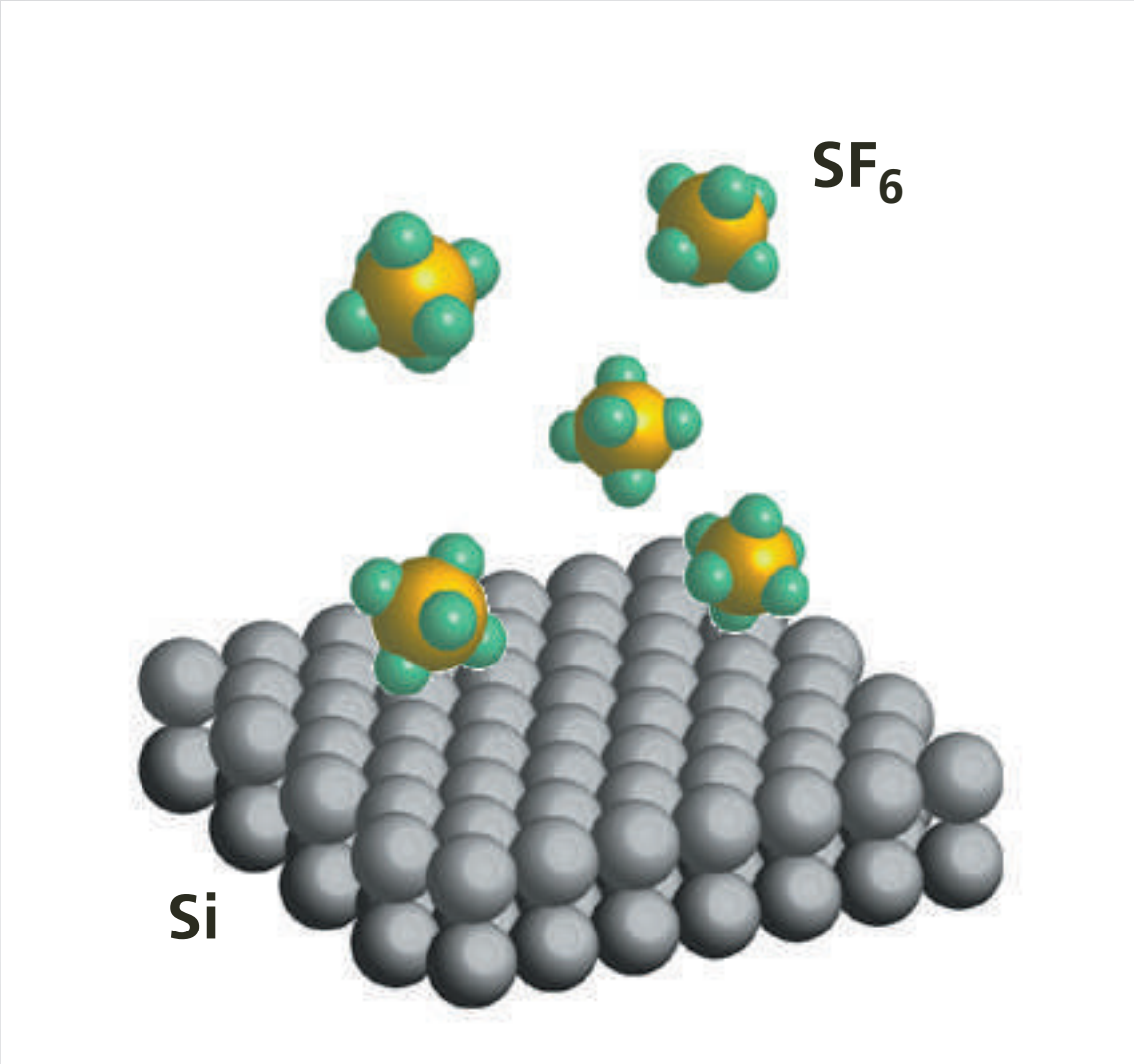
Femtosecond laser-assisted fabrication of micro- and nanostructure arrays

