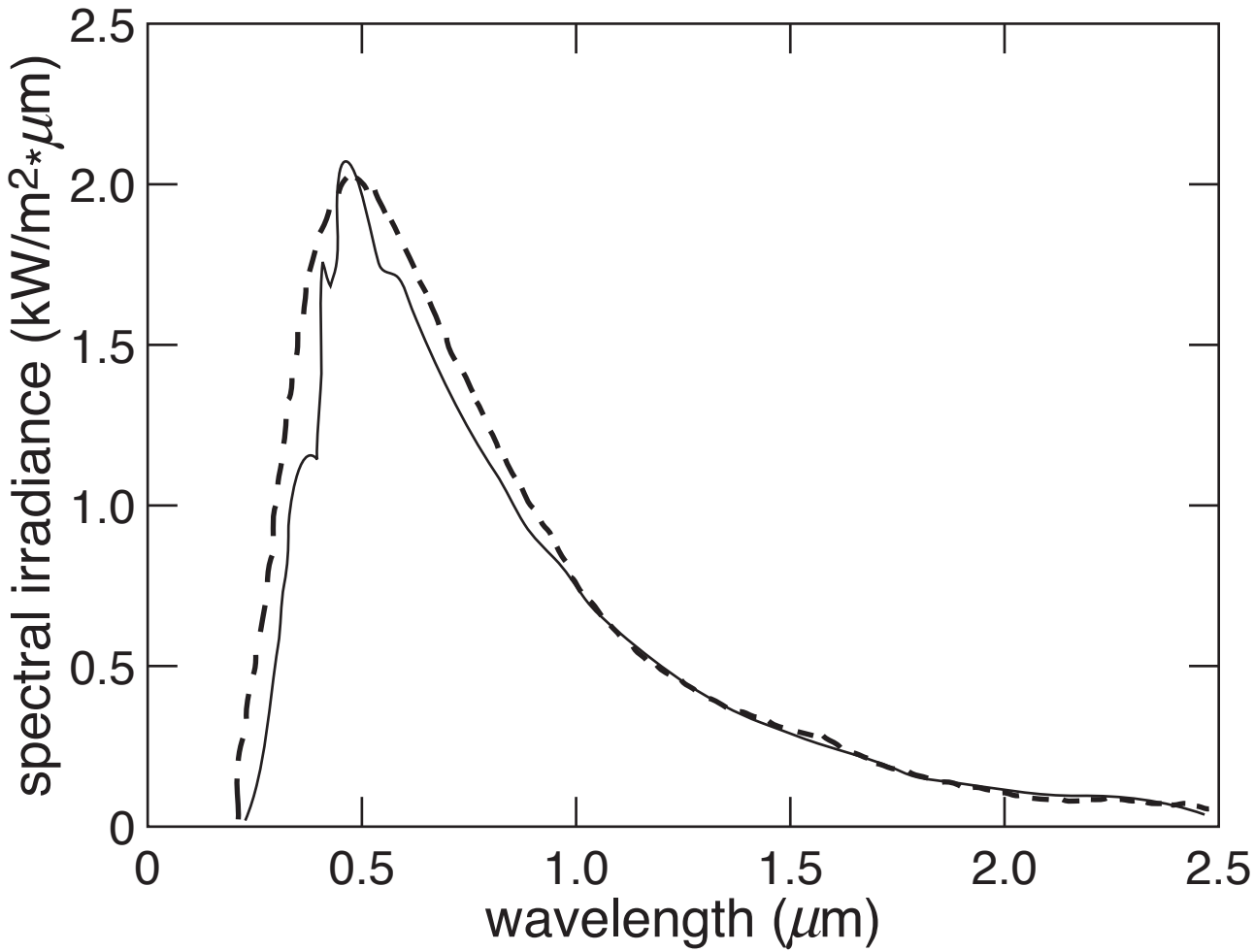
Femtosecond-laser microstructuring of silicon for novel photovoltaic devices