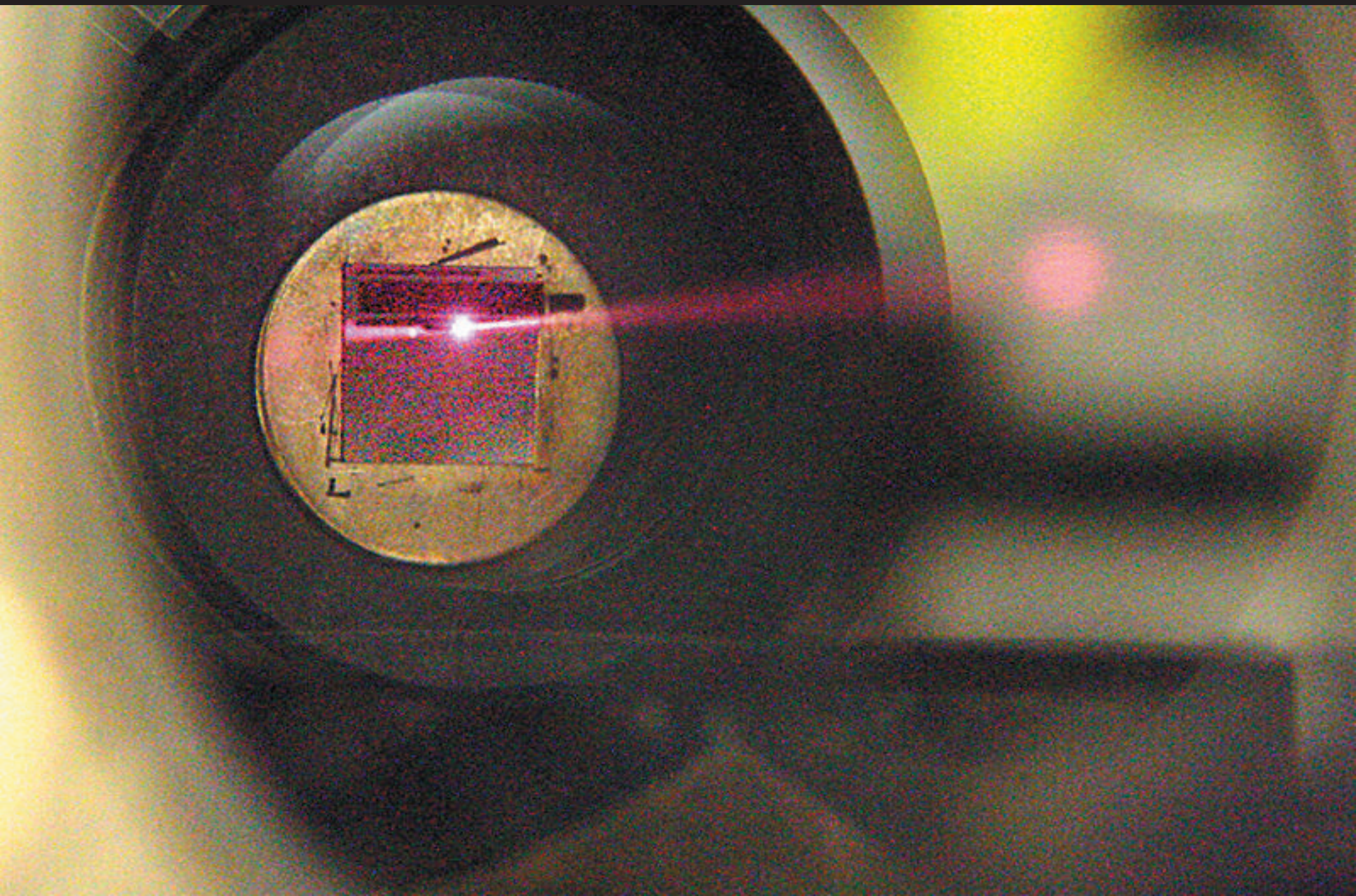
DARPA review
Arlington, VA, 31 May 2005

Introduction

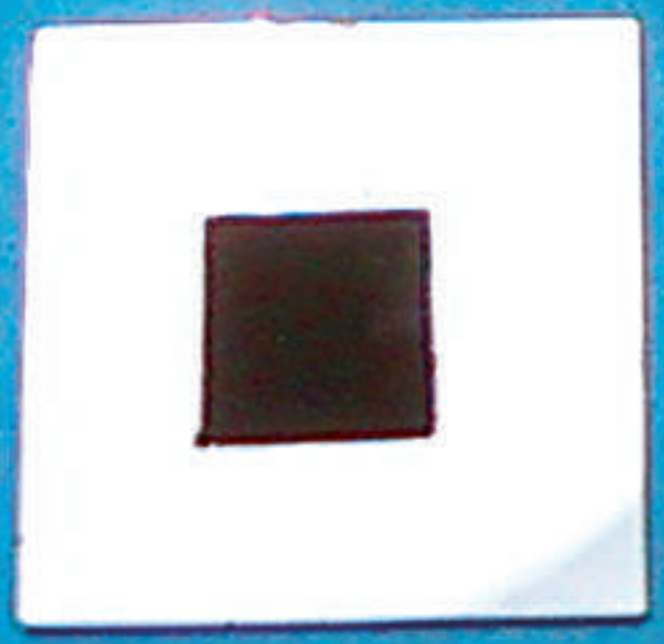


irradiate with 100-fs 10 kJ/m^2 pulses

Introduction

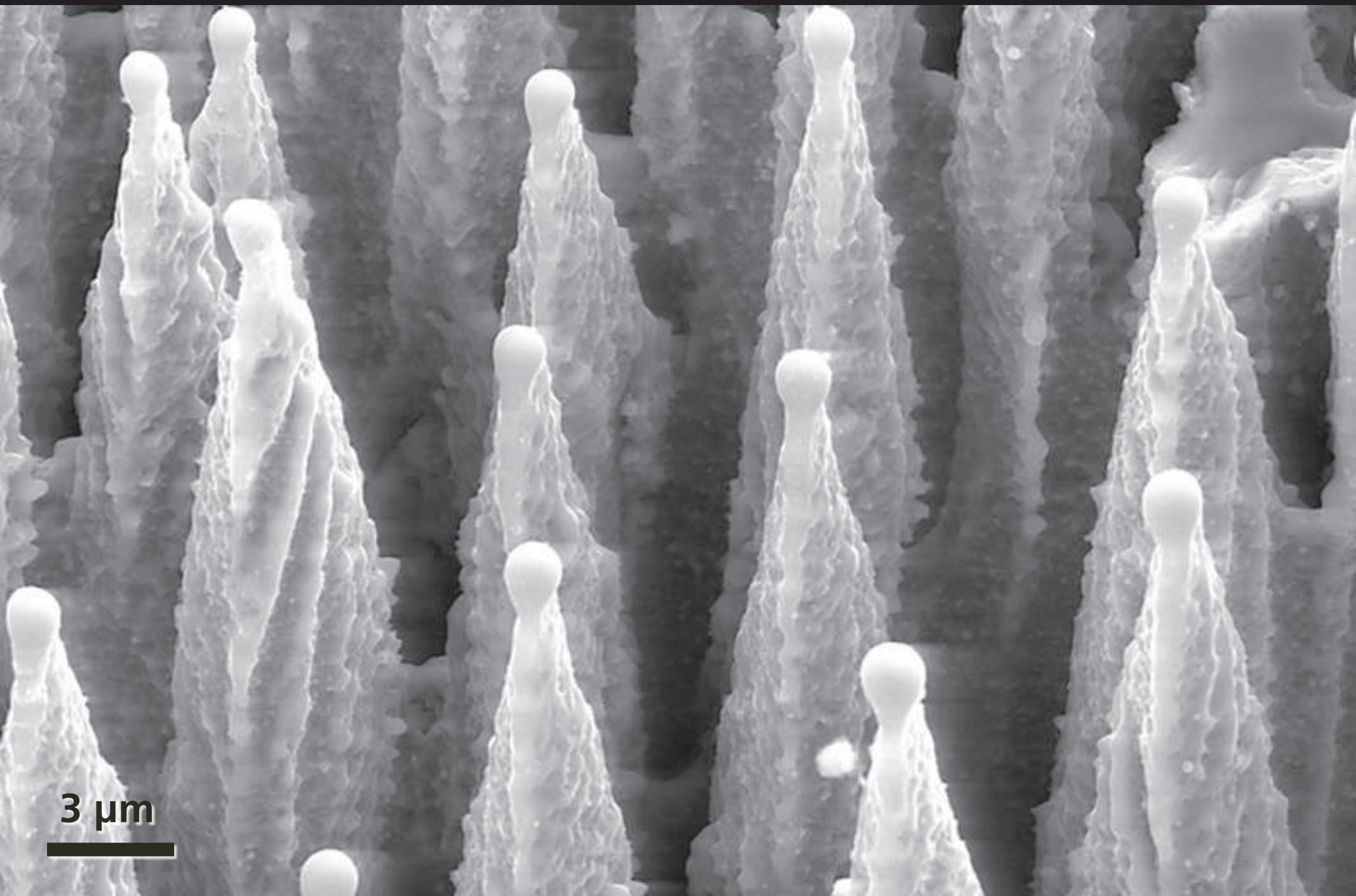


Introduction



“black silicon”

Introduction



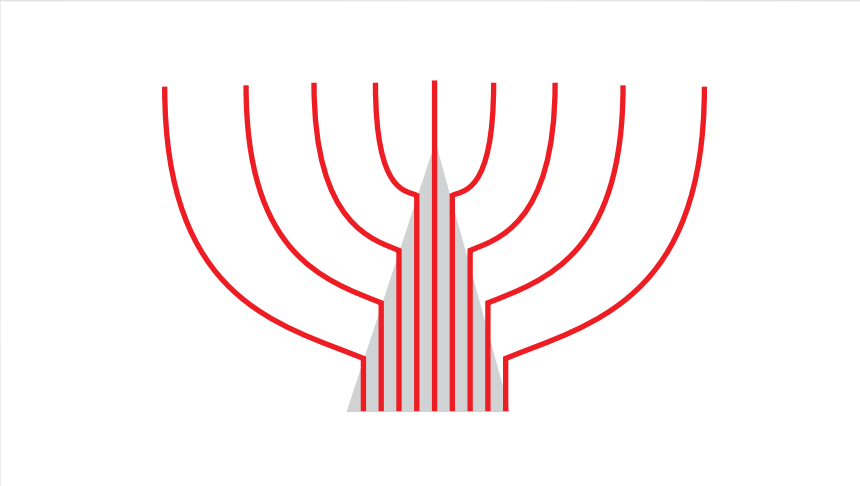
Introduction

Use microstructures to create high-gradient B-fields

Introduction

Force on particle in magnetic field gradient:

$$F = \chi \, V \left(\tfrac{1}{2} \nabla^2 H\right)$$

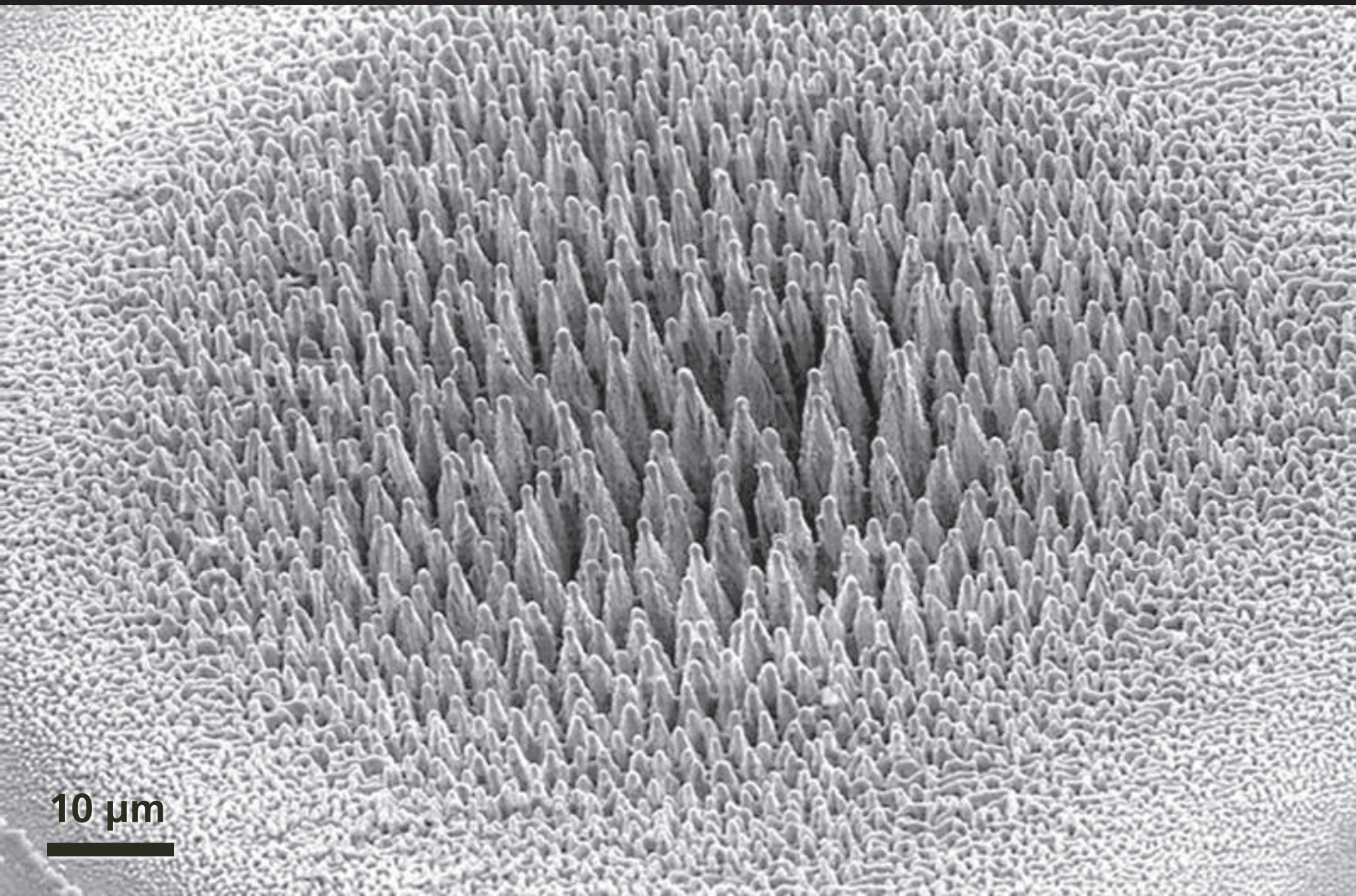


sharp tip produces high gradient

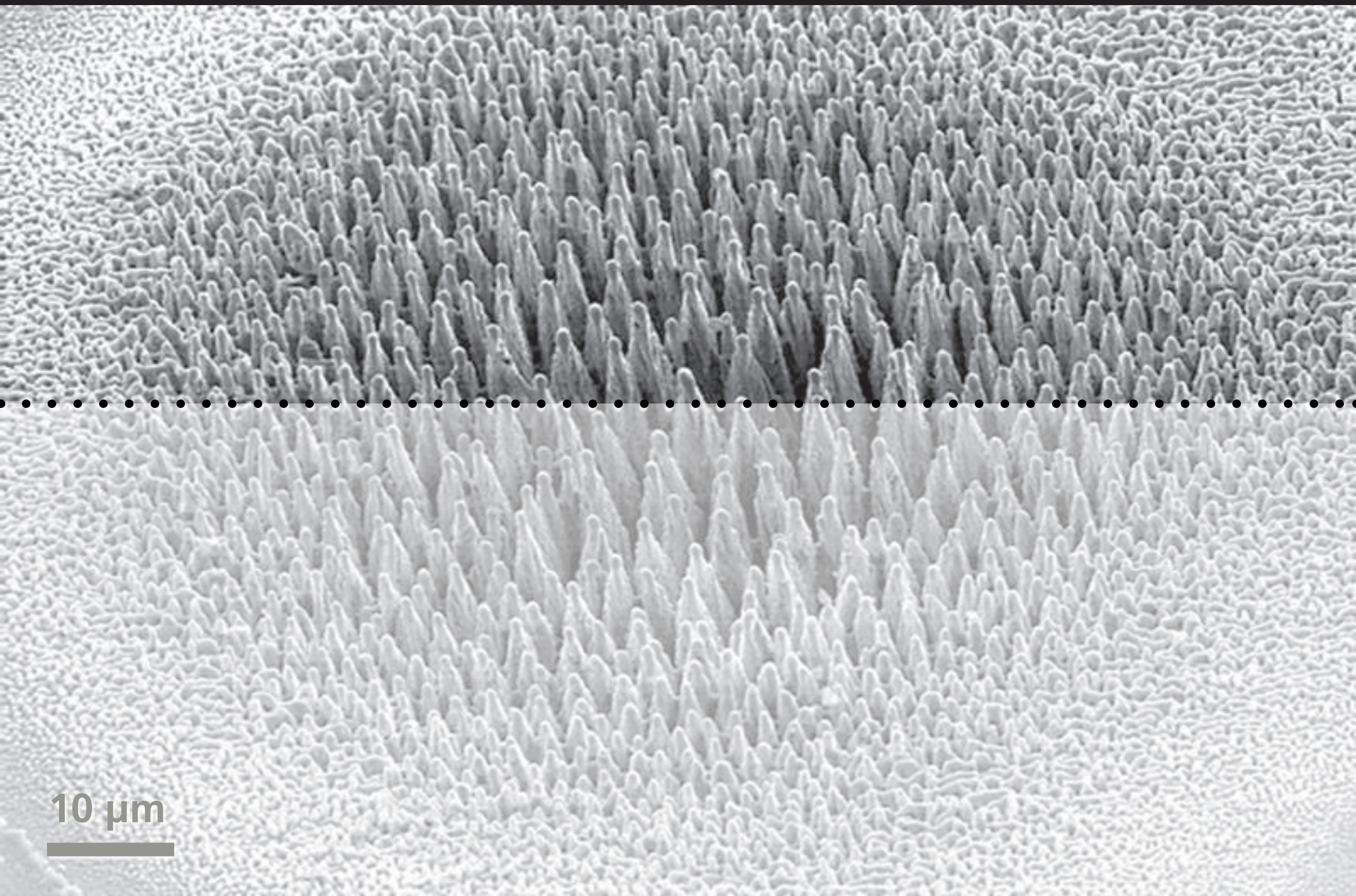
Outline

- silicon microstructures
- magnetic microstructures
- nanomagnetics

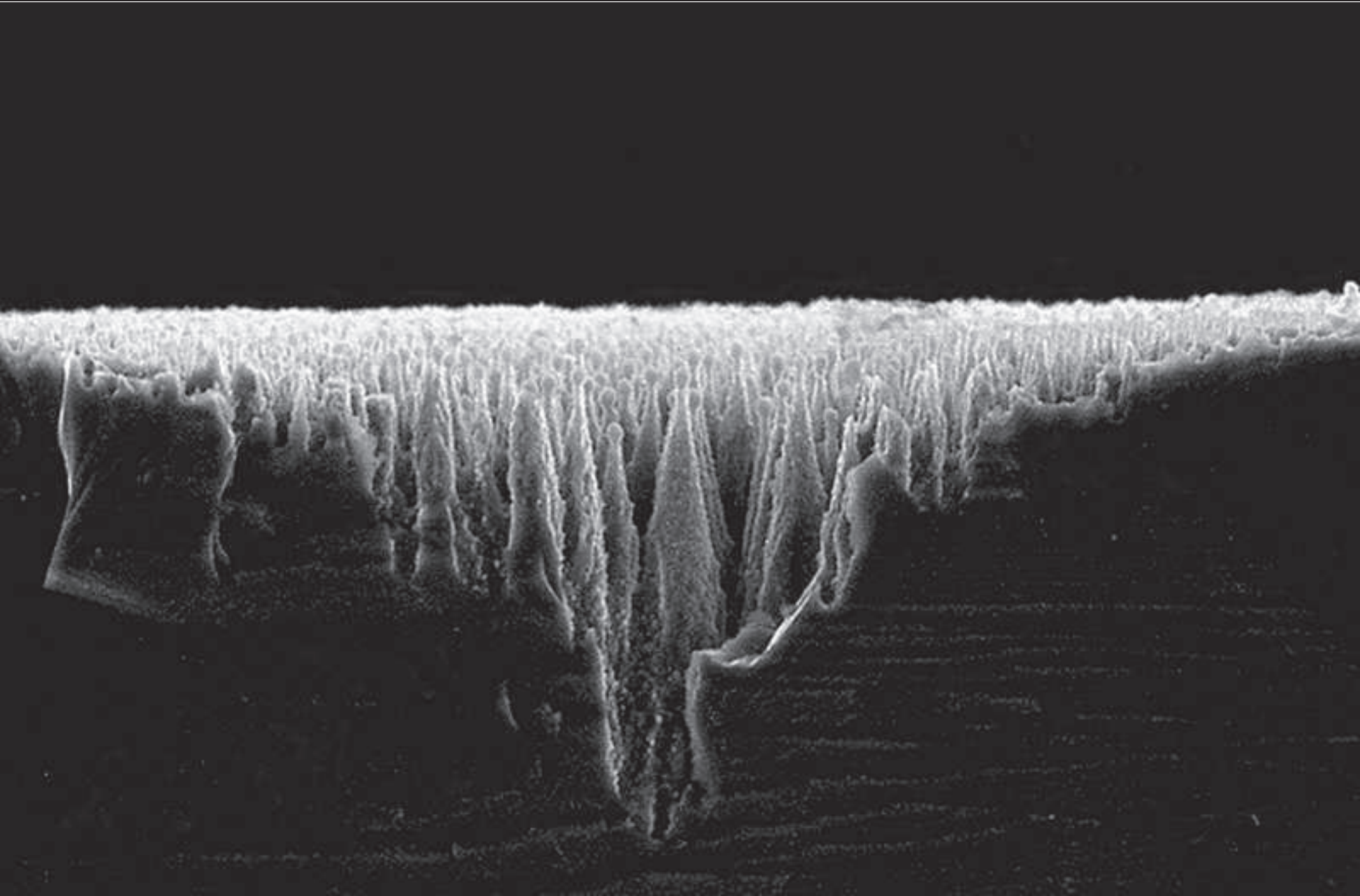
Silicon microstructures



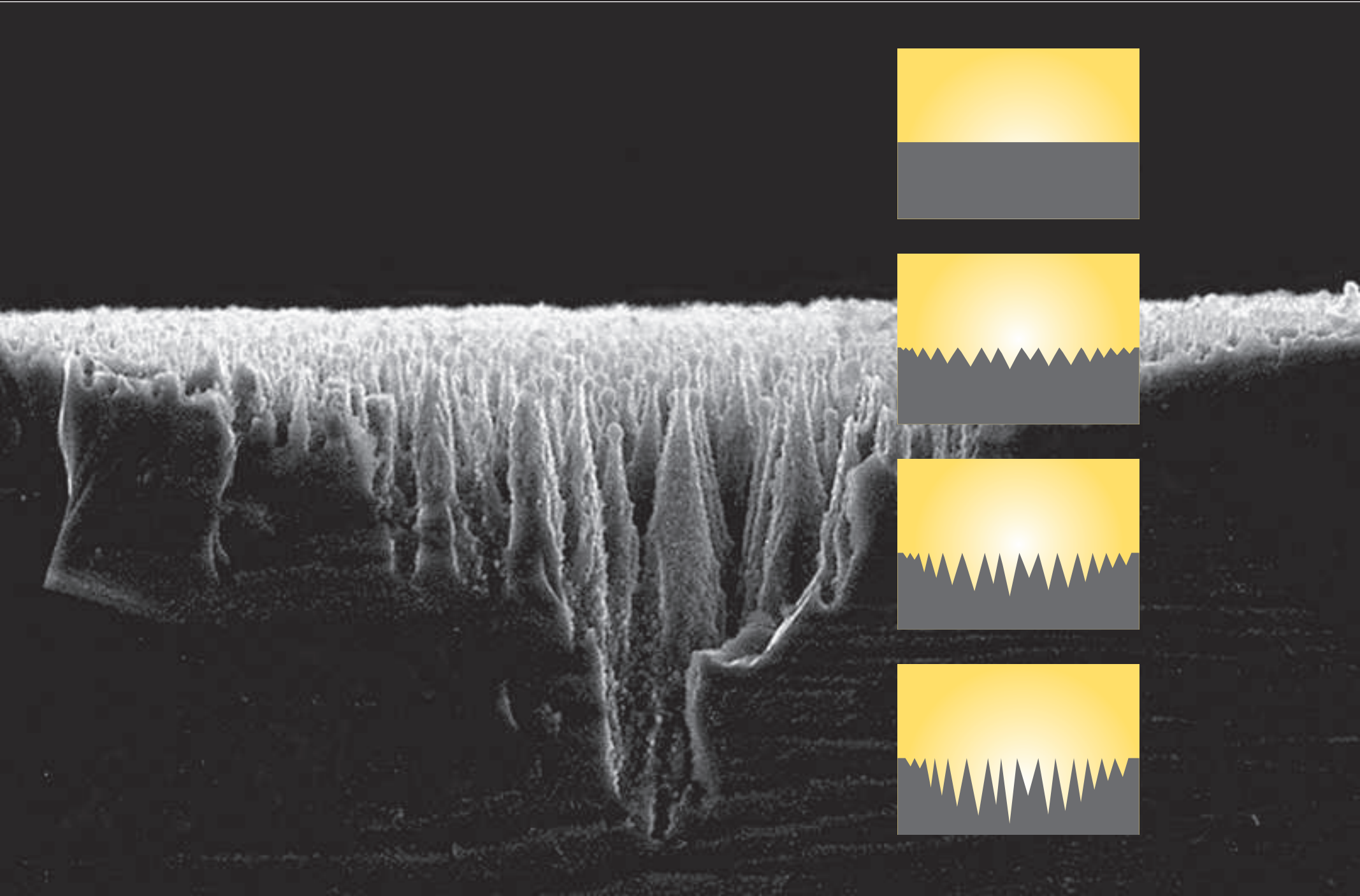
Silicon microstructures



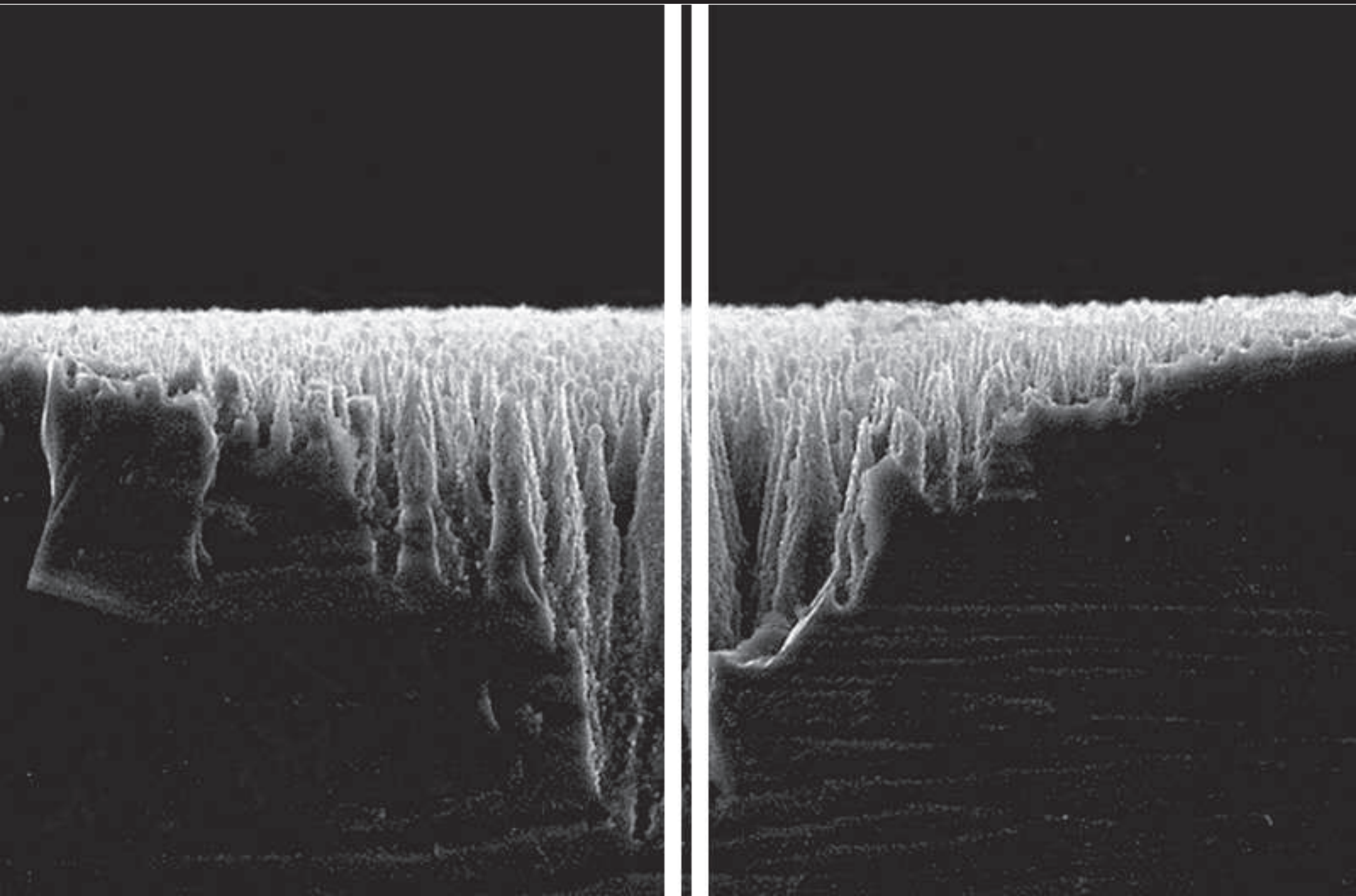
Silicon microstructures



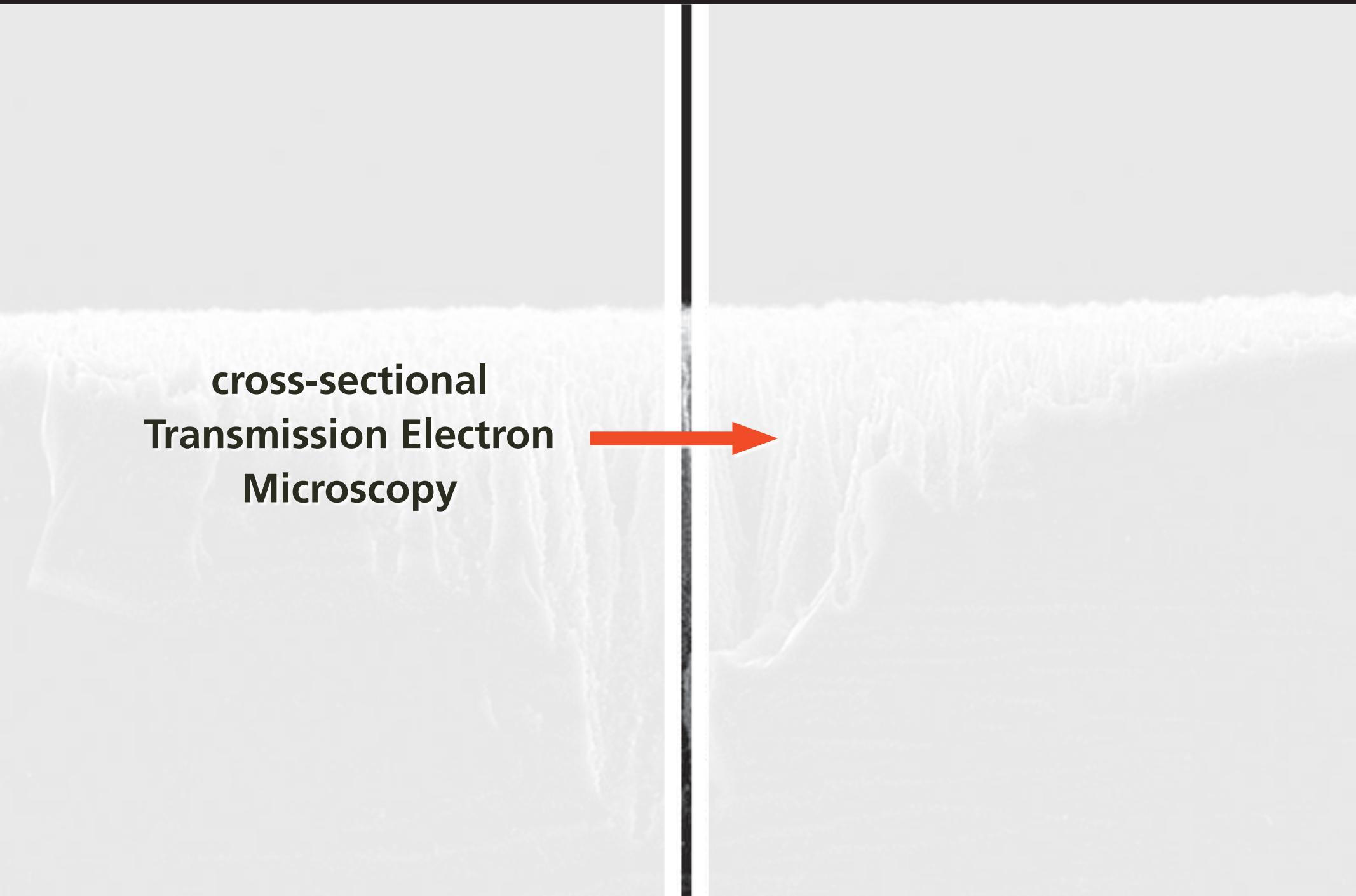
Silicon microstructures



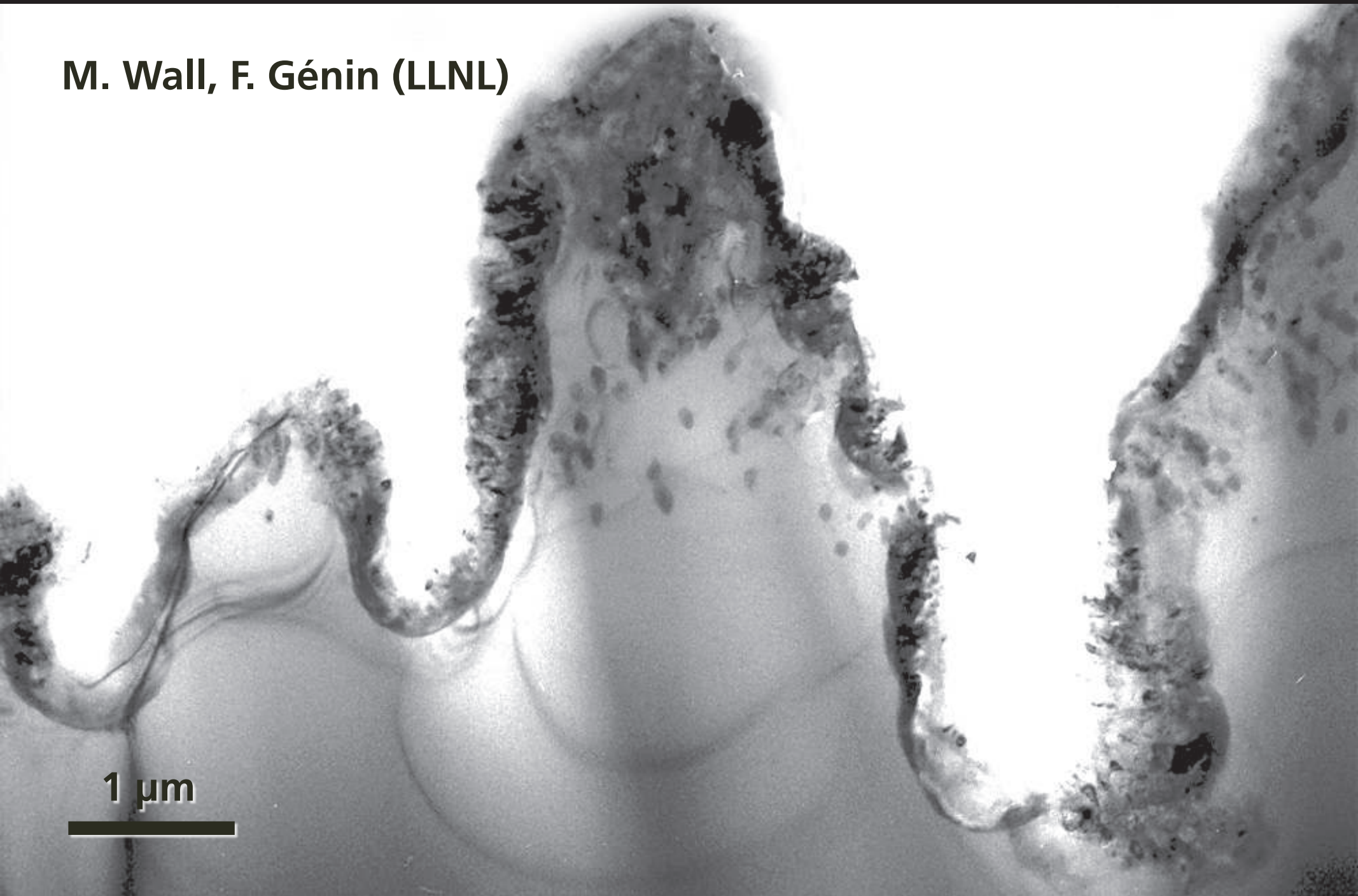