Brian Tull
Harvard University
Photonics West
San Jose, CA, 24 January 2006

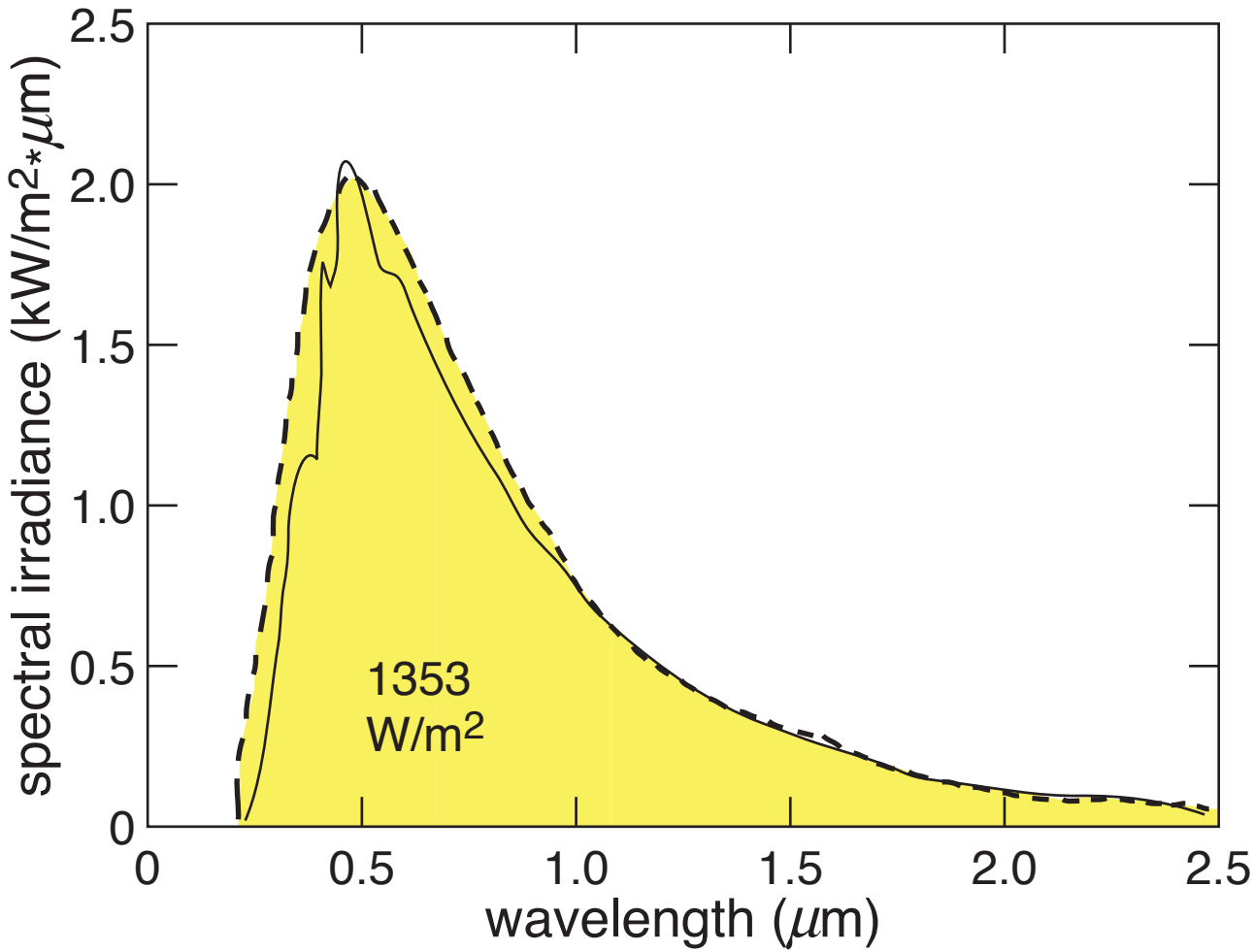
Motivation

solar spectrum



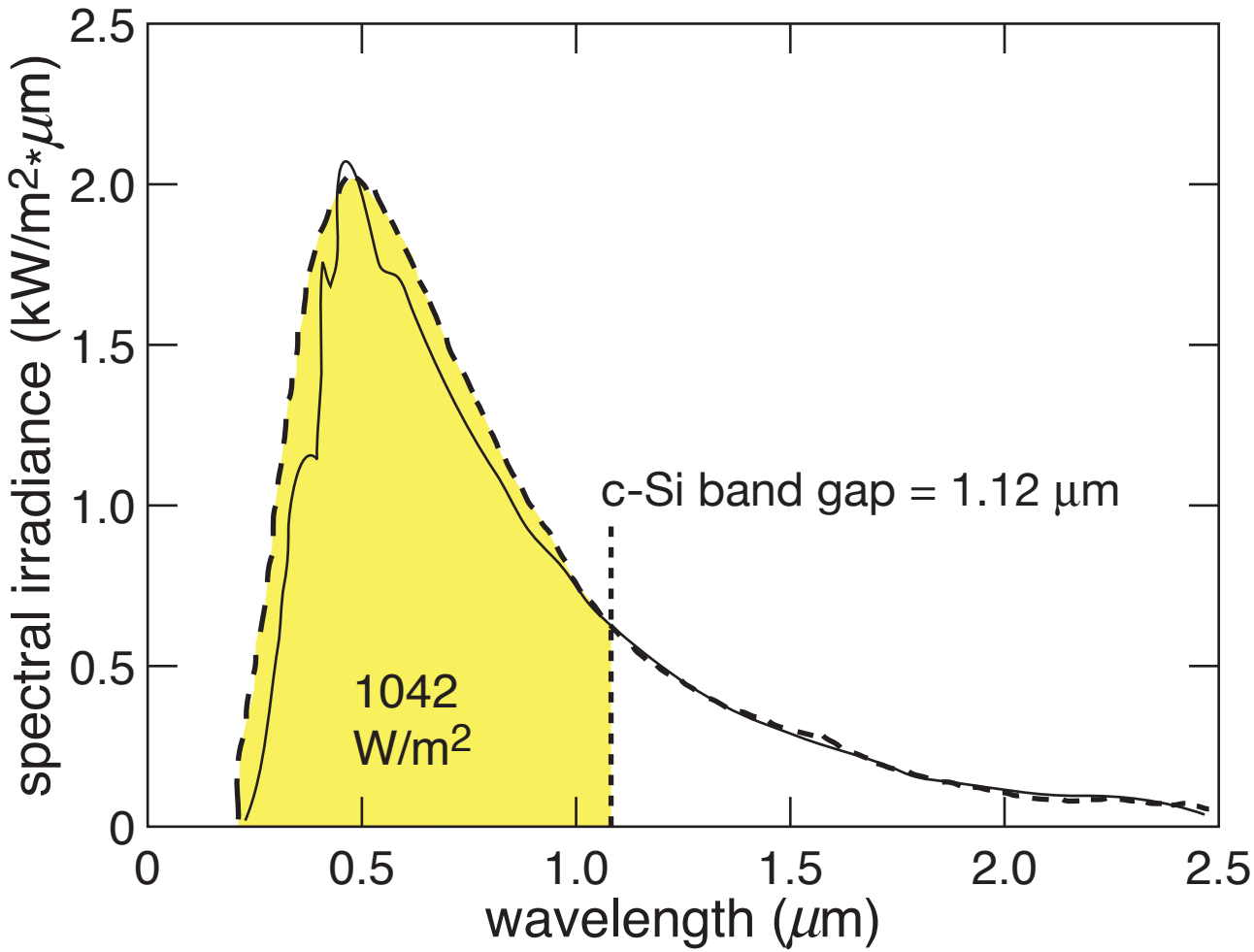
Motivation

solar spectrum



Motivation

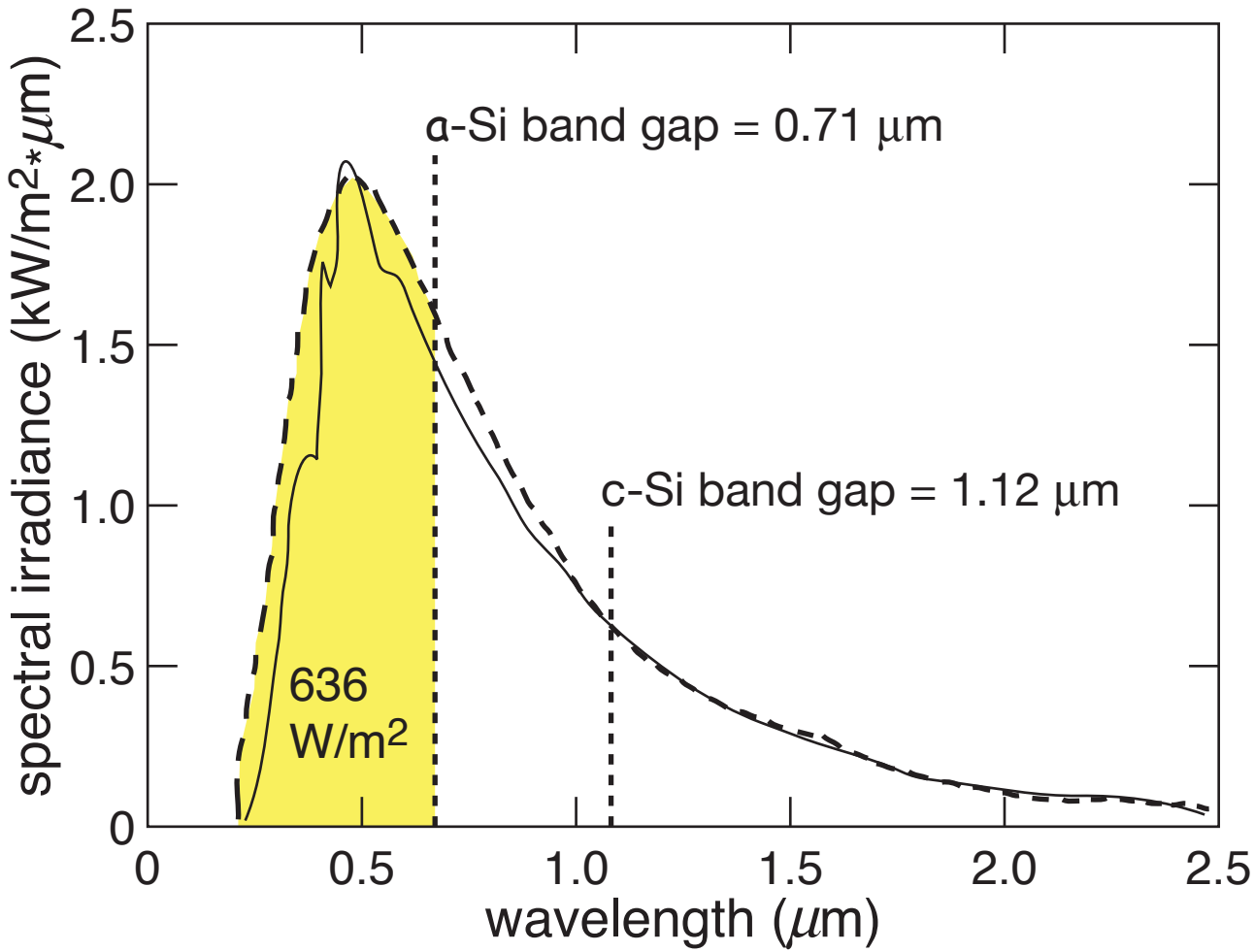
solar spectrum



crystalline silicon: transparent to **23%** of sun's energy

Motivation

current silicon-based solar cells cannot absorb all available energy



amorphous silicon: transparent to **53%**

crystalline silicon: transparent to **23%** of sun's energy

Outline

femtosecond-laser structuring process

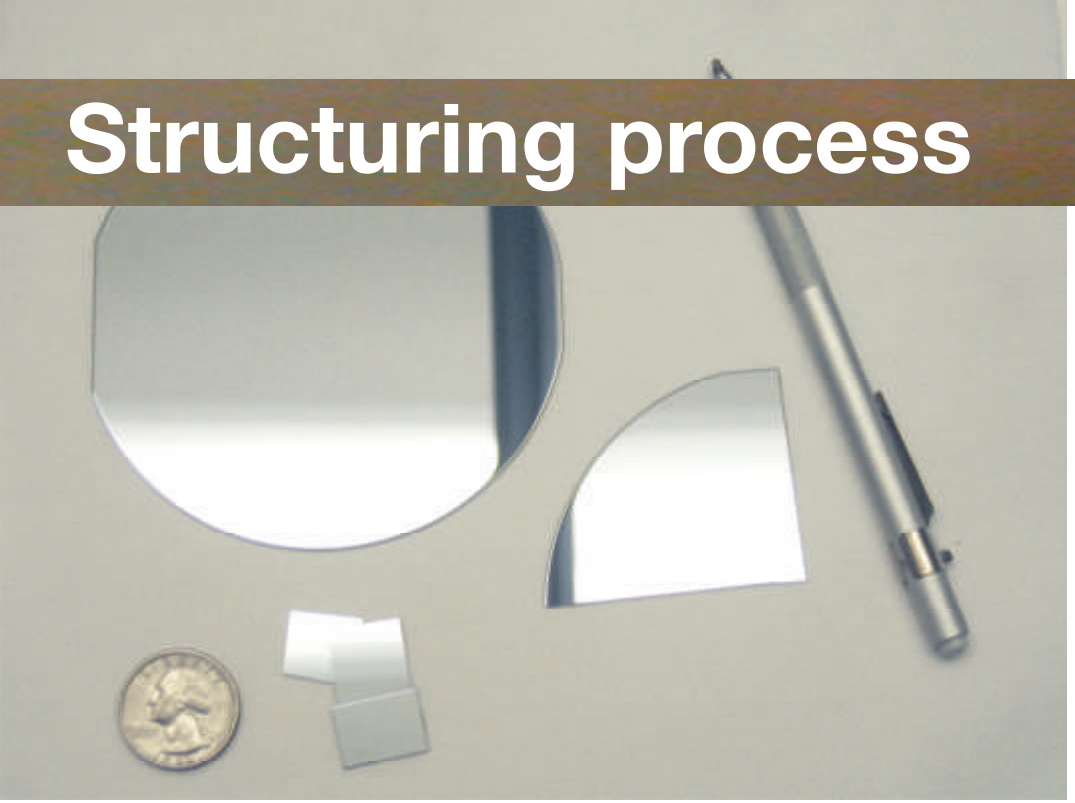
material properties

solar cell results on crystalline silicon wafers

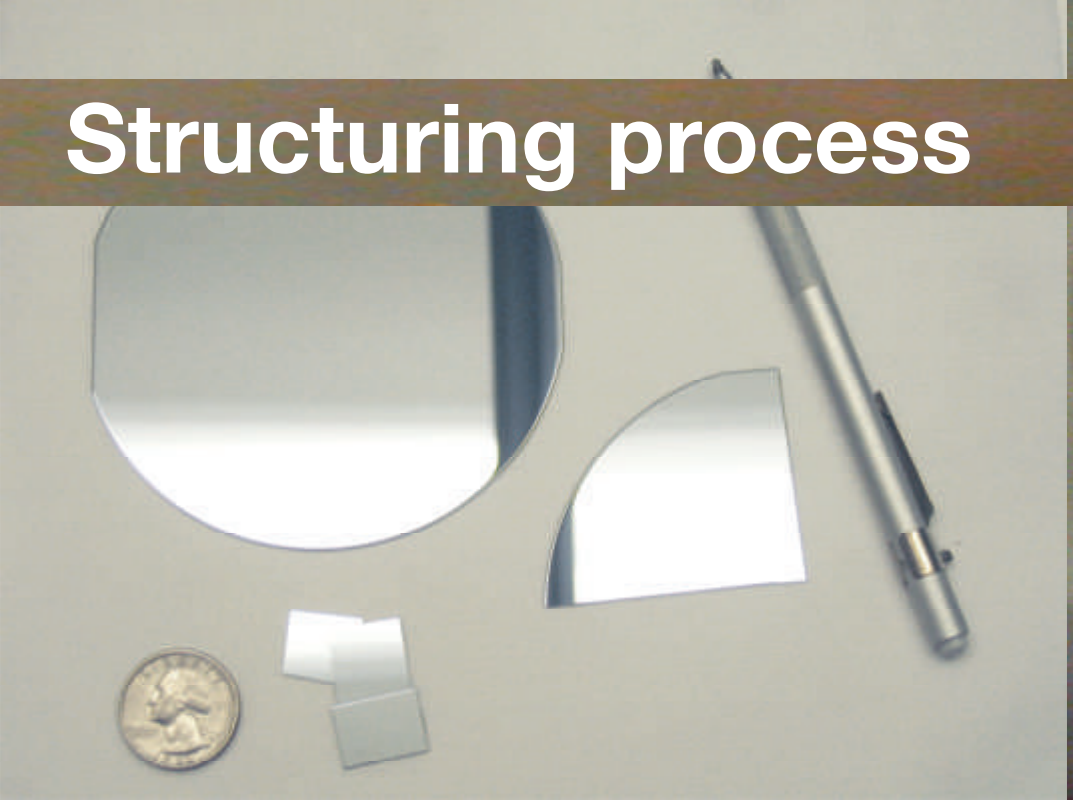
thin-film silicon results

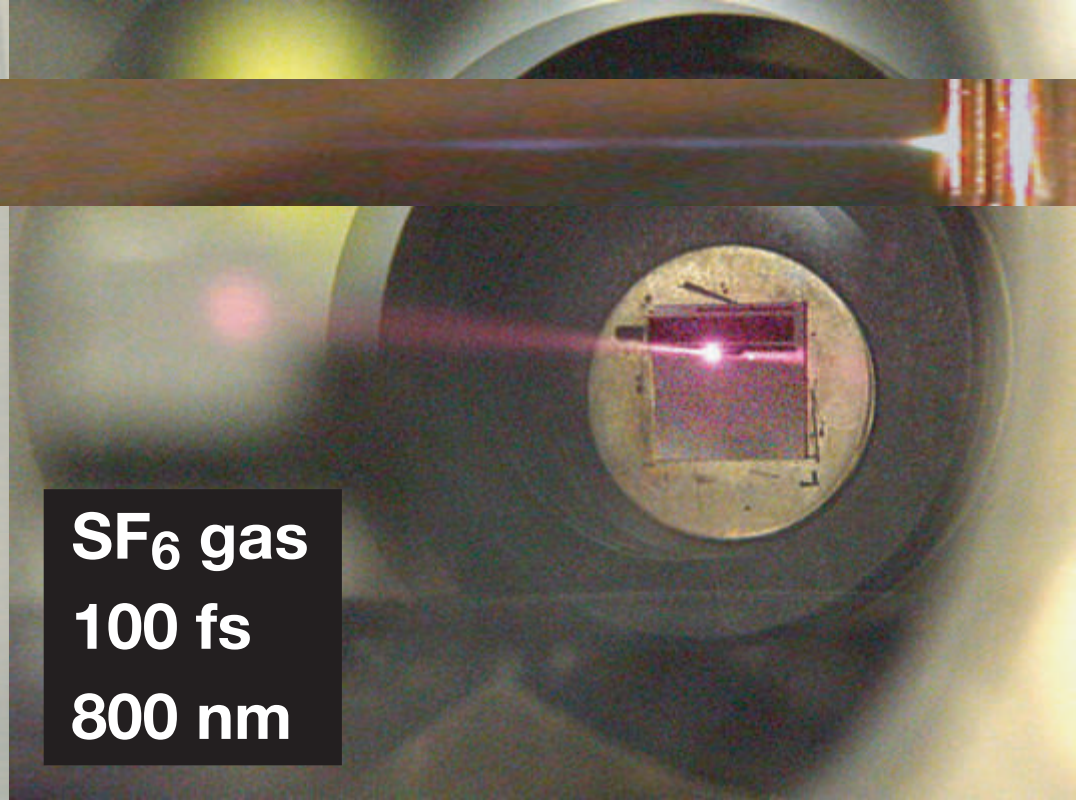
outlook

Structuring process



Structuring process





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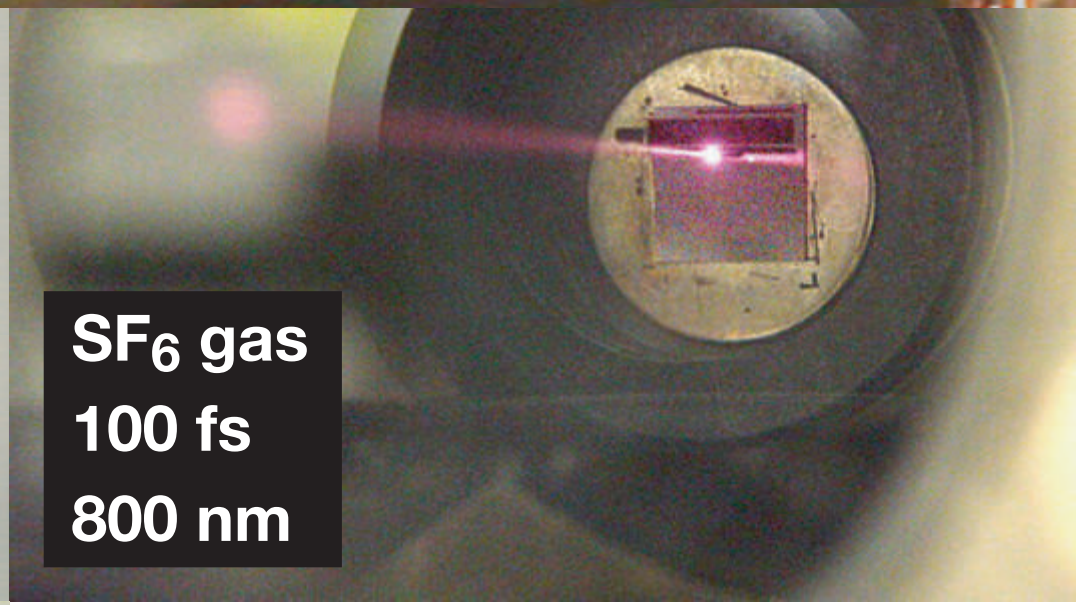
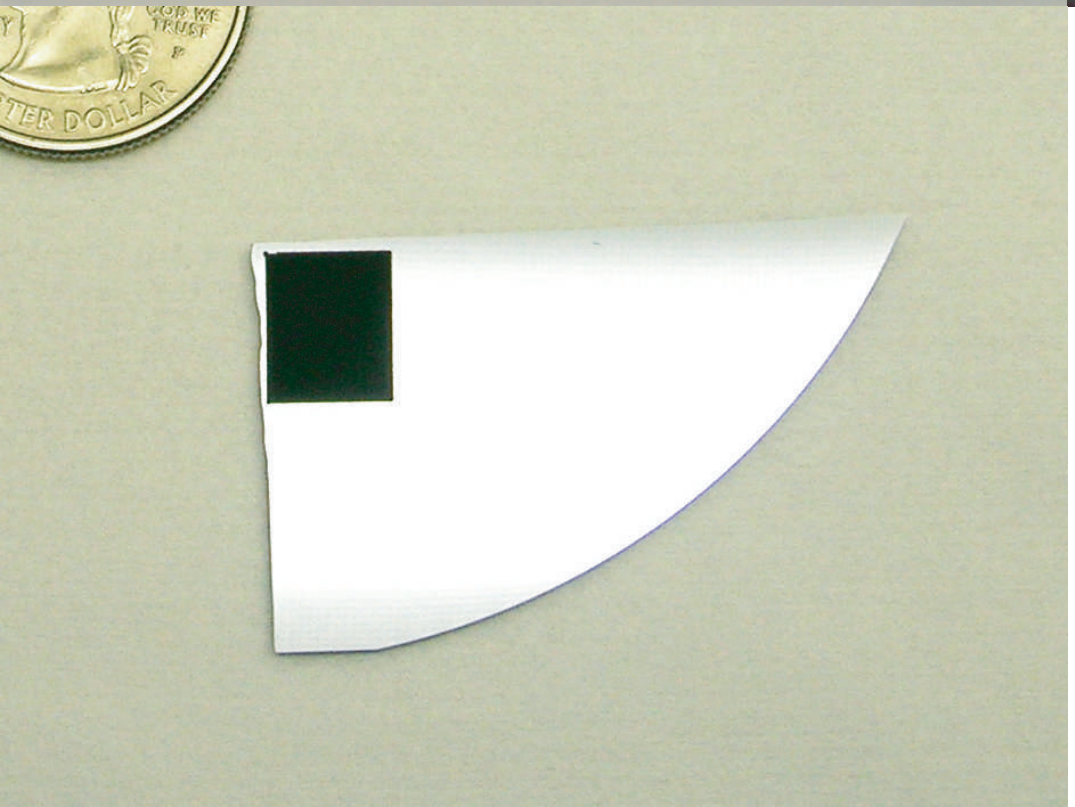
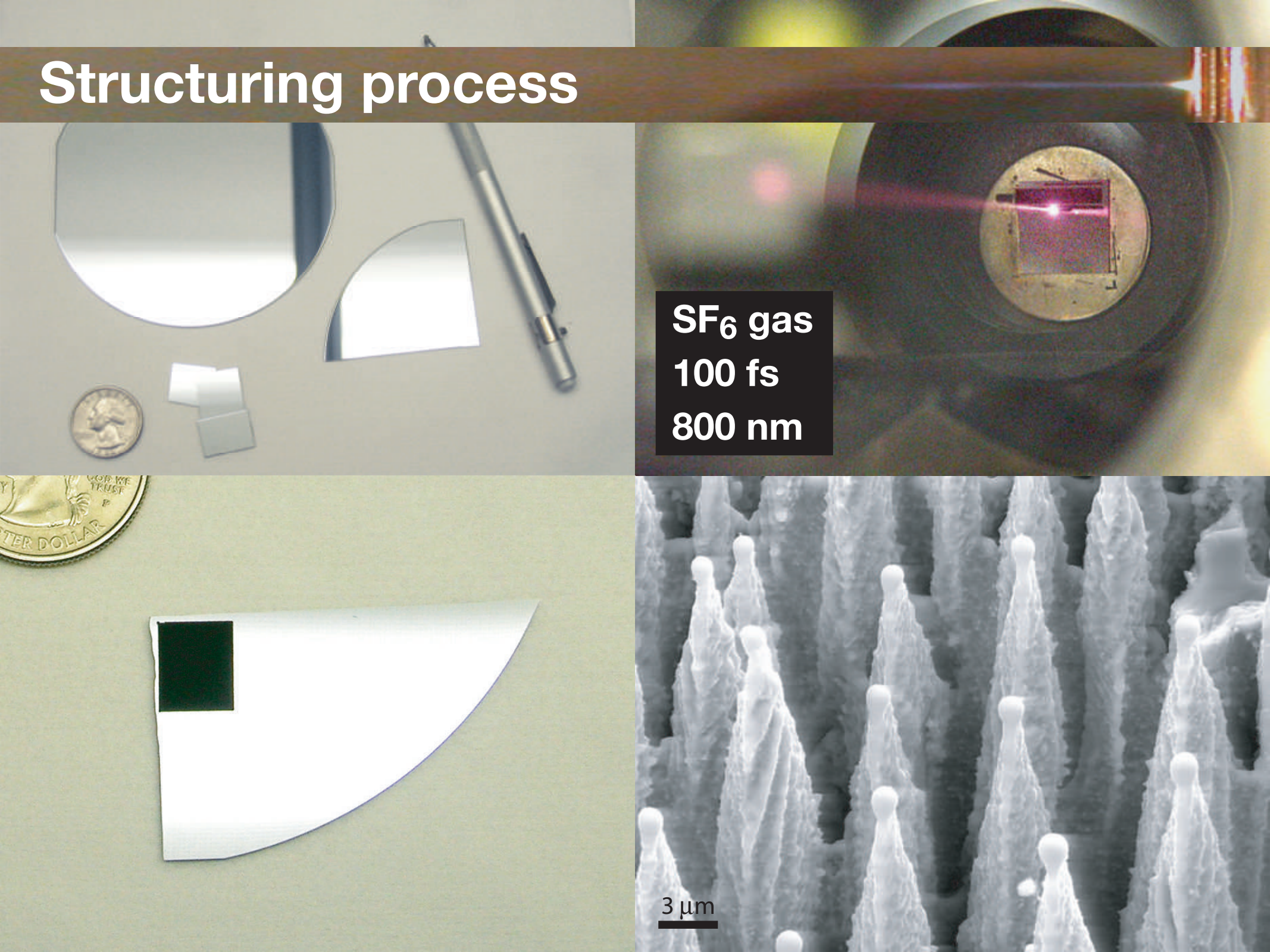




Structuring process



Material properties

Material properties

absorptance: $A = 1 - (T + R)$

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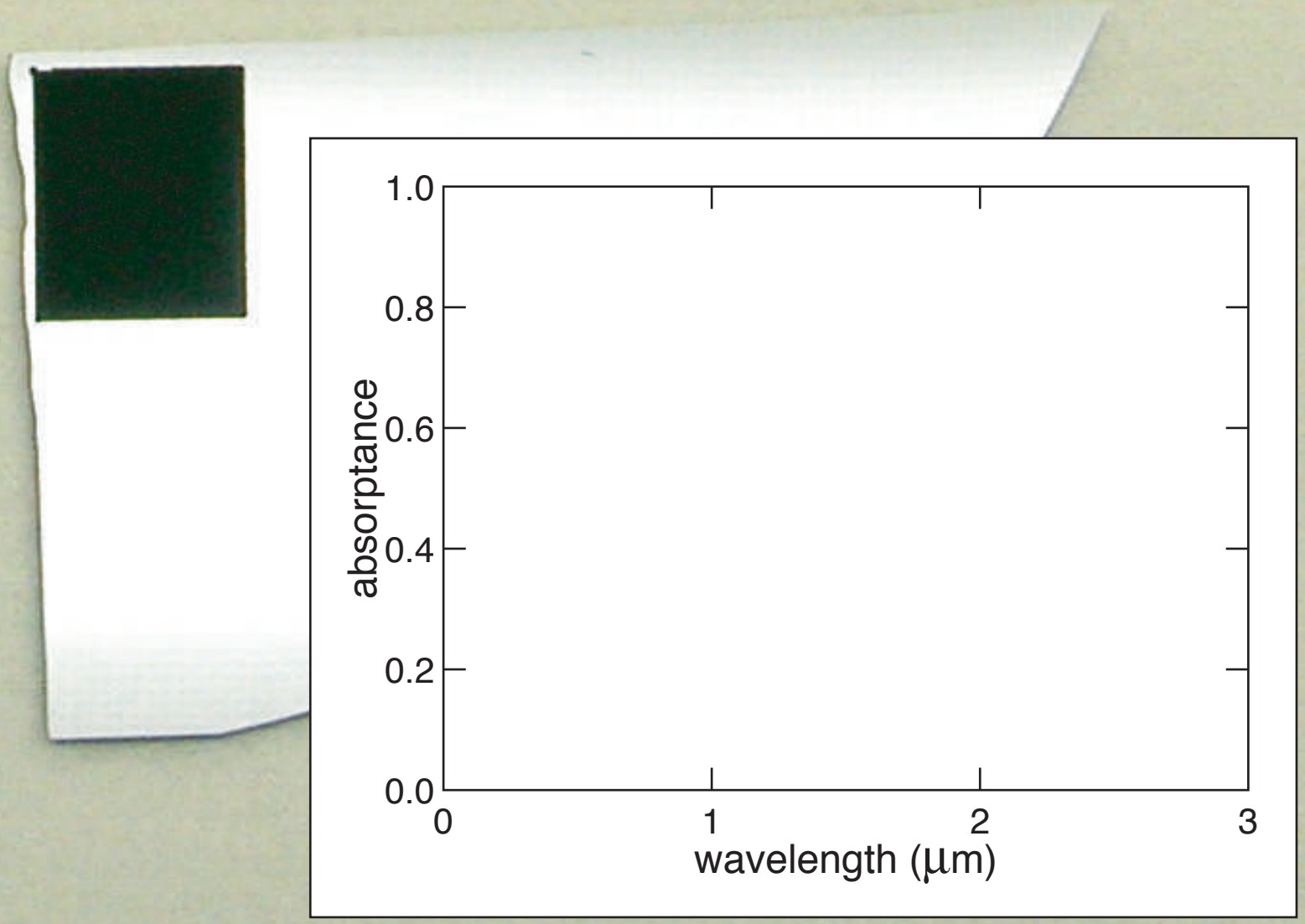

Material properties

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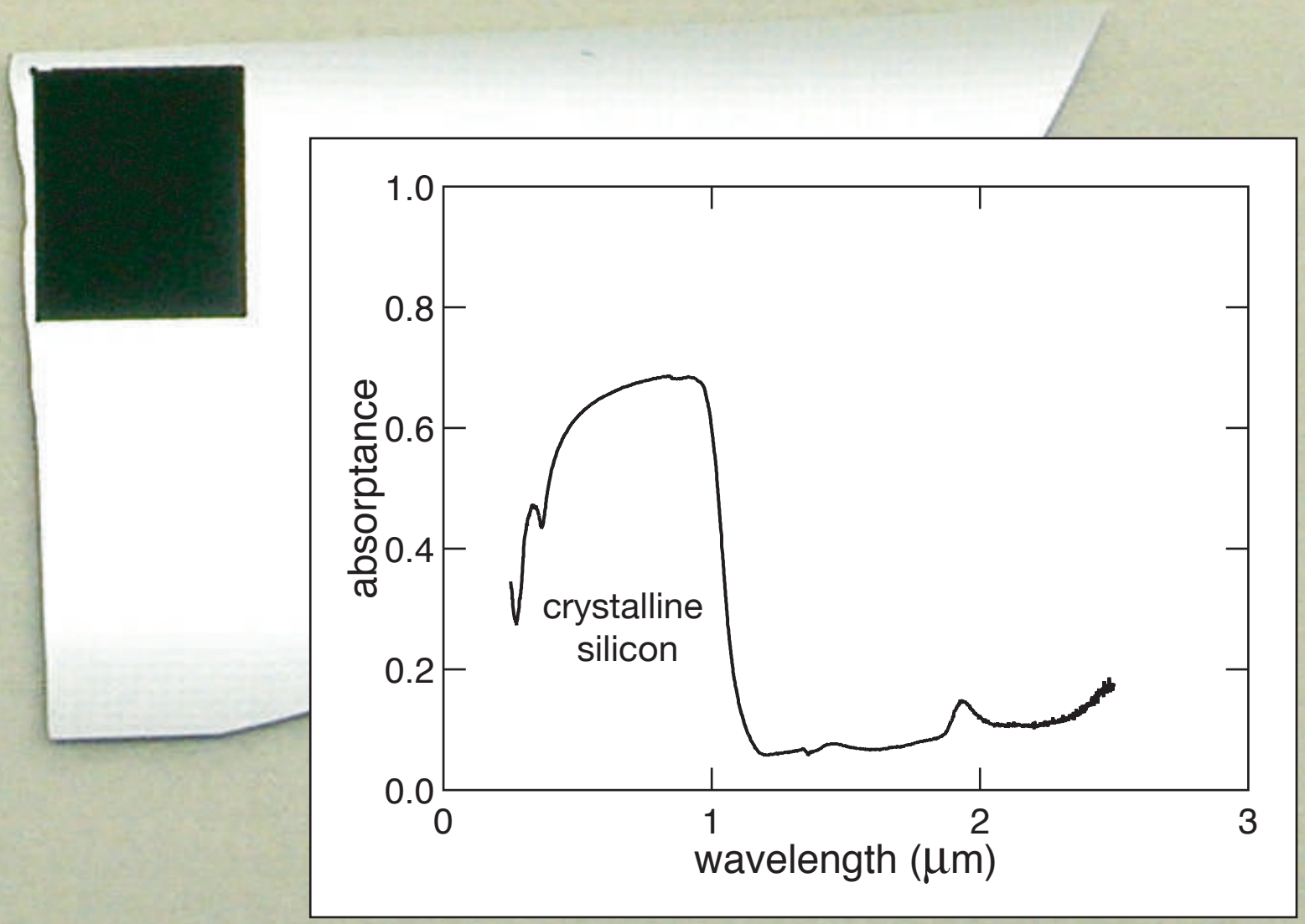
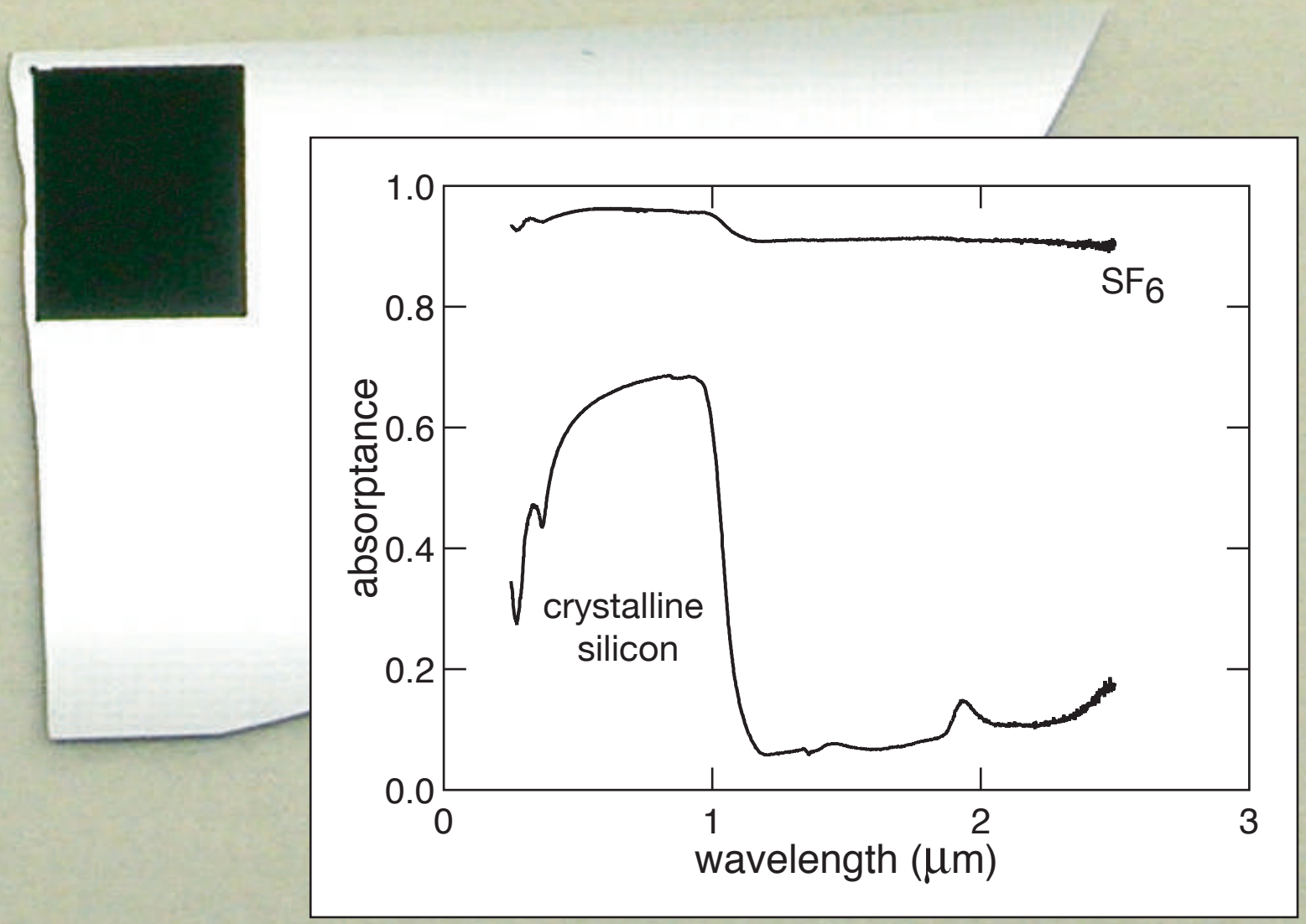


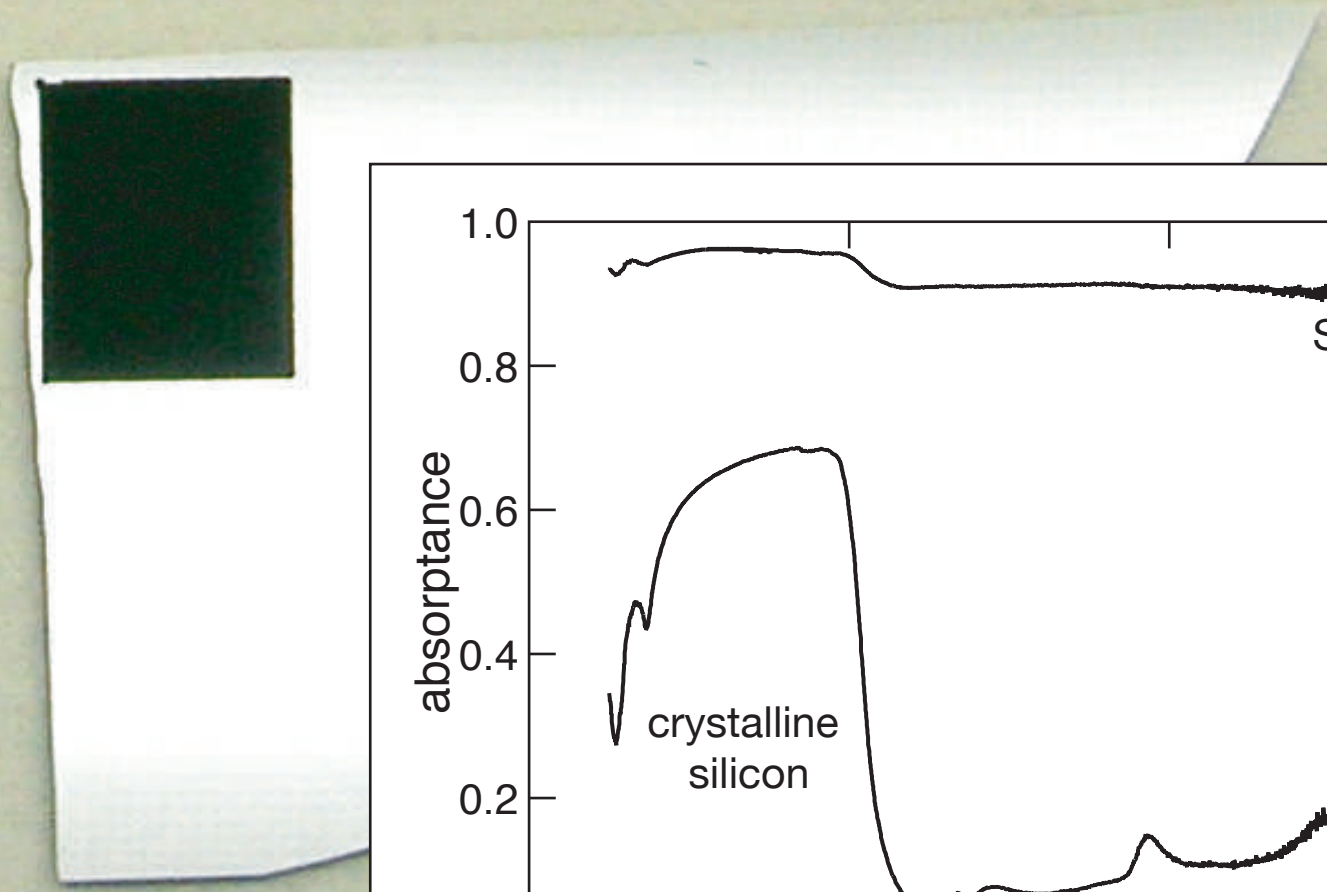
Material properties

absorbs nearly all incident light!



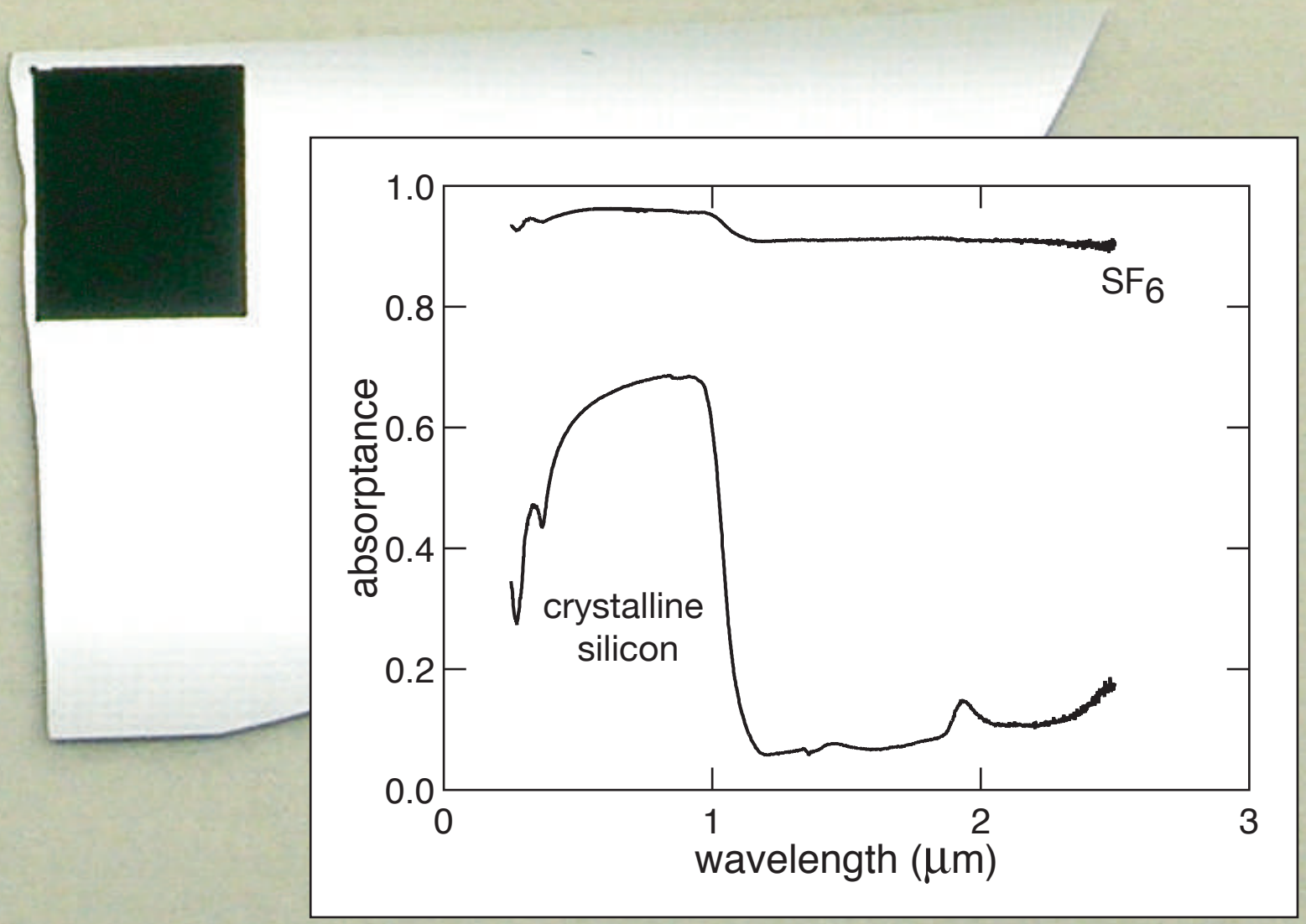
Material properties

why?