Silicon microstructures



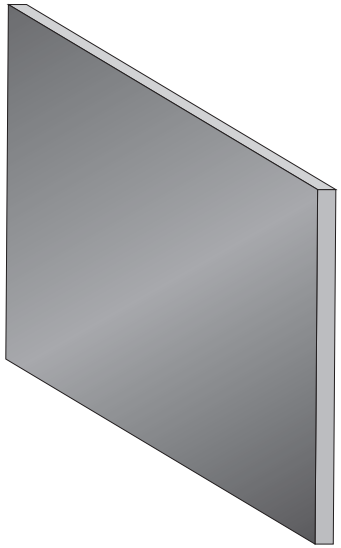
Silicon microstructures



Silicon microstructures



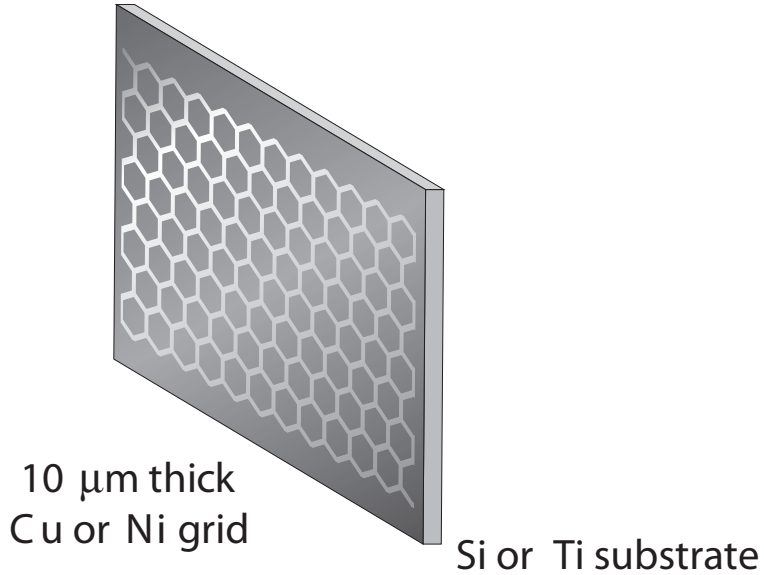
Silicon microstructures



Si or Ti substrate

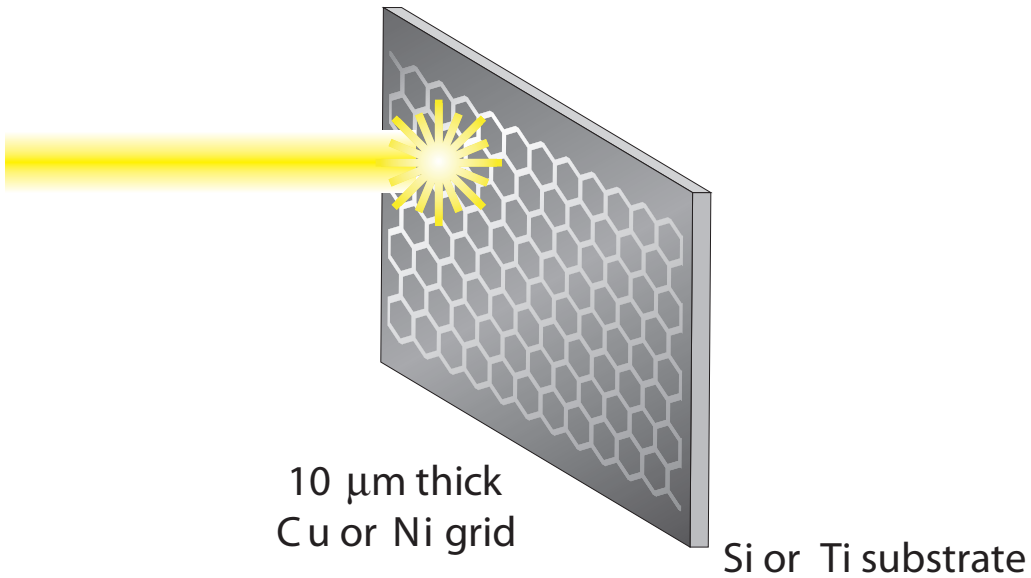
Silicon microstructures