Material properties

surface morphology?



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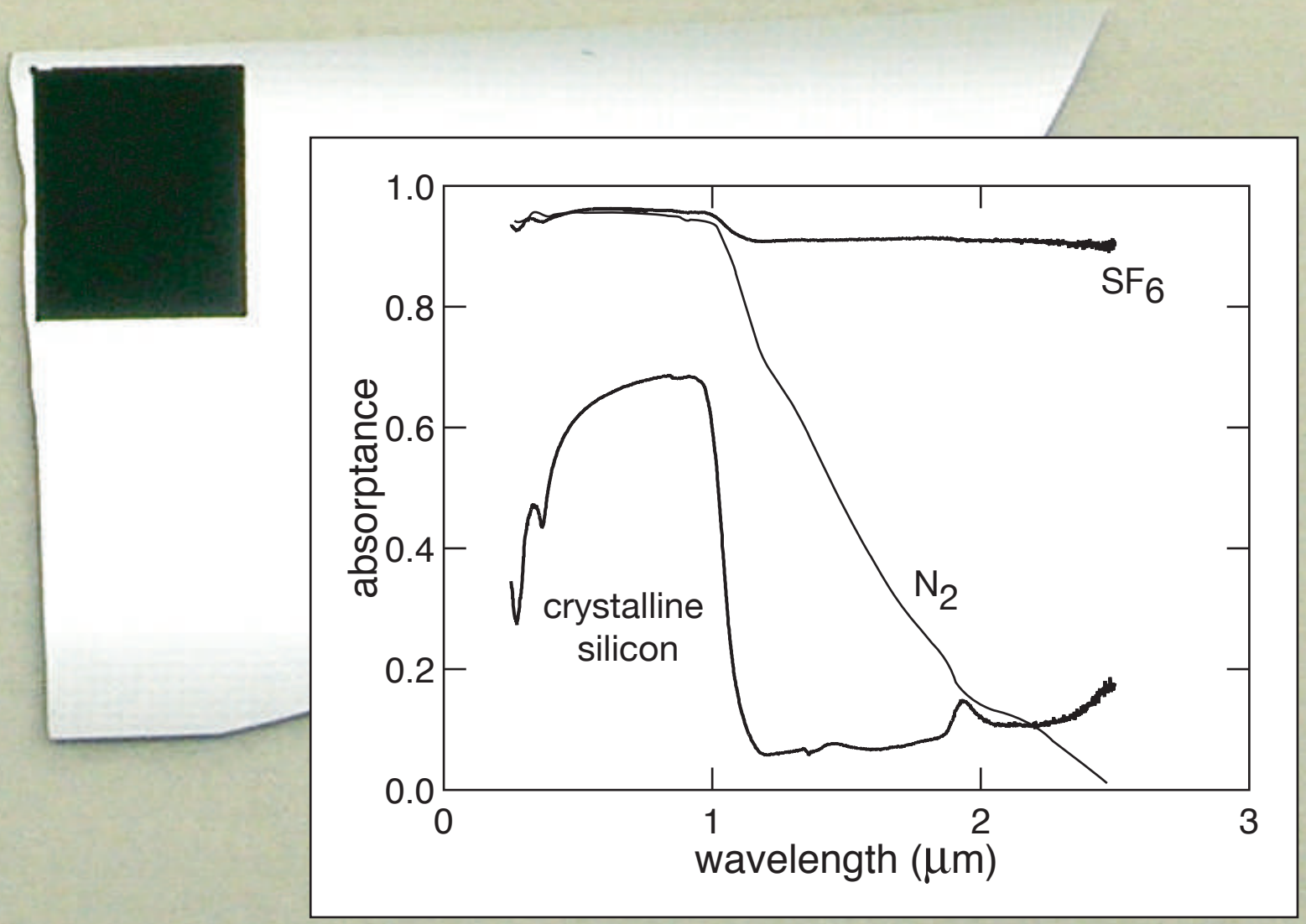

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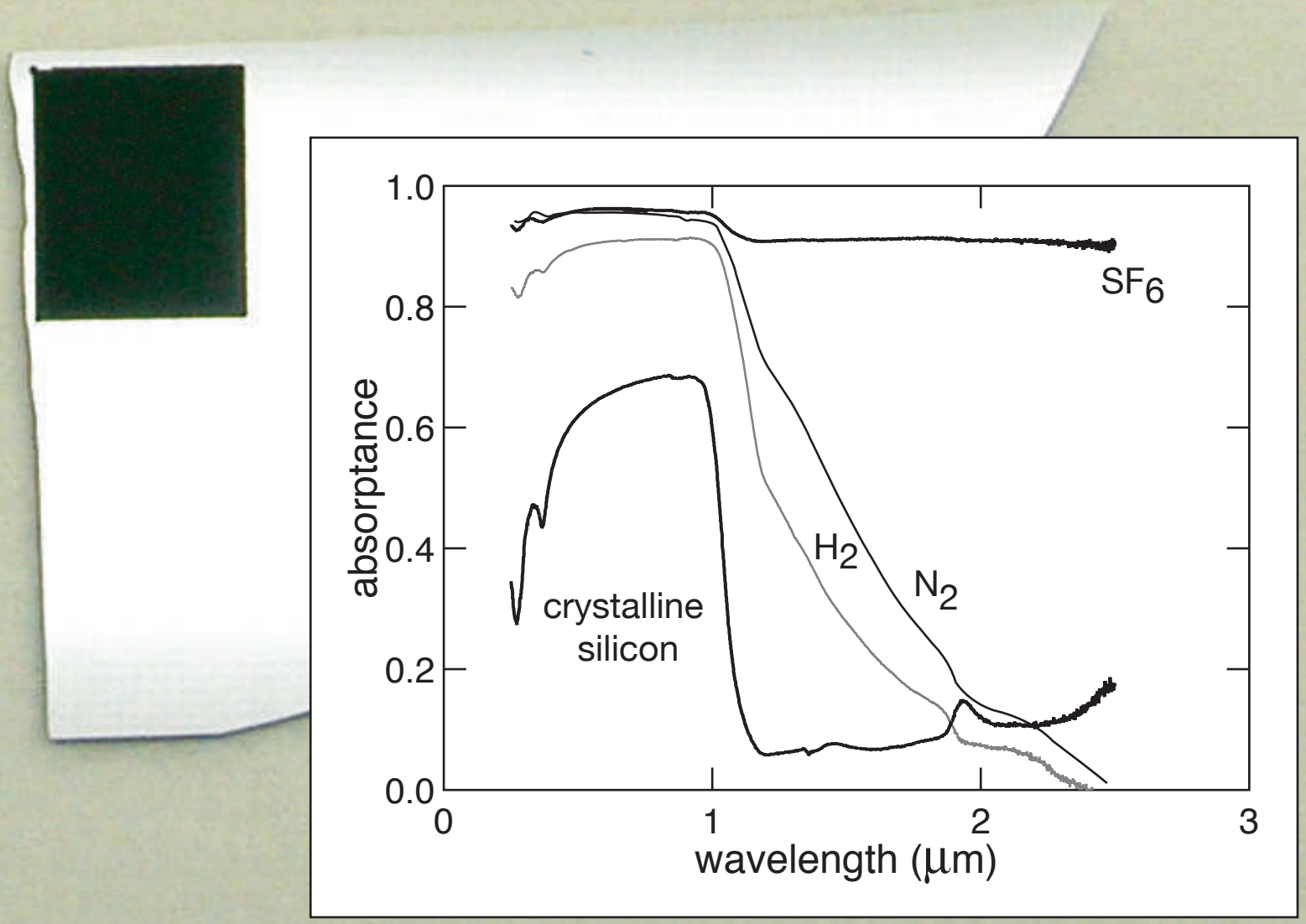

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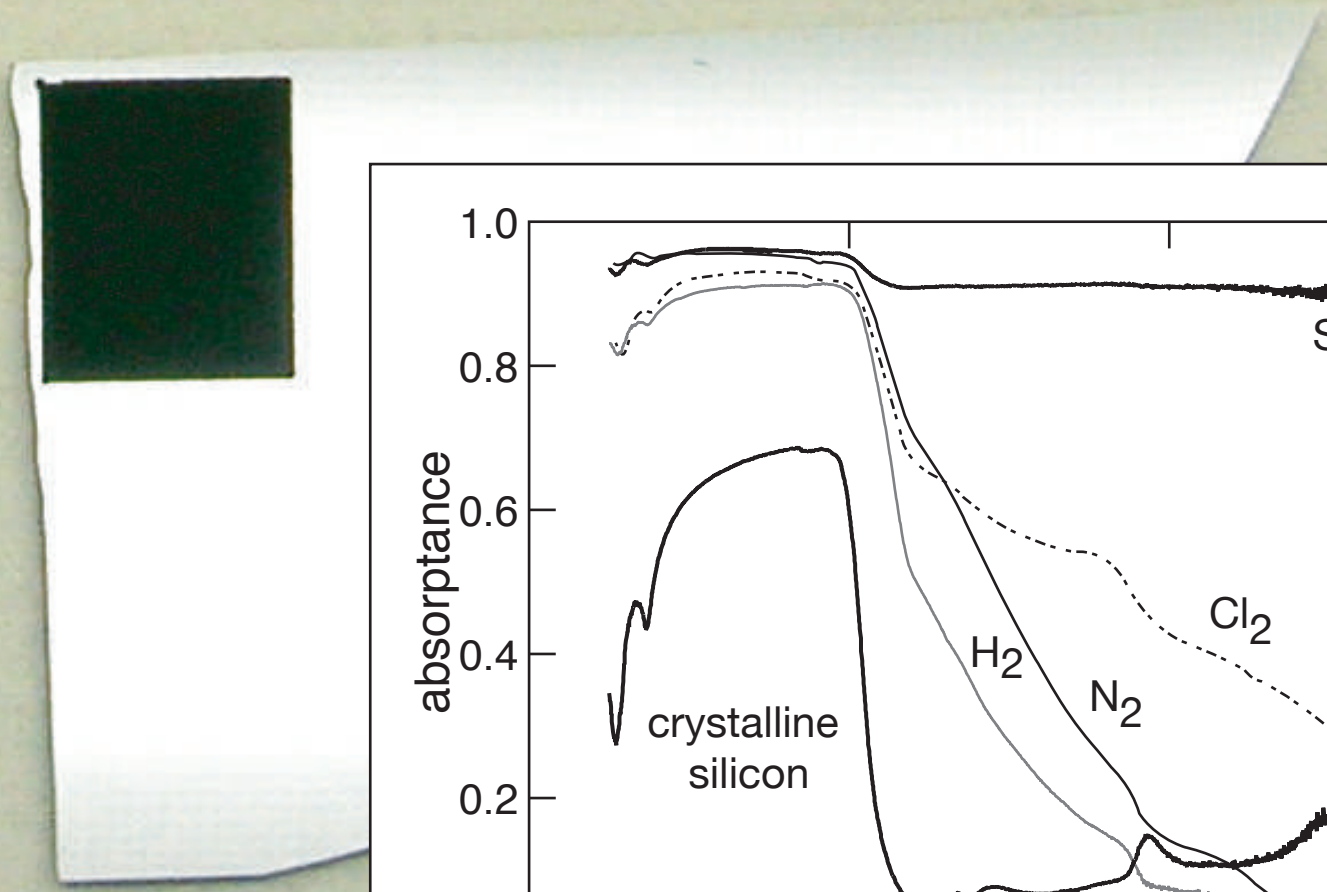

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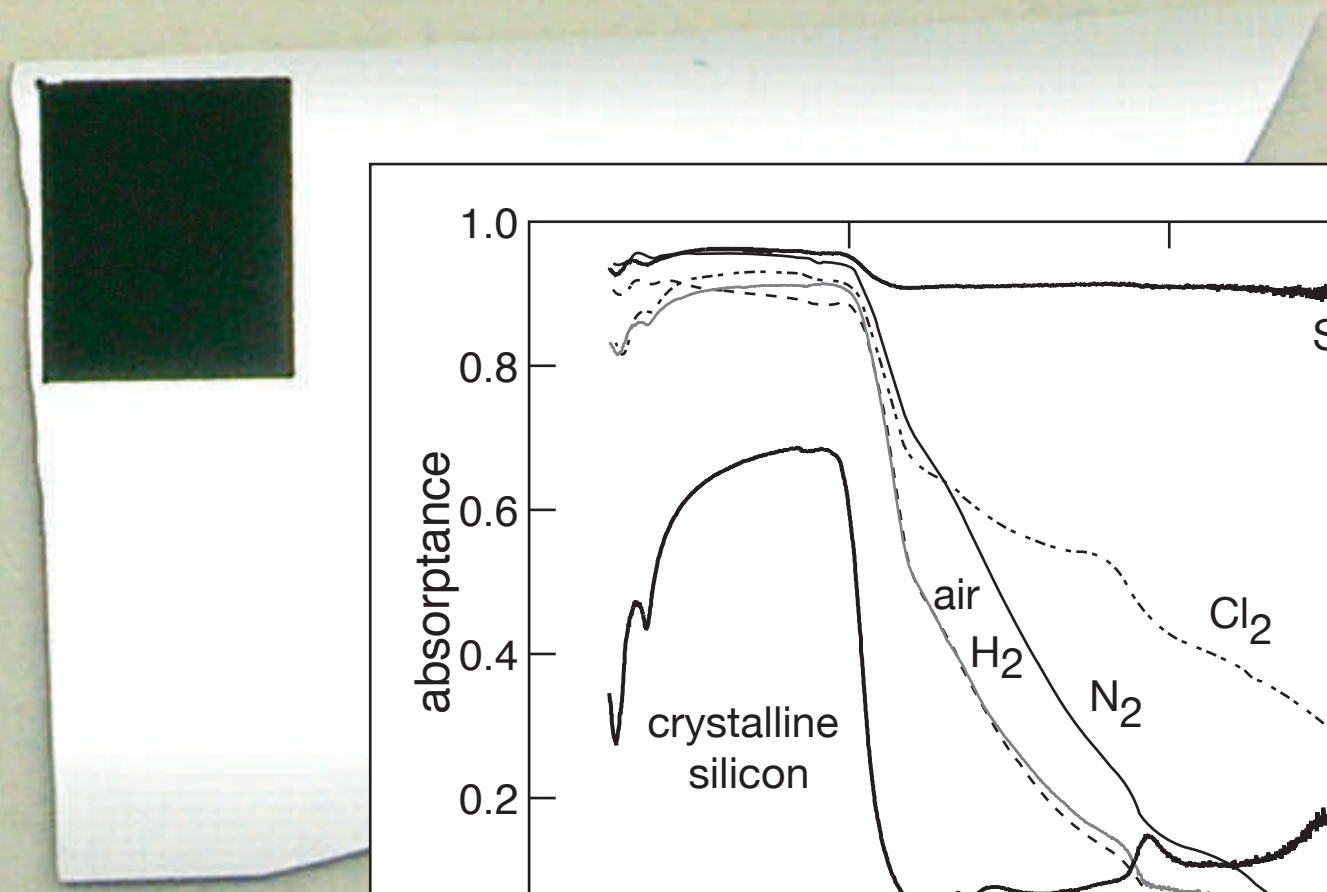

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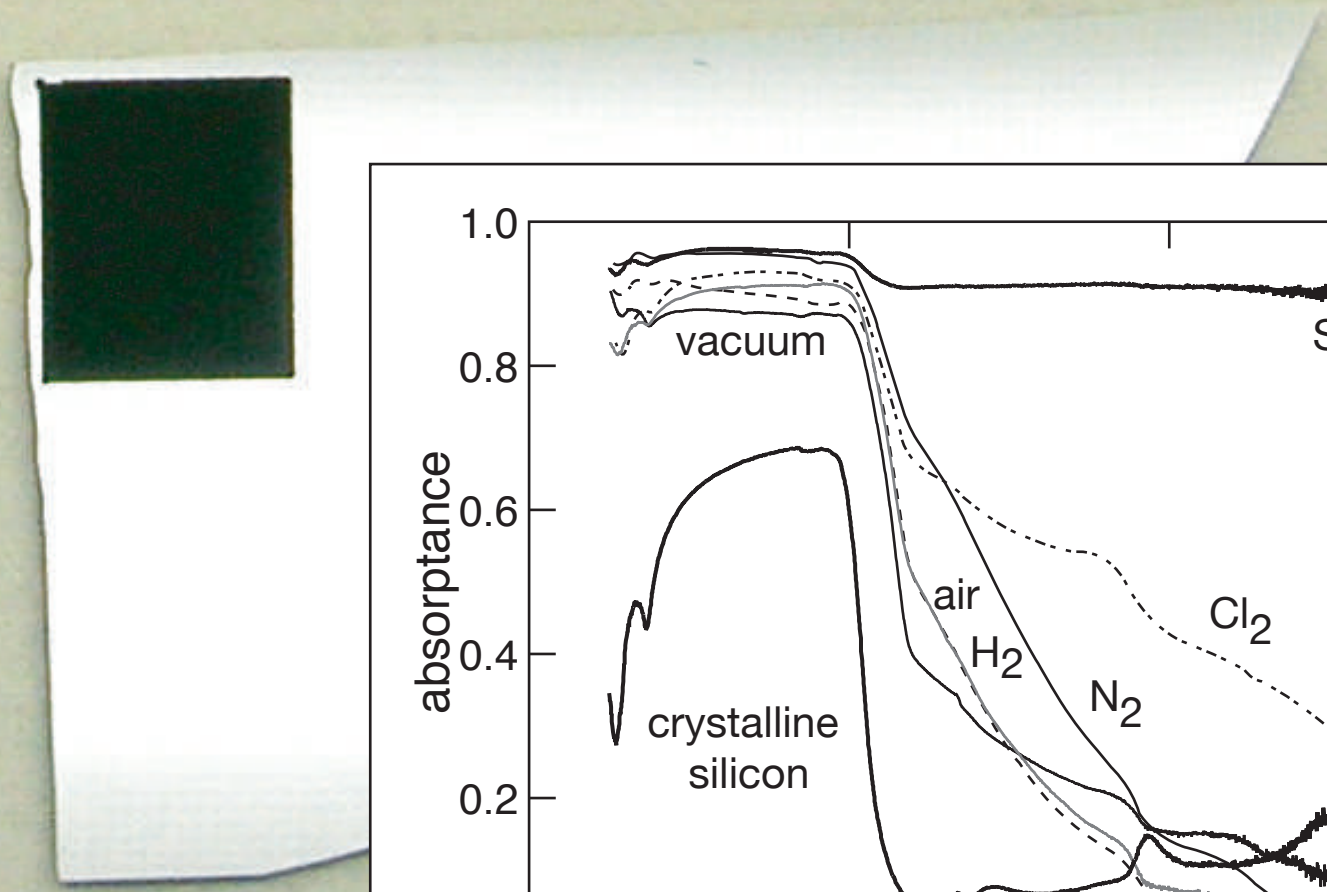
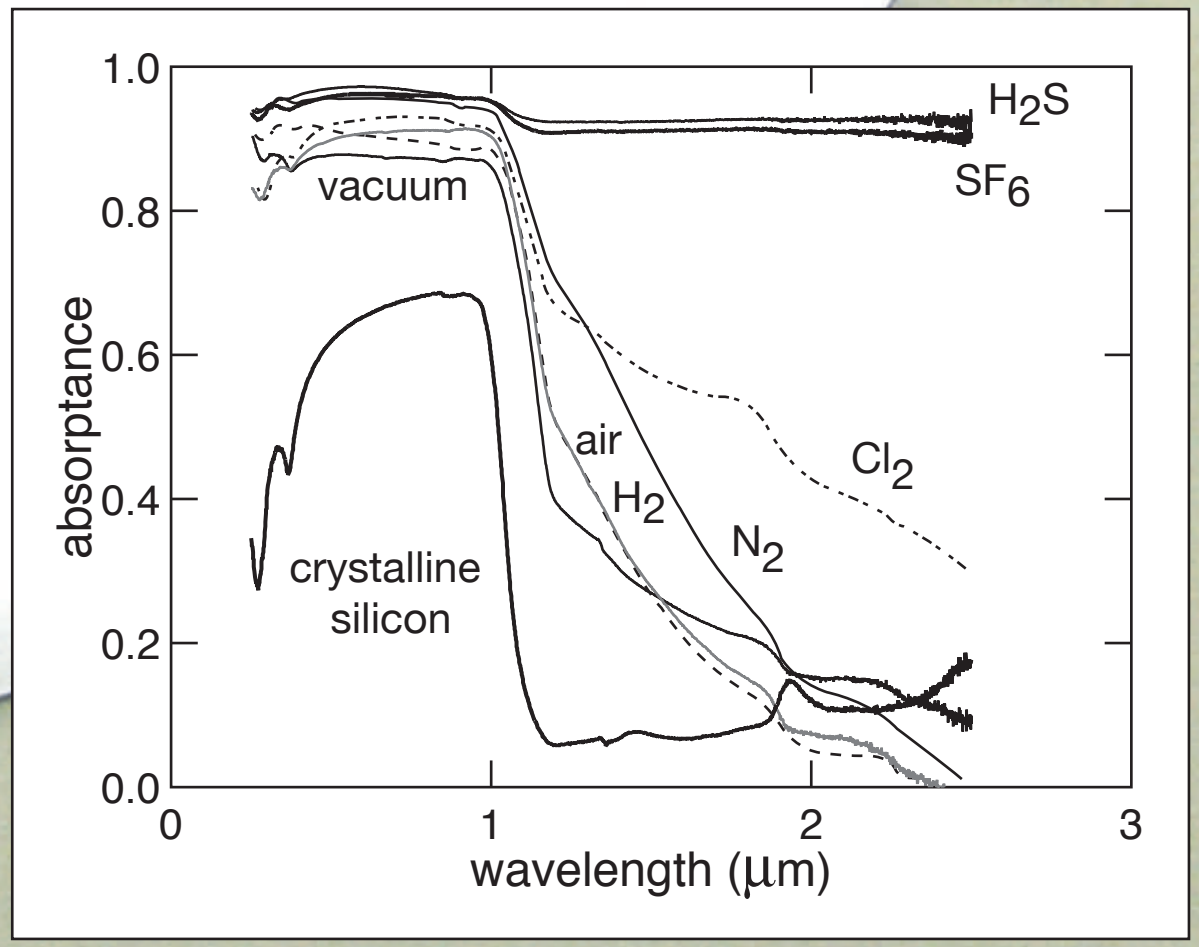
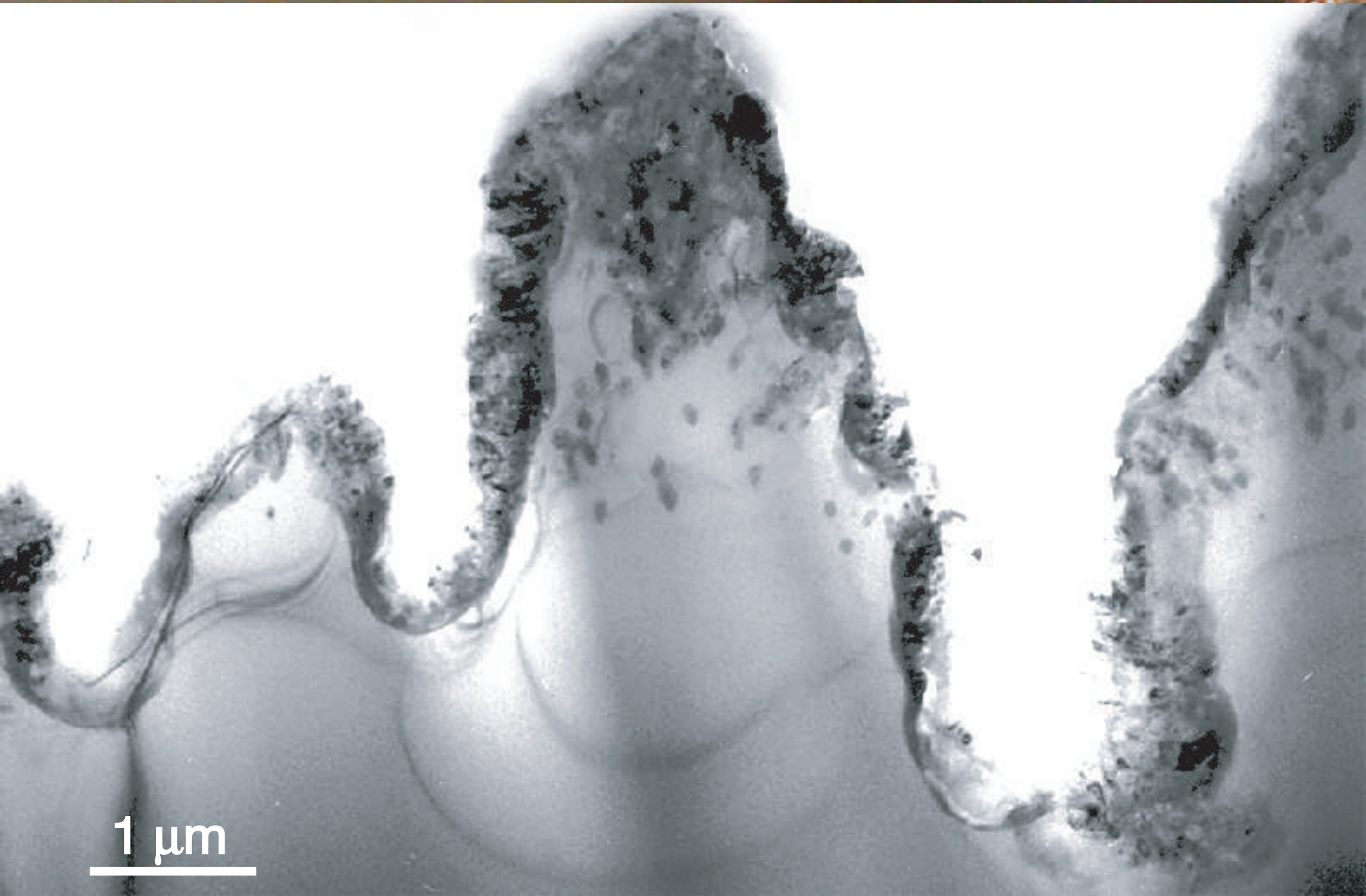


Material properties

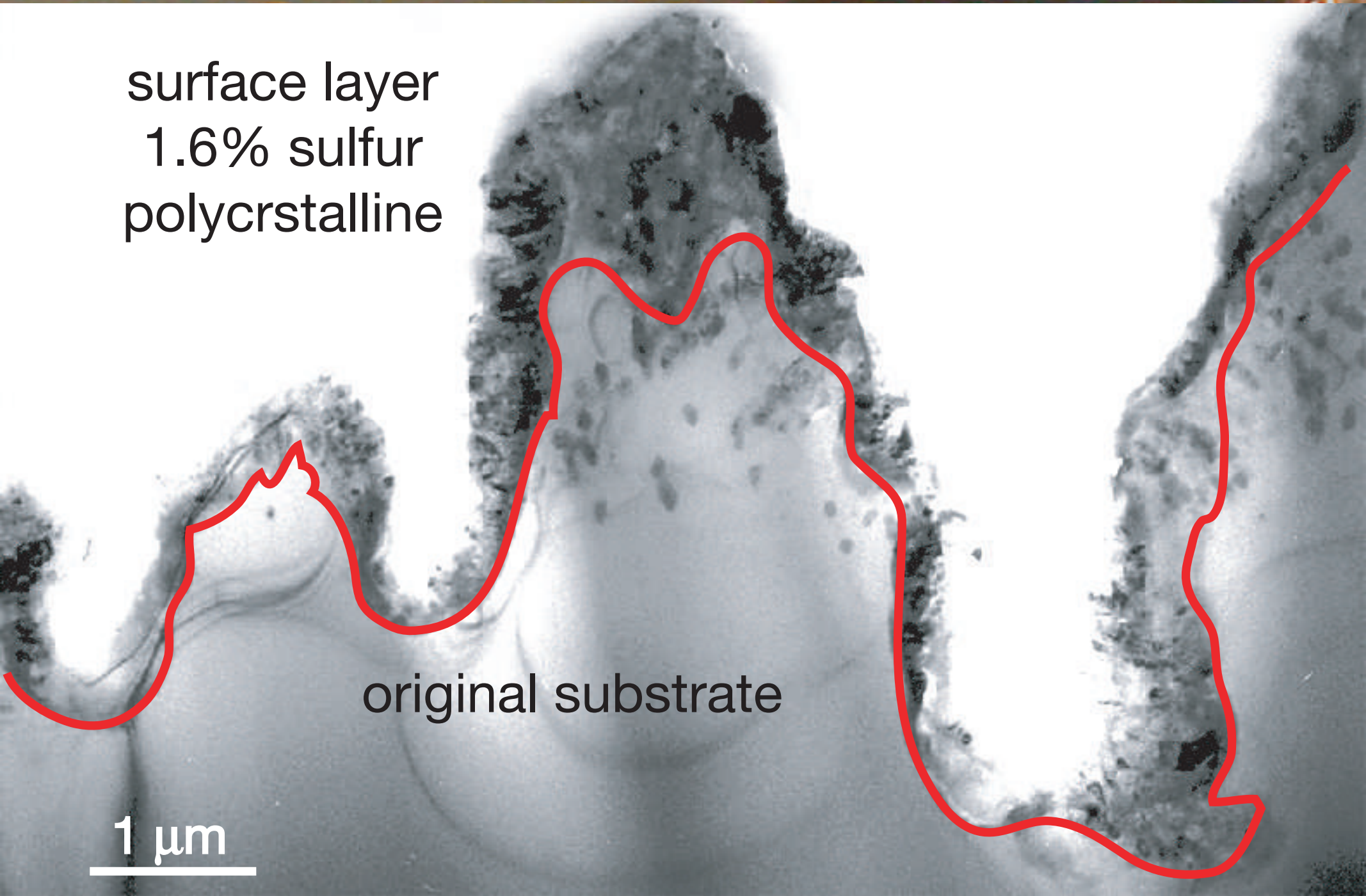
sulfur is the key



Material properties



Material properties



Material properties

diodic junction forms across interface

Material properties

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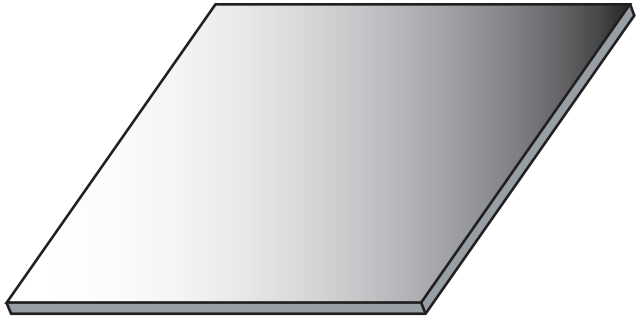

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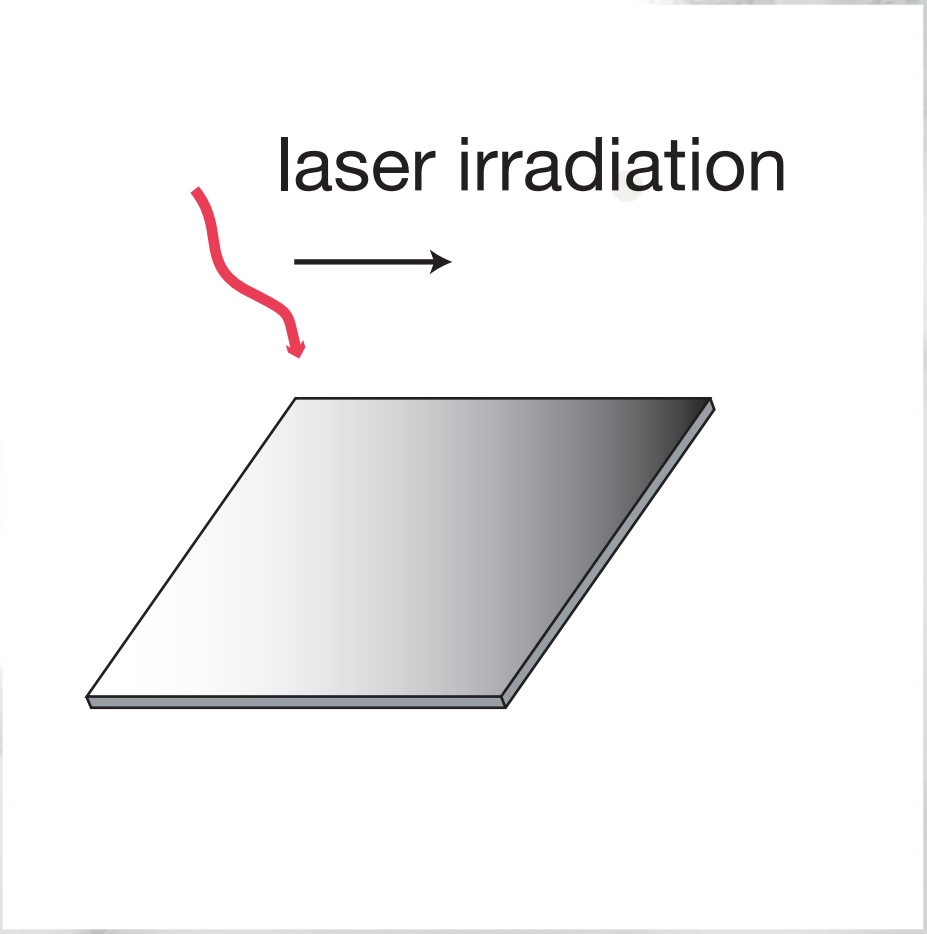