place grid in front of sample



Silicon microstructures

scan laser beam



Silicon microstructures

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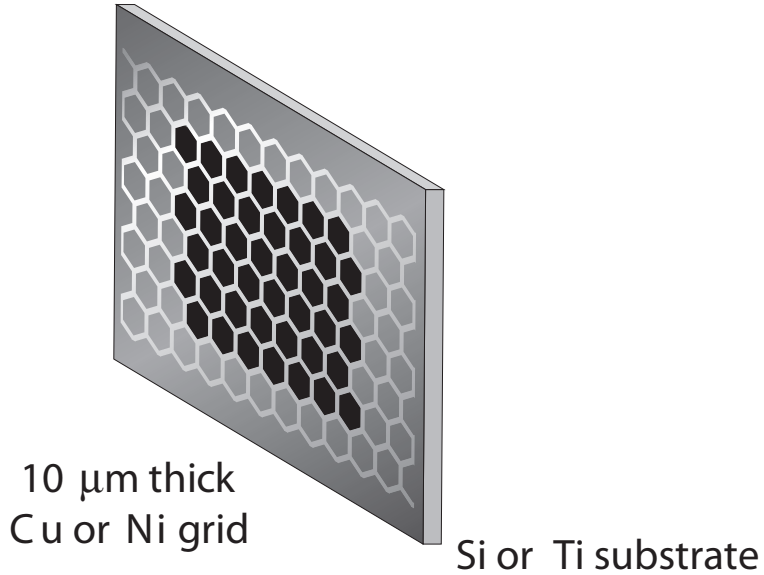
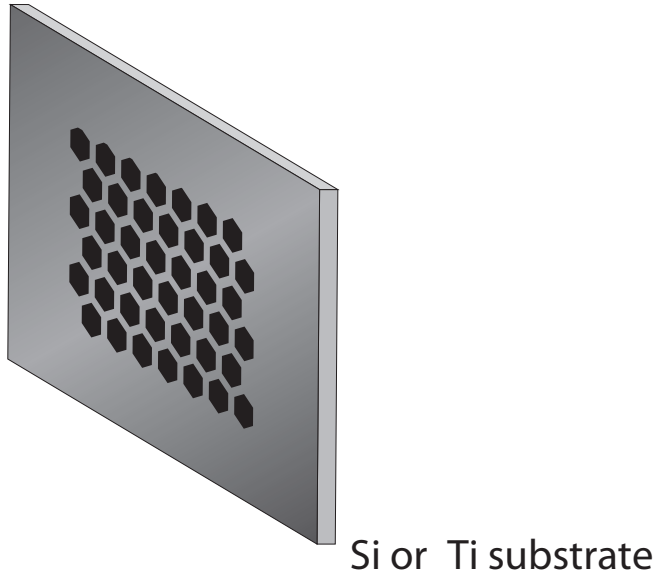
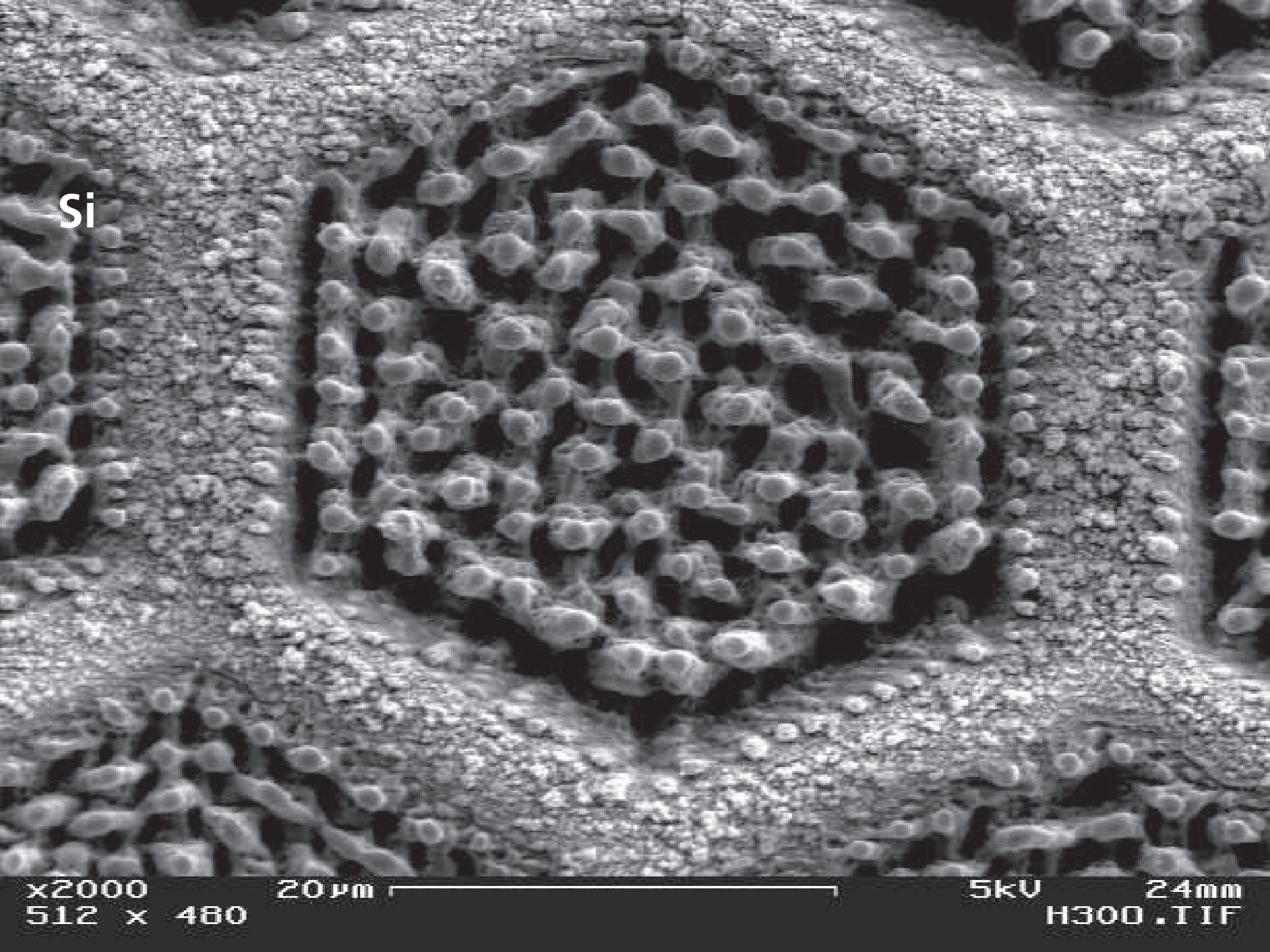