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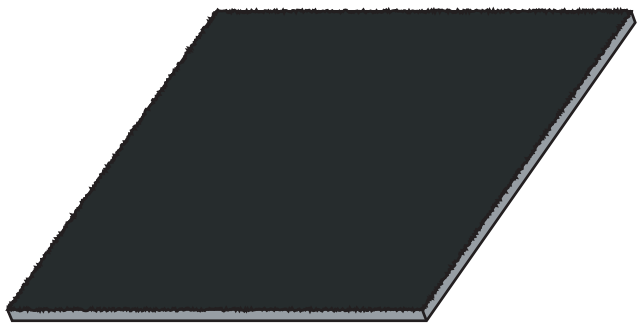
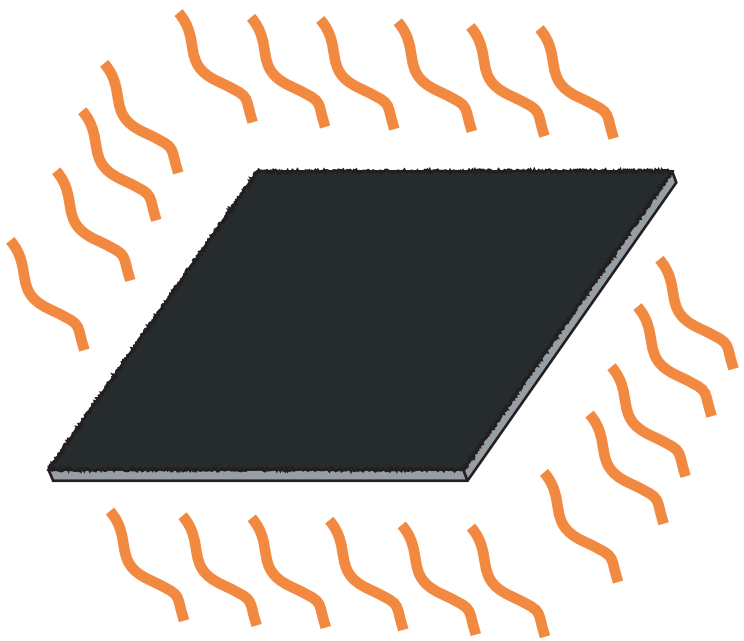


Material properties

diodic junction forms across interface

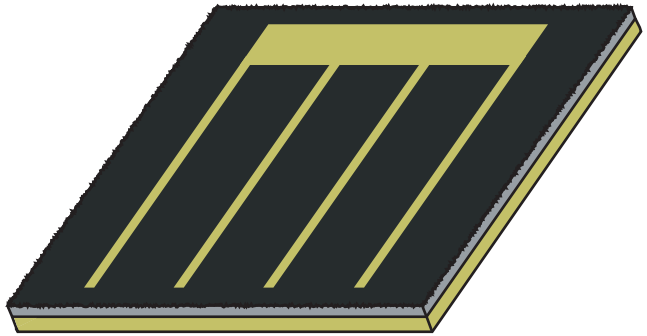
thermal anneal



Material properties

diodic junction forms across interface

evaporate Cr/Au



Material properties

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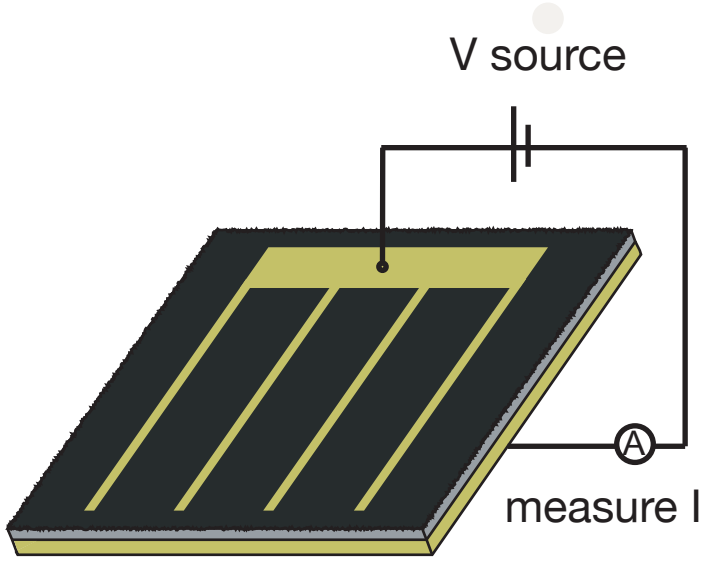
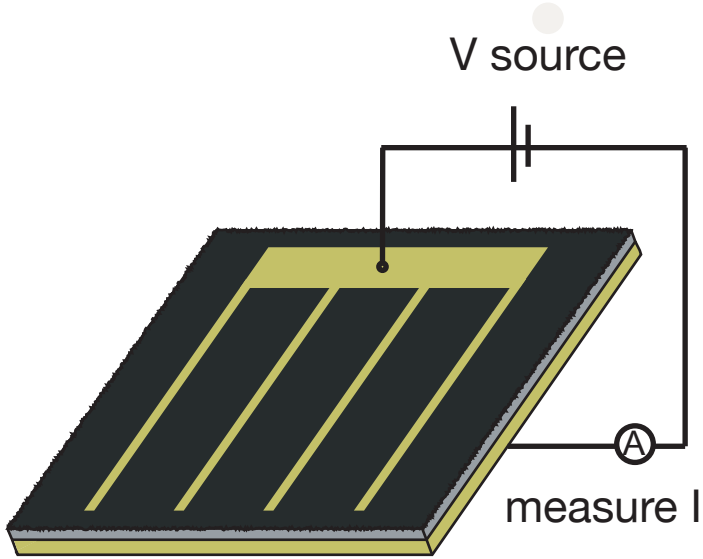
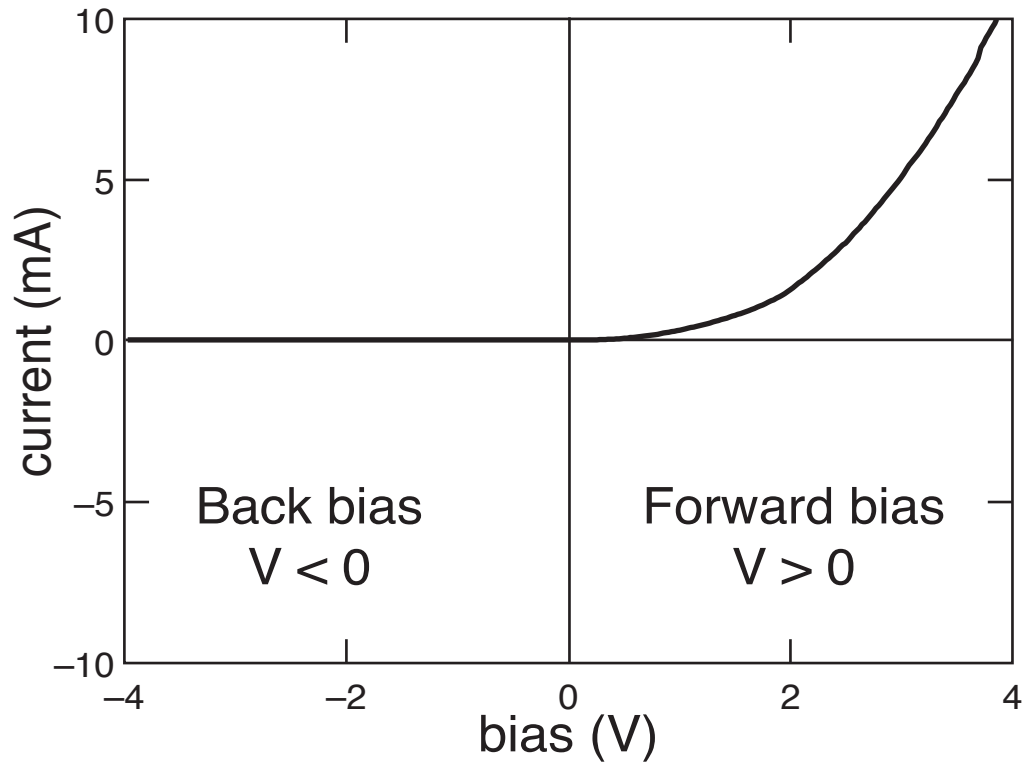


Material properties

diodic junction forms across interface

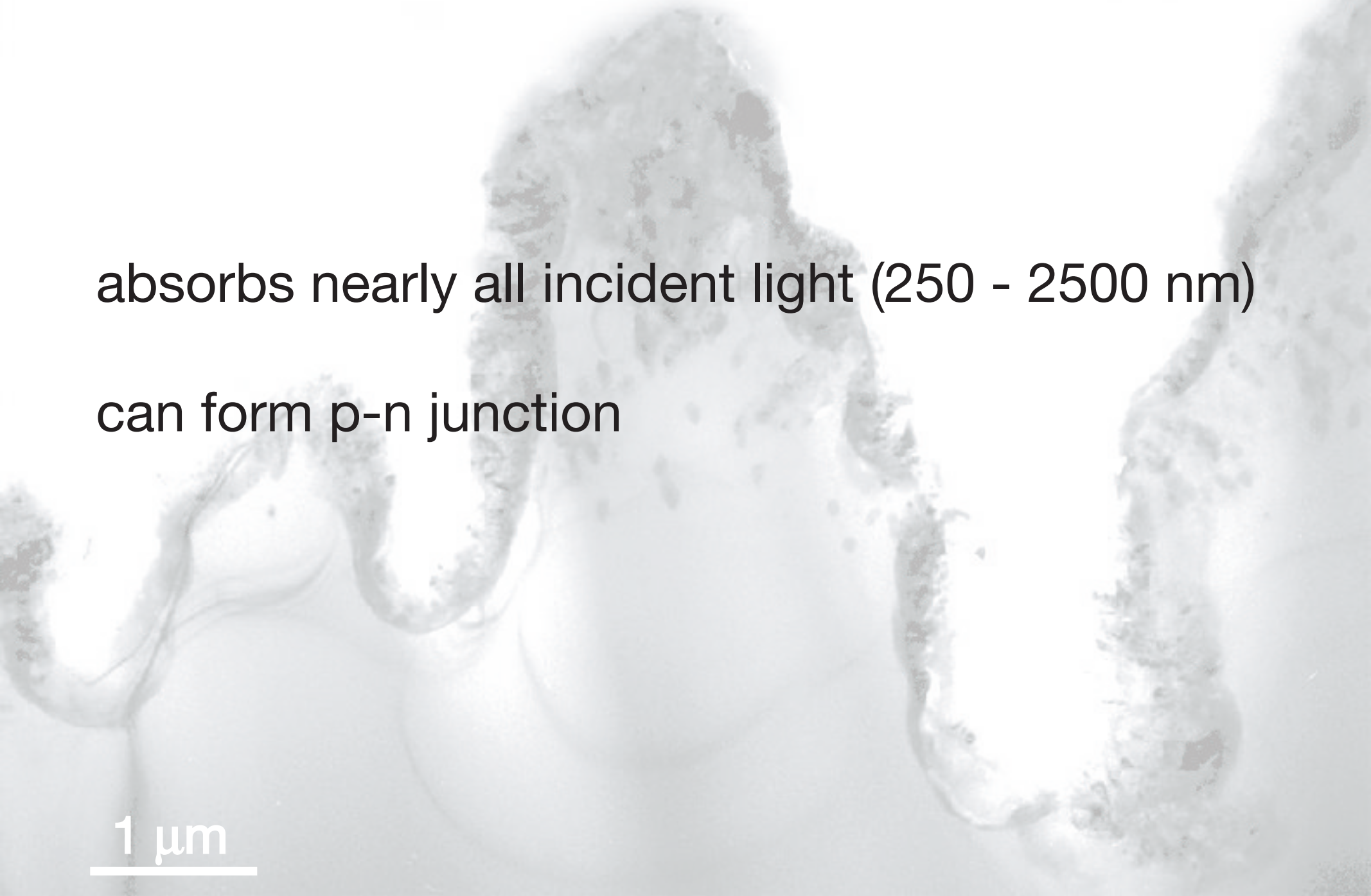




Material properties

absorbs nearly all incident light (250 - 2500 nm)