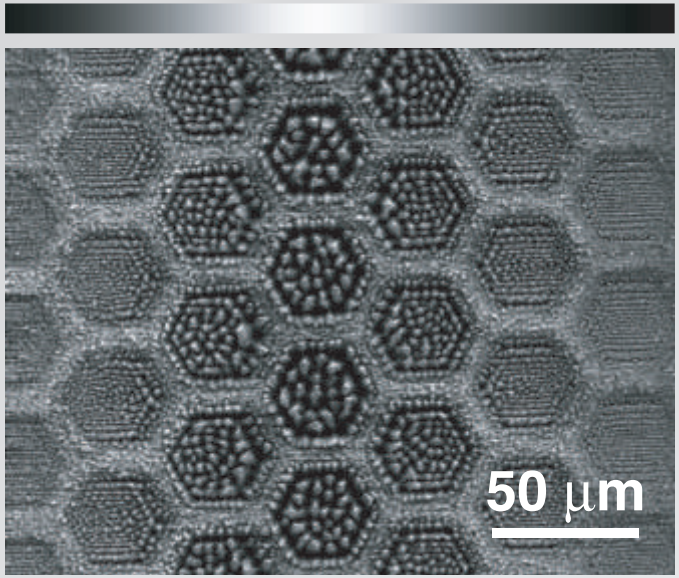
Silicon microstructures

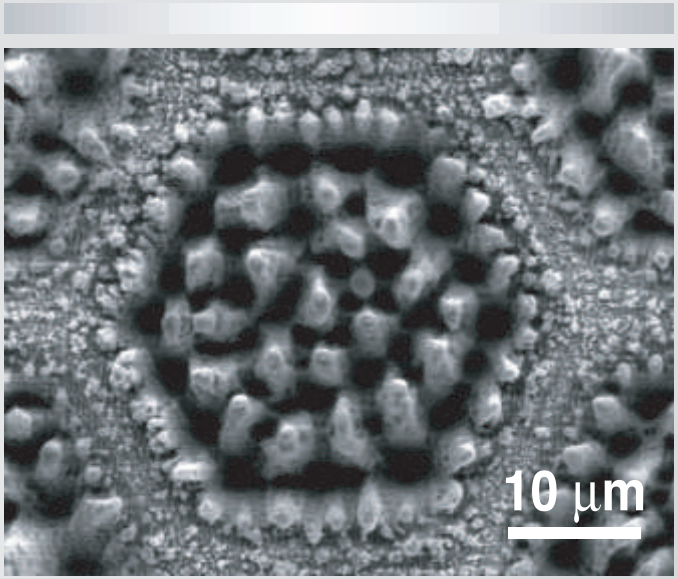
remove grid

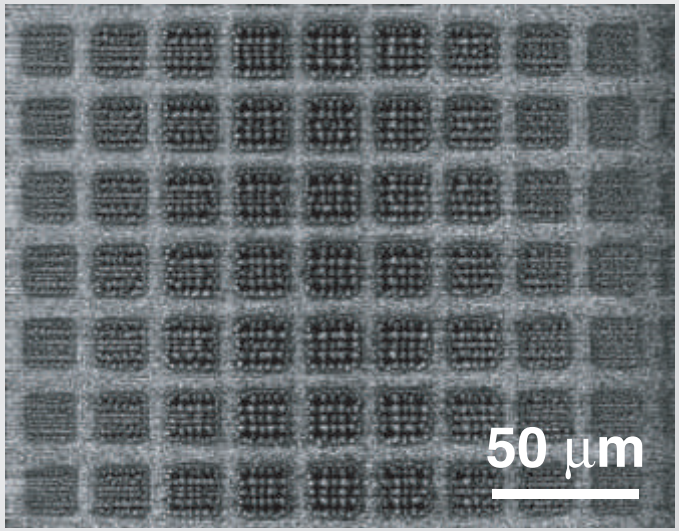


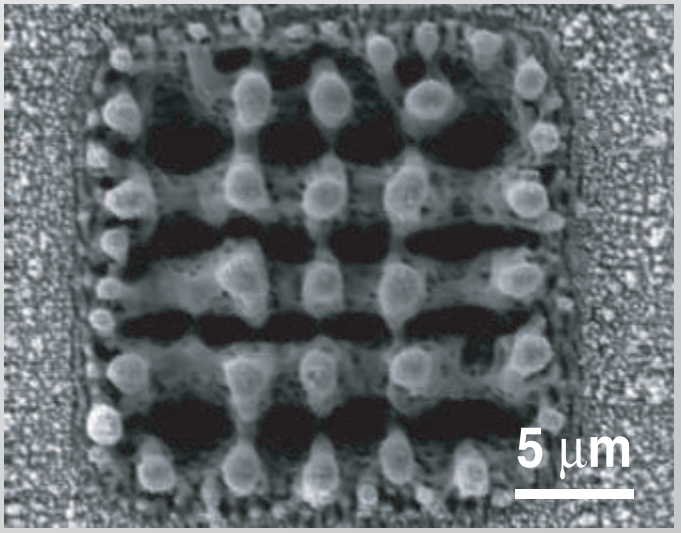

Si
x2000
20μm
5kV
24mm
512 x 480
H300.TIF

Silicon microstructures





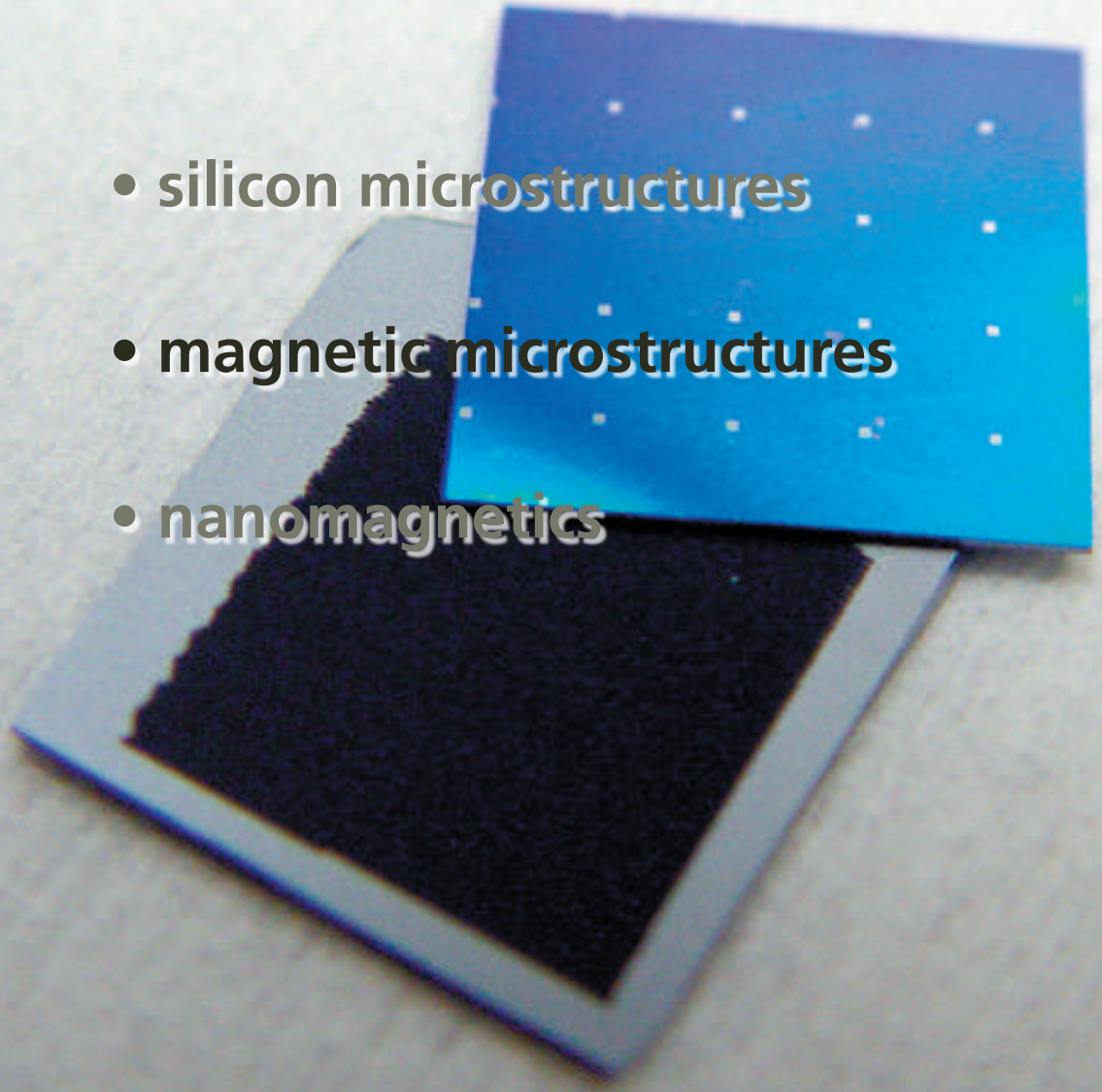




Appl. Phys. Lett., **82**, 1715 (2003)

Outline

- silicon microstructures
- magnetic microstructures
- nanomagnetics



Magnetic microstructures

Fabricating magnetic microstructures:

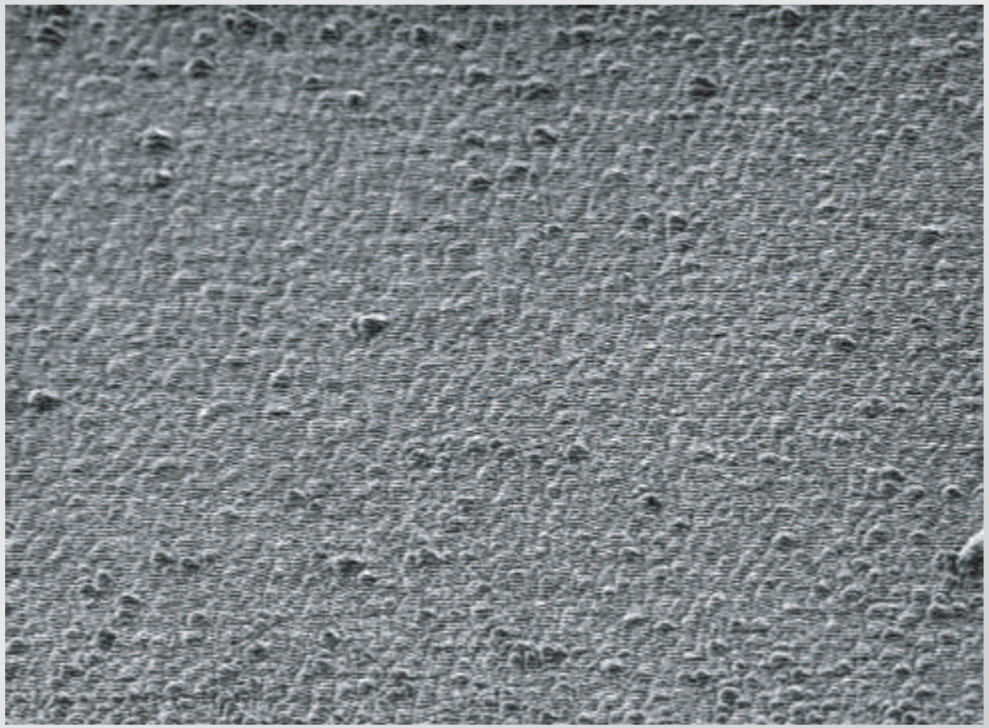
- structure magnetic materials
- coat silicon microstructures

Magnetic microstructures

fs microstructuring does not work on all materials

Magnetic microstructures

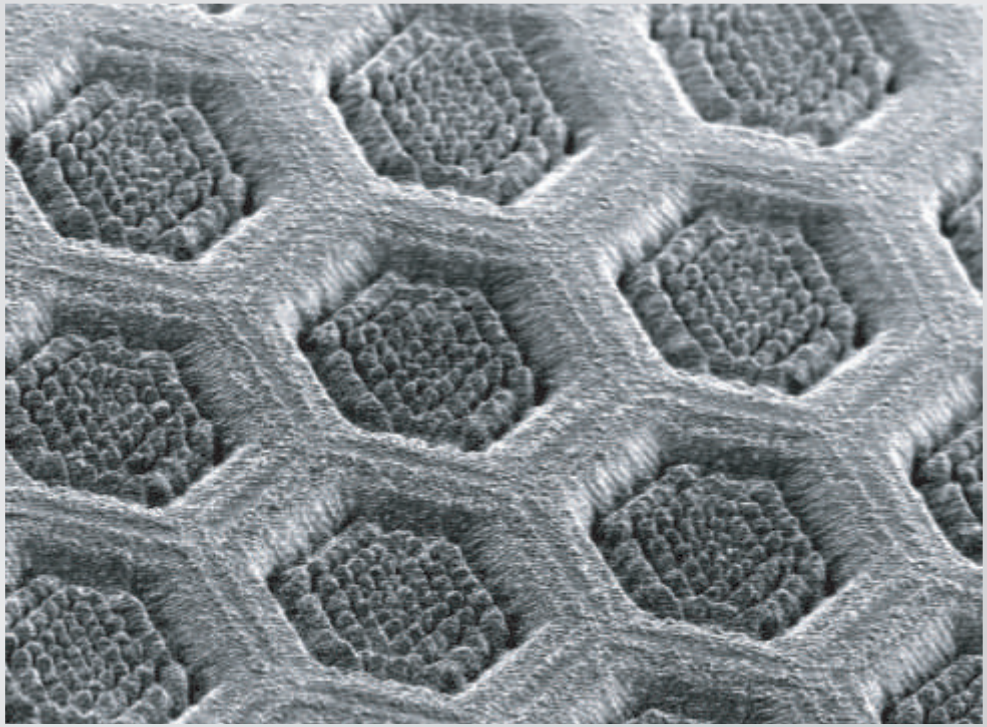
fs microstructuring does not work on all materials