can form p-n junction

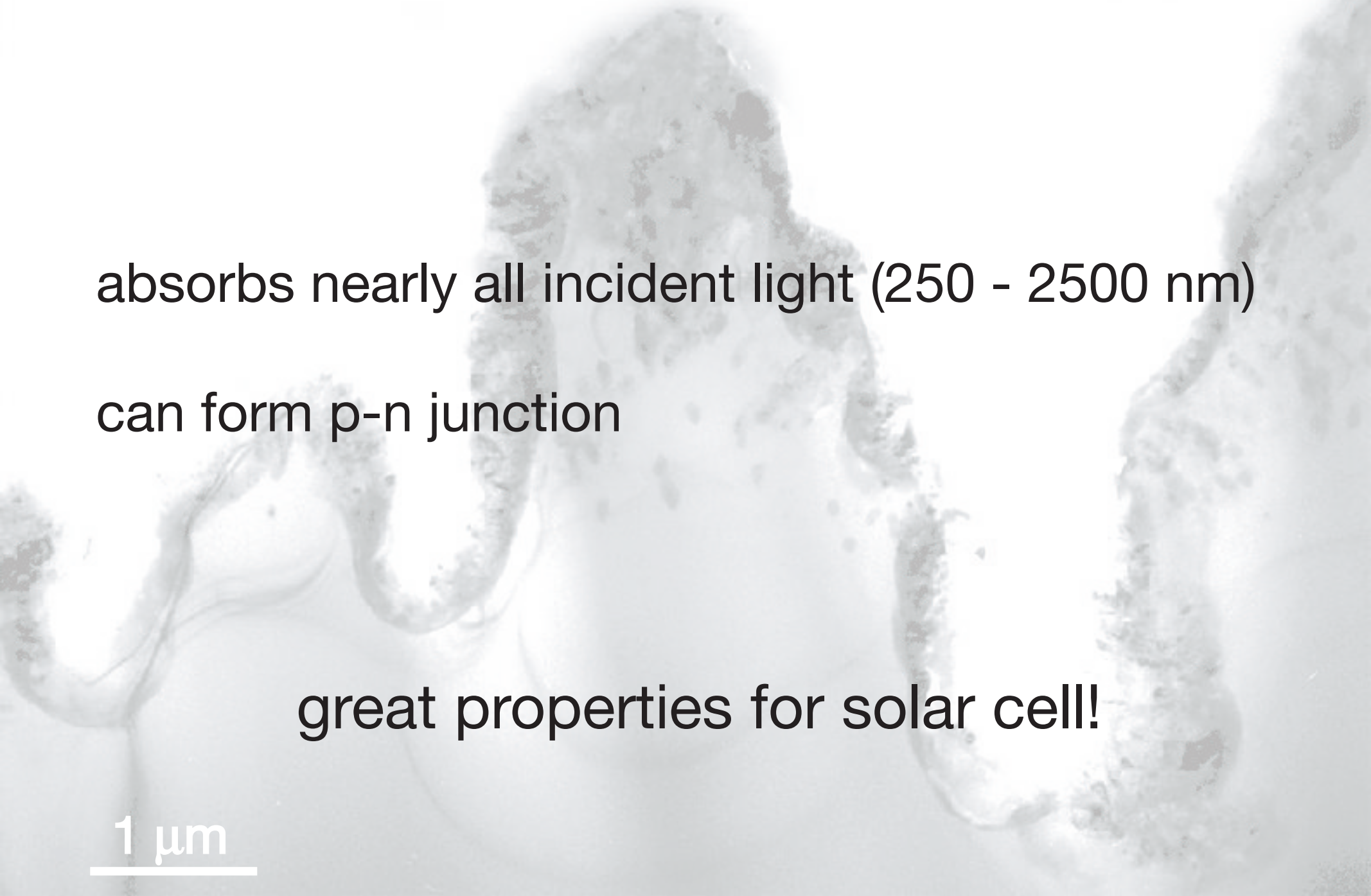


Material properties

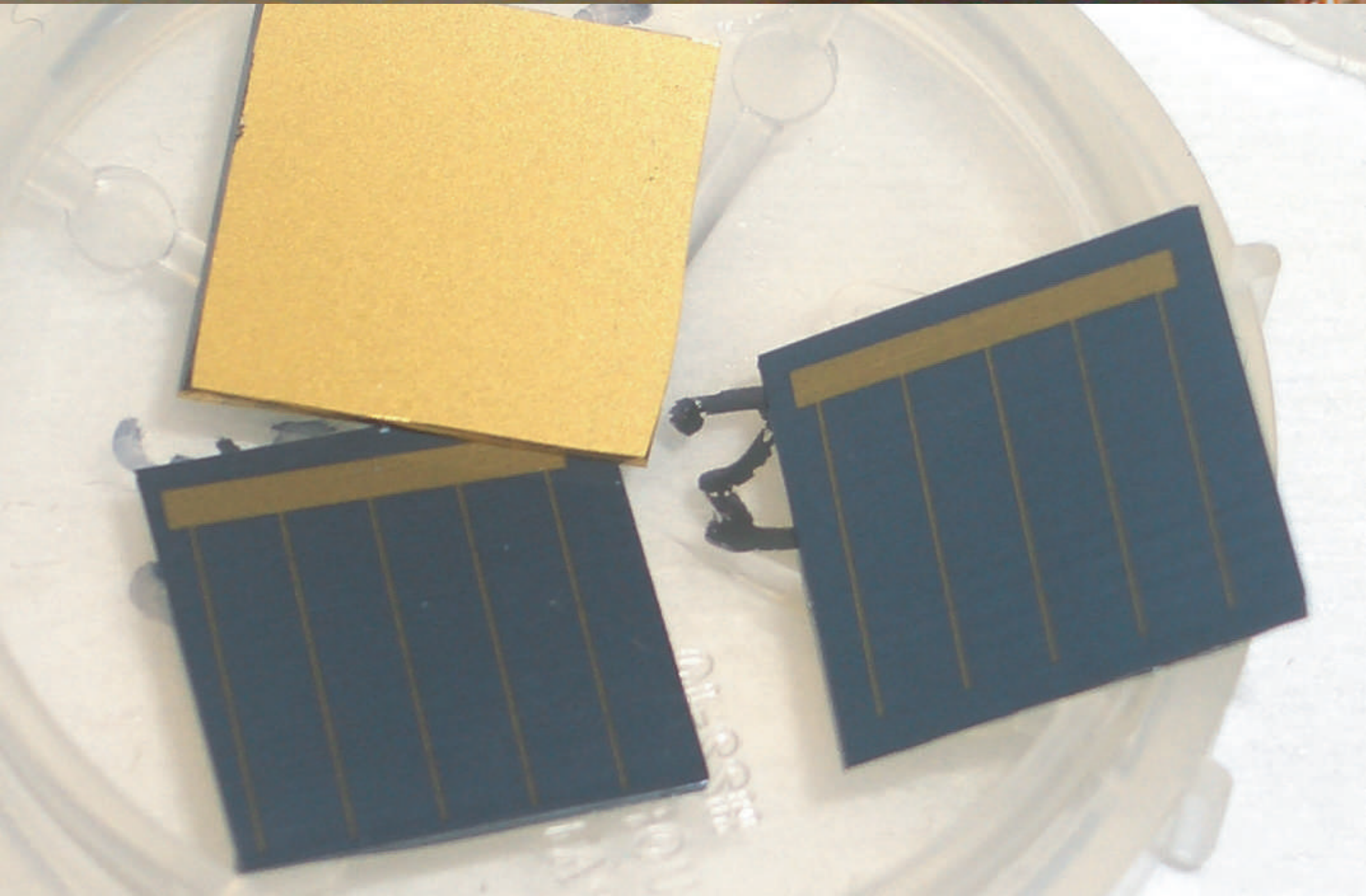
absorbs nearly all incident light (250 - 2500 nm)

can form p-n junction

great properties for solar cell!

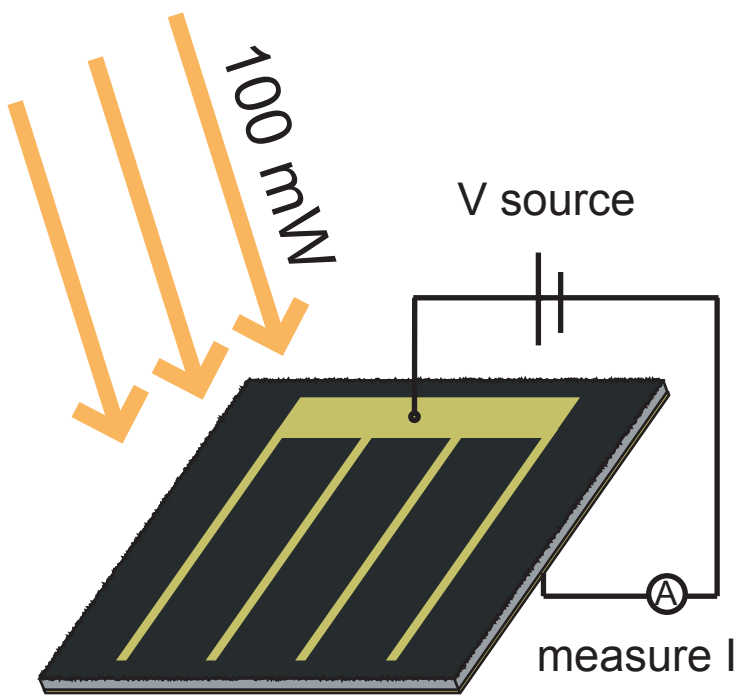


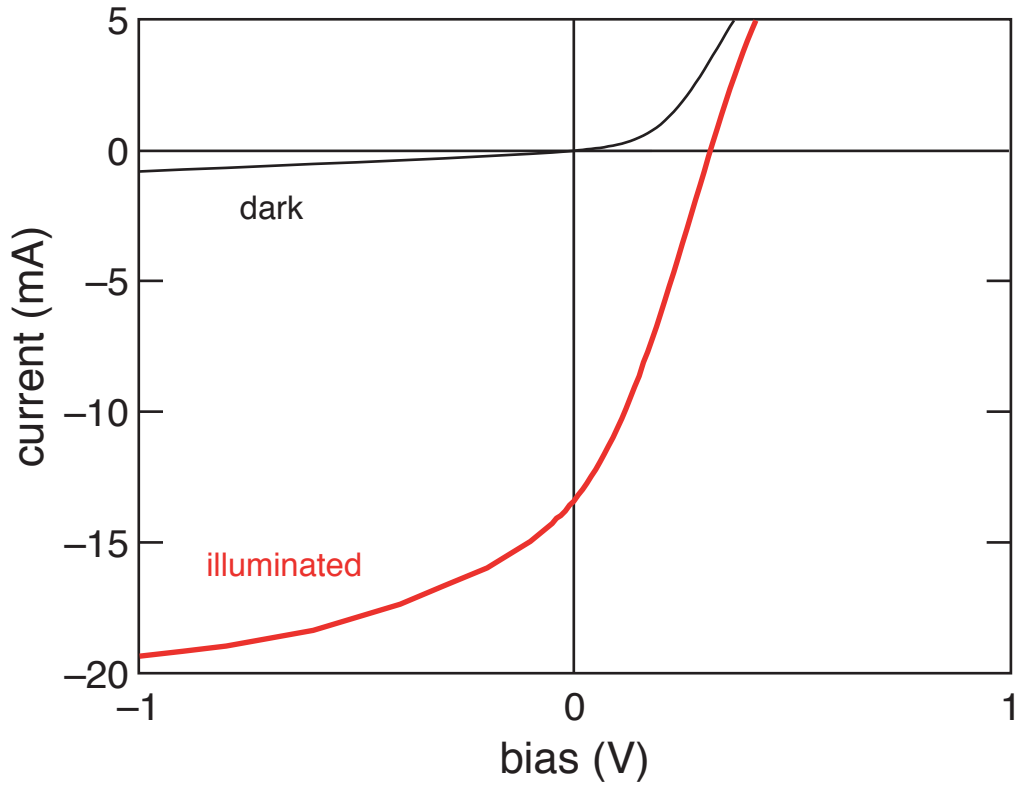
Solar cell results



Solar cell results

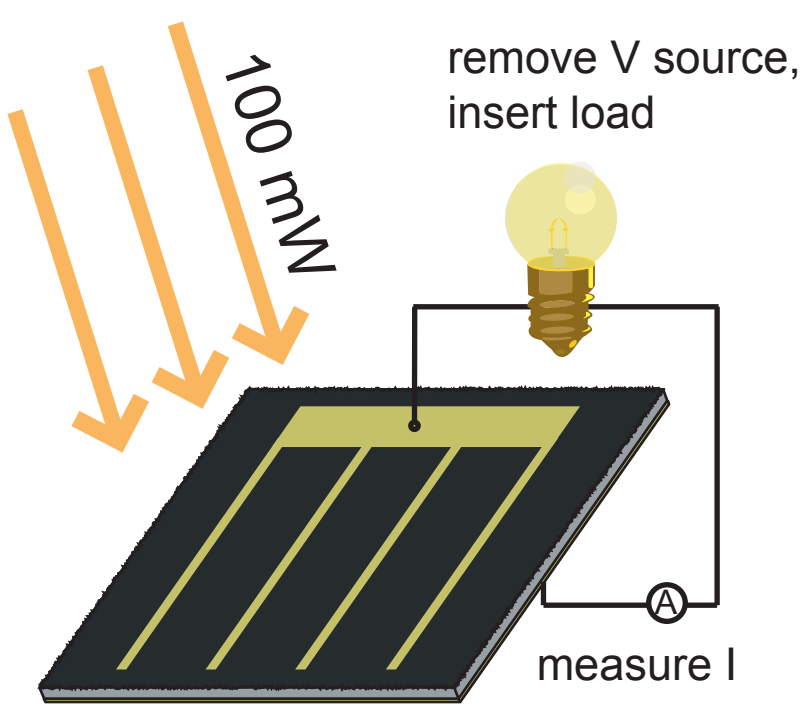
illuminated *IV* curve

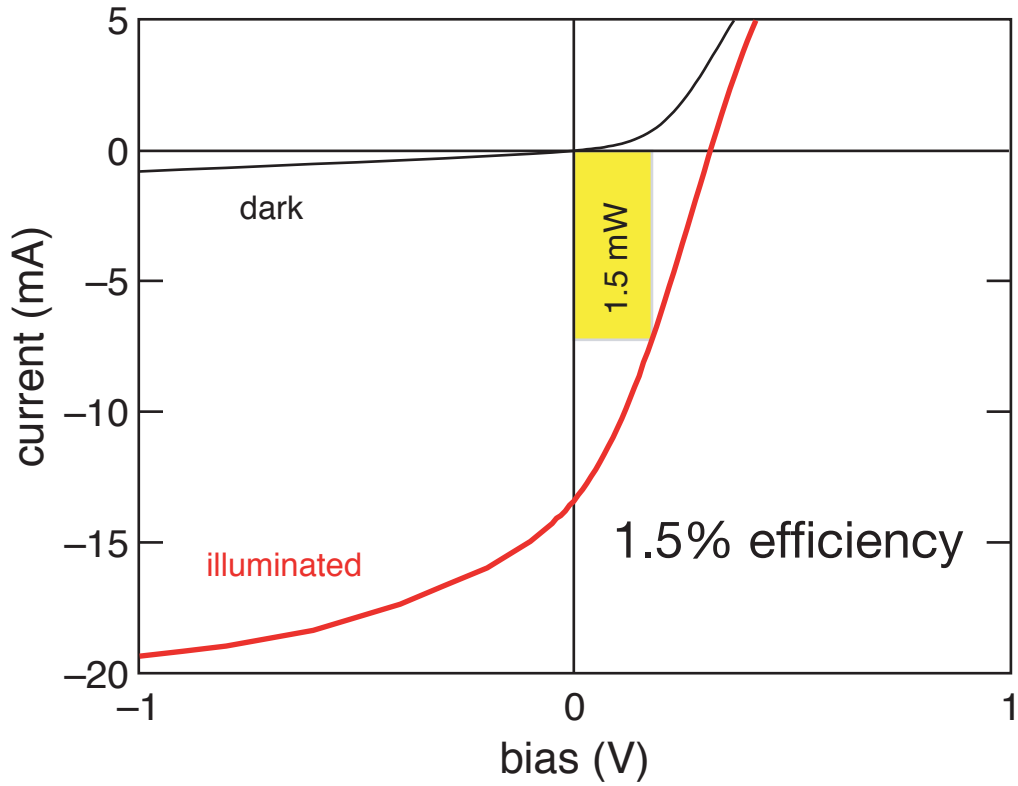




Solar cell results

1.5% efficiency, a good beginning





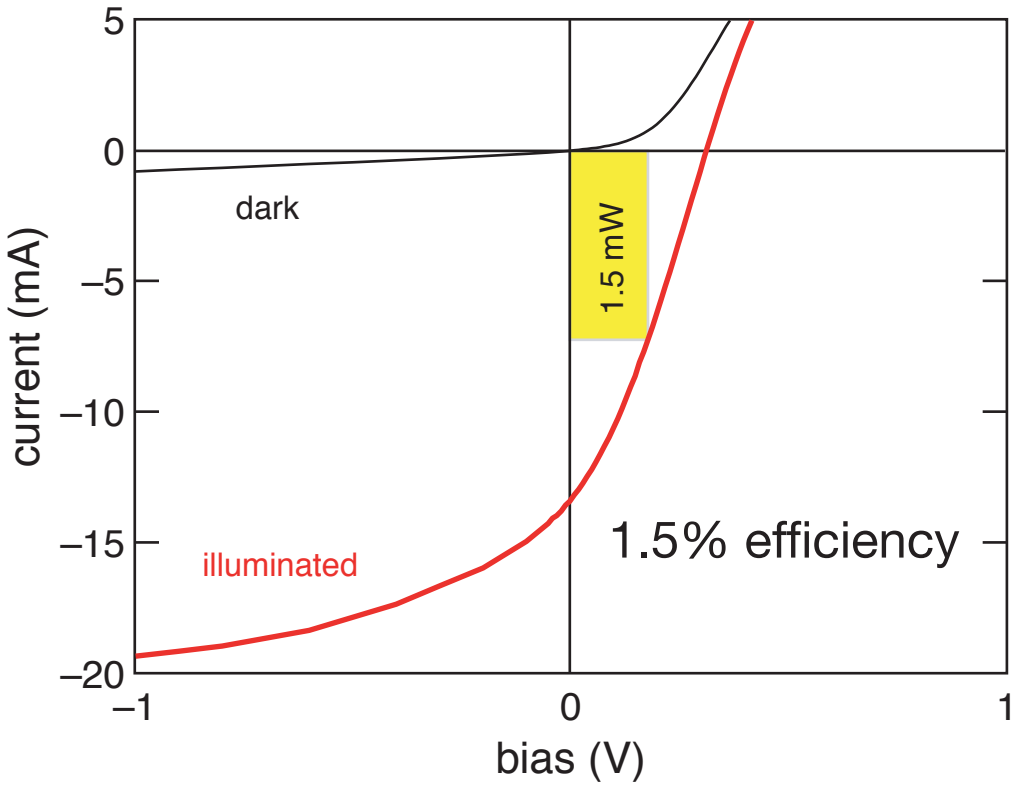
Solar cell results

compare to current silicon-based solar cells

single crystal
25 – 28%

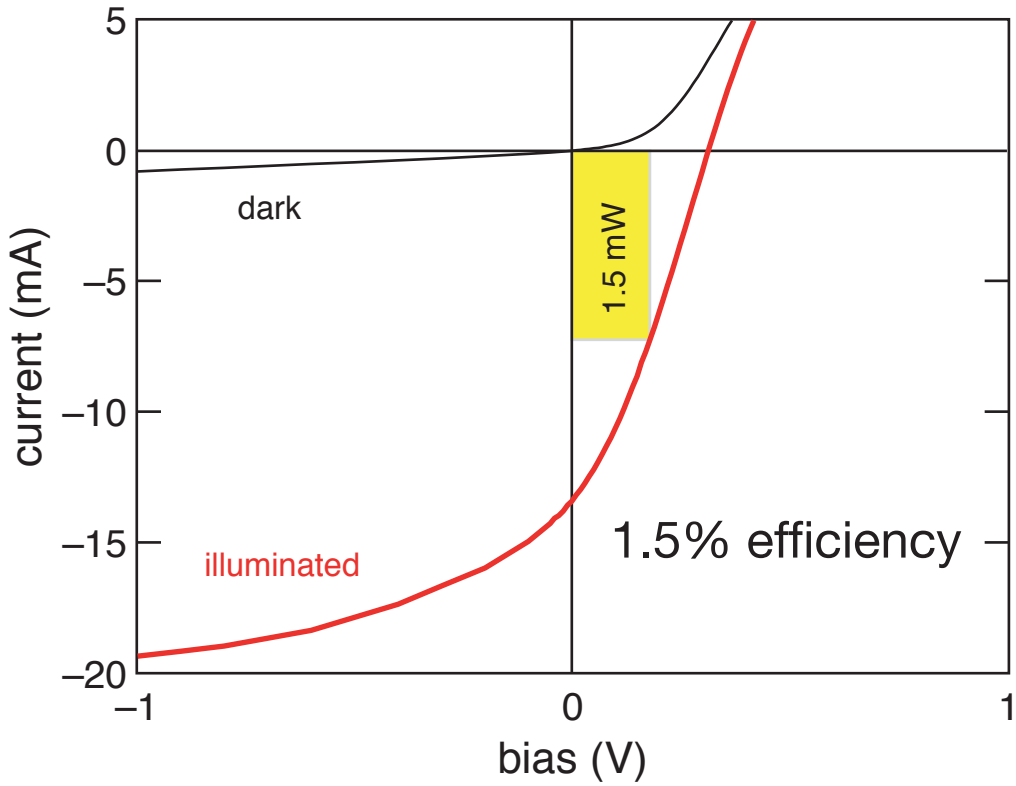
polycrystalline
14 – 15%

thin-film: amorphous
and microcrystalline
8 – 10%



Solar cell results

thin-film: amorphous
and microcrystalline
8 – 10%



Thin-film silicon

advantages:

thin-film silicon is cheaper

Thin-film silicon

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has a similar structure to our microstructured layer

Thin-film silicon

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thin-film silicon is cheaper

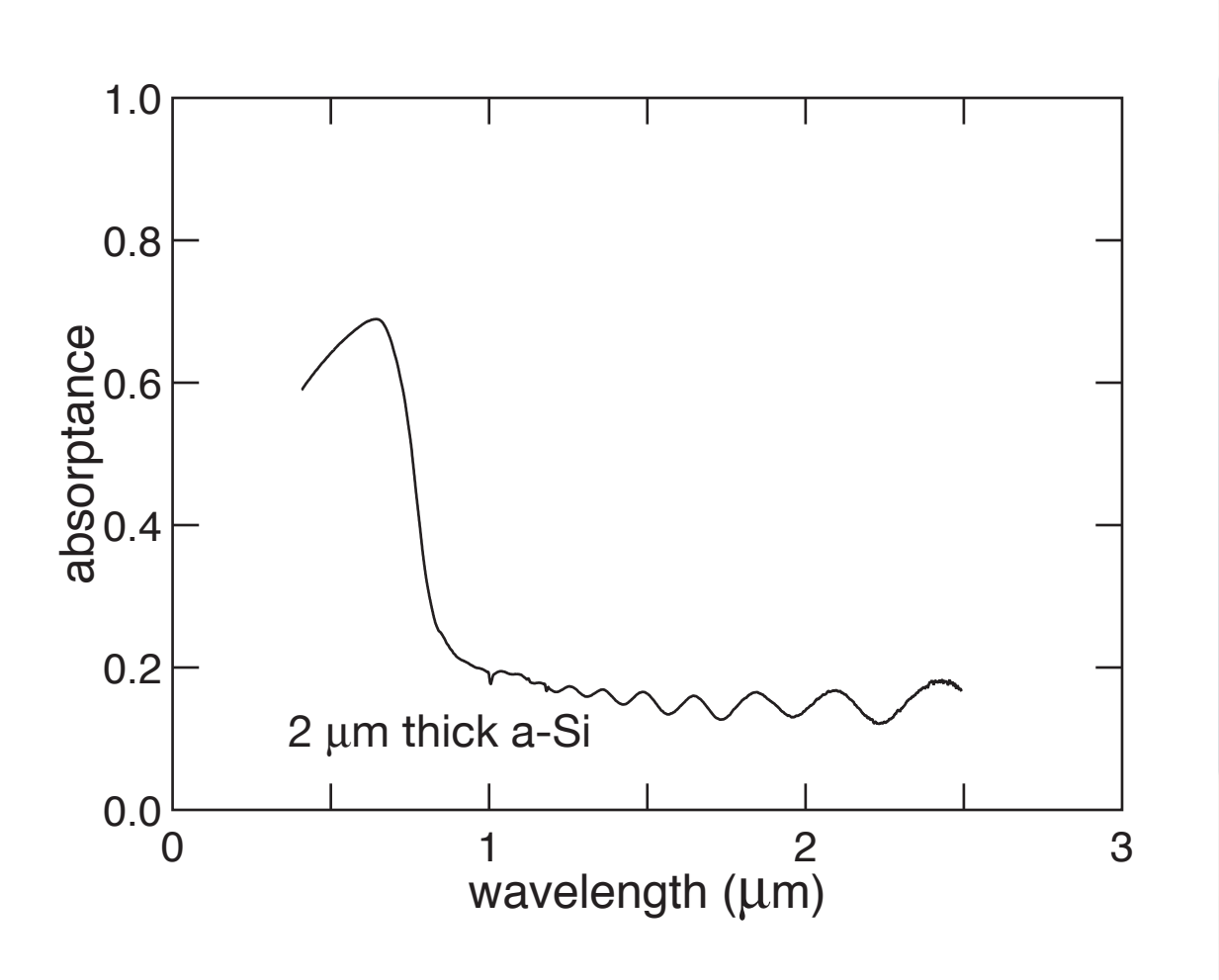
has a similar structure to our microstructured layer

potential significant increase in efficiency of thin film silicon solar cells

our samples absorb nearly all sunlight after formation of layer < 1 μm thick

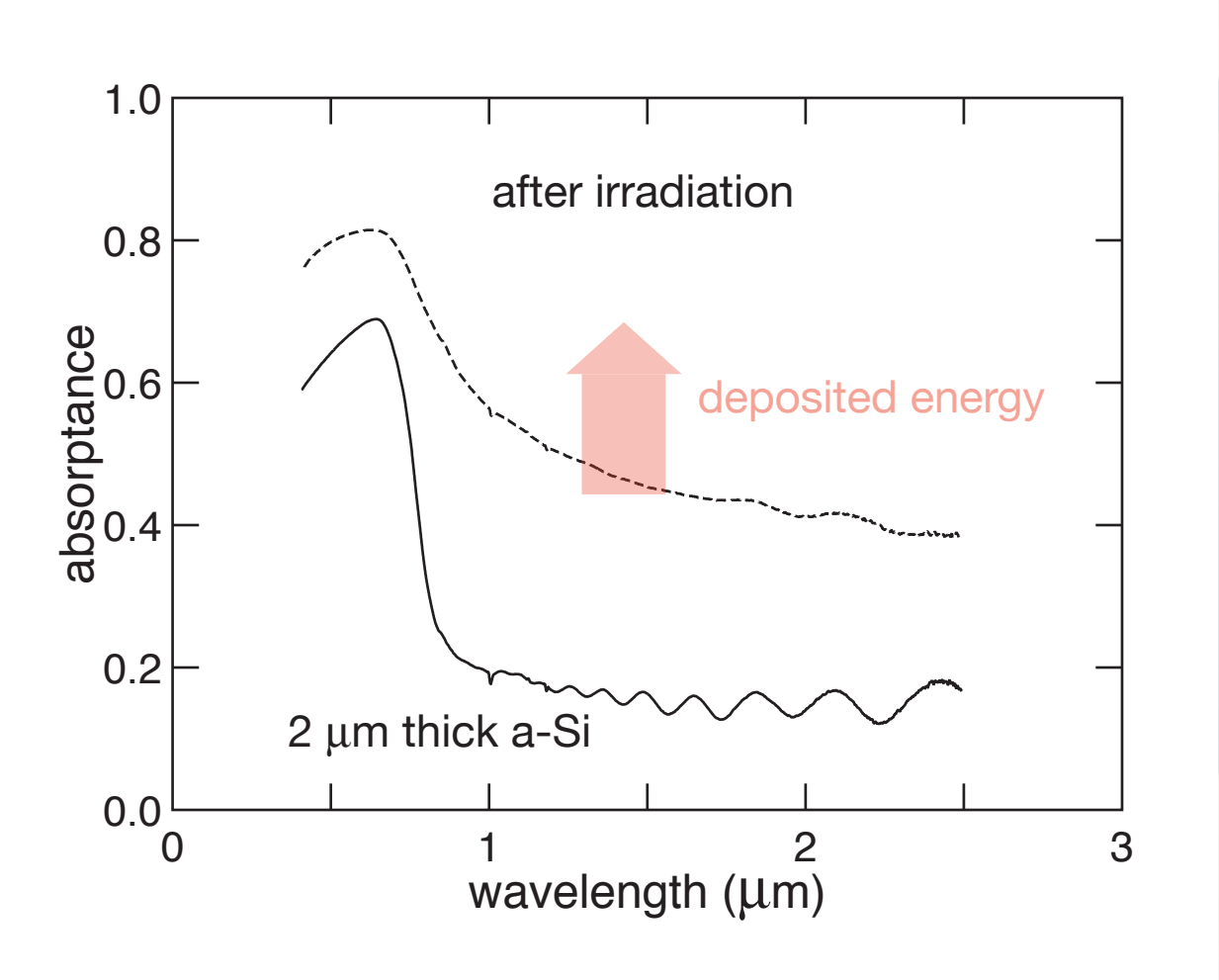
Thin-film silicon results

irradiation of amorphous silicon thin-film



Thin-film silicon results

irradiation of amorphous silicon thin-film



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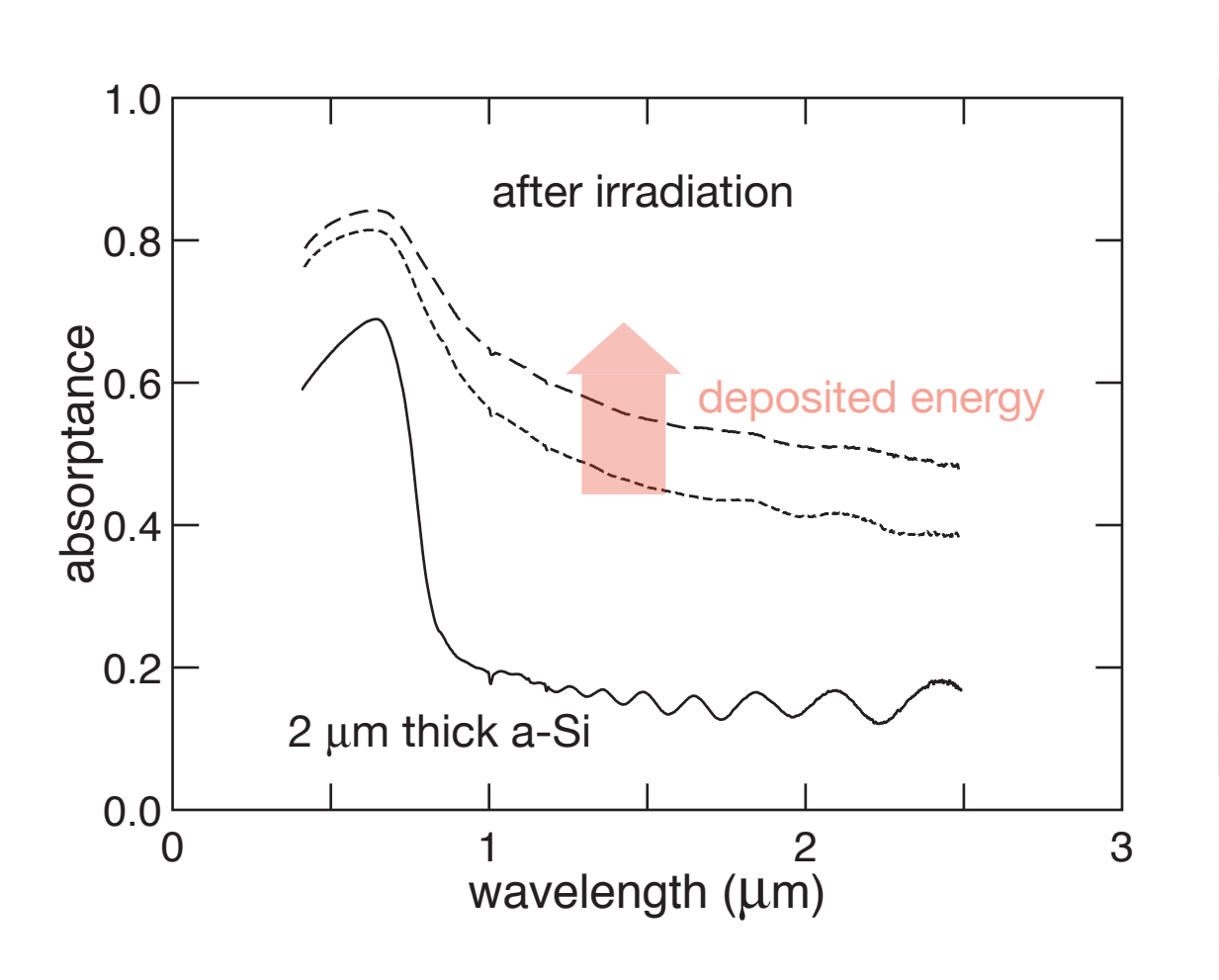
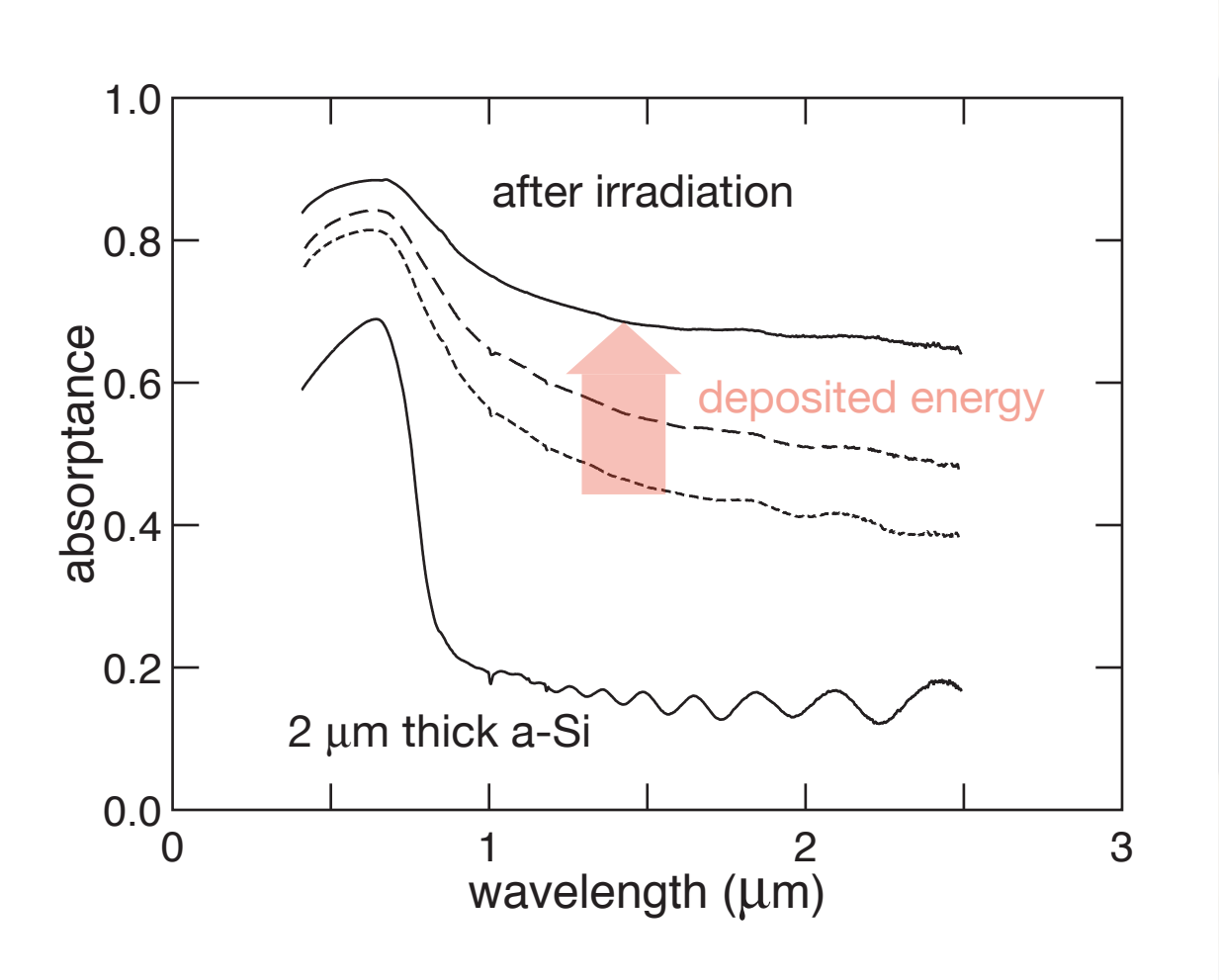


Thin-film silicon results

irradiation of amorphous silicon thin-film



Outlook

manufacture solar cells from femtosecond-laser microstructured thin-film silicon

Summary

femtosecond-laser microstructured silicon:

- absorbs nearly all incident sunlight
- can be incorporated into a photovoltaic device
- may increase efficiency of silicon thin film solar cells

Acknowledgements

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http://mazur-www.harvard.edu/