stainless steel

Magnetic microstructures

…but microstructuring through grid often does work



stainless steel with grid

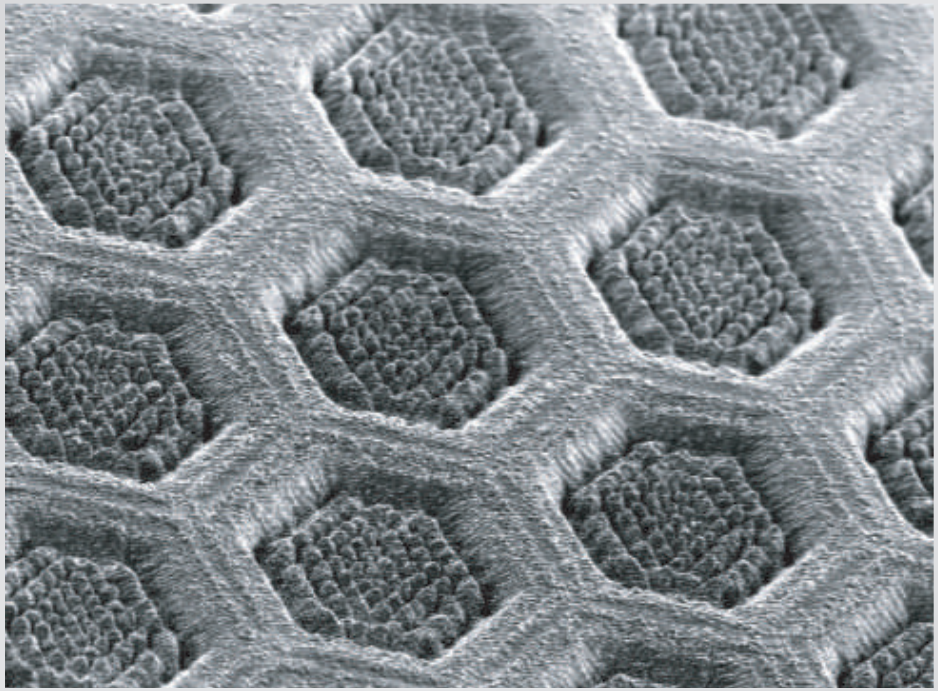
Magnetic microstructures

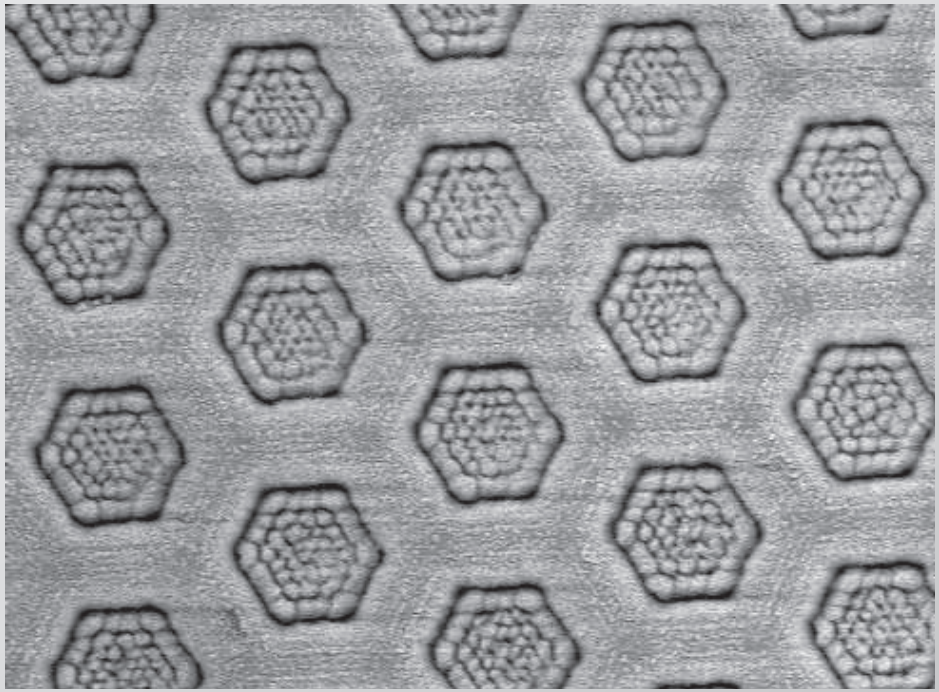
use TEM grids to pattern:

- carbon steel
- stainless steel
- Co/Fe alloys

Magnetic microstructures

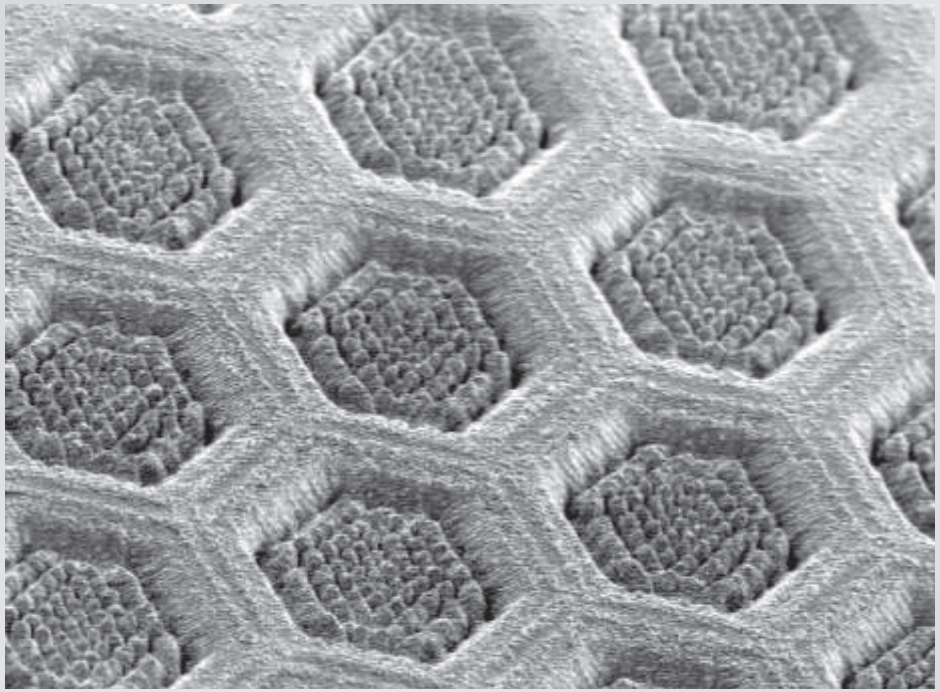
stainless steel

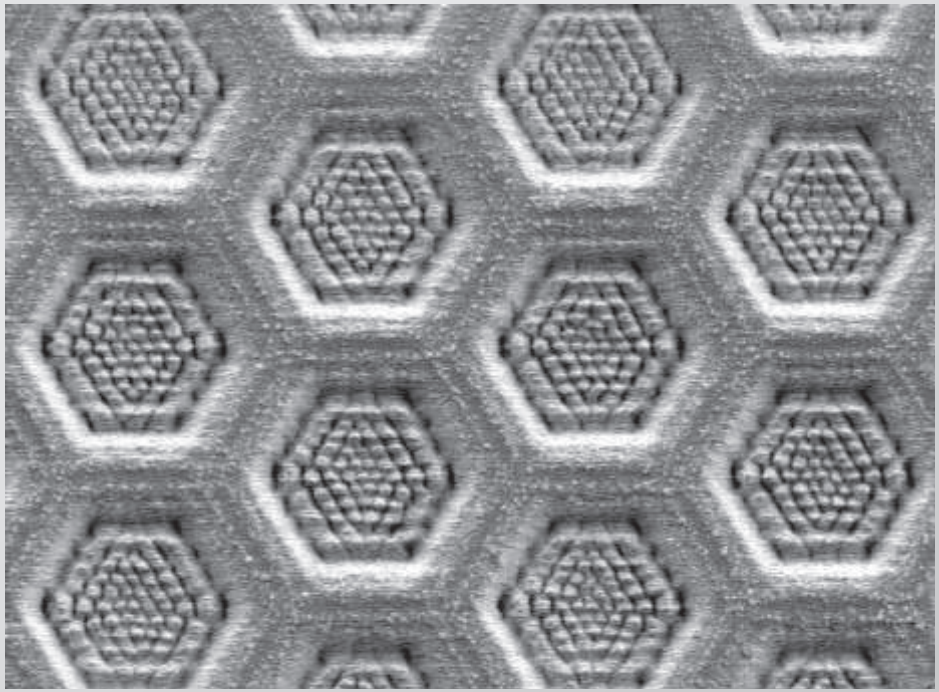




Magnetic microstructures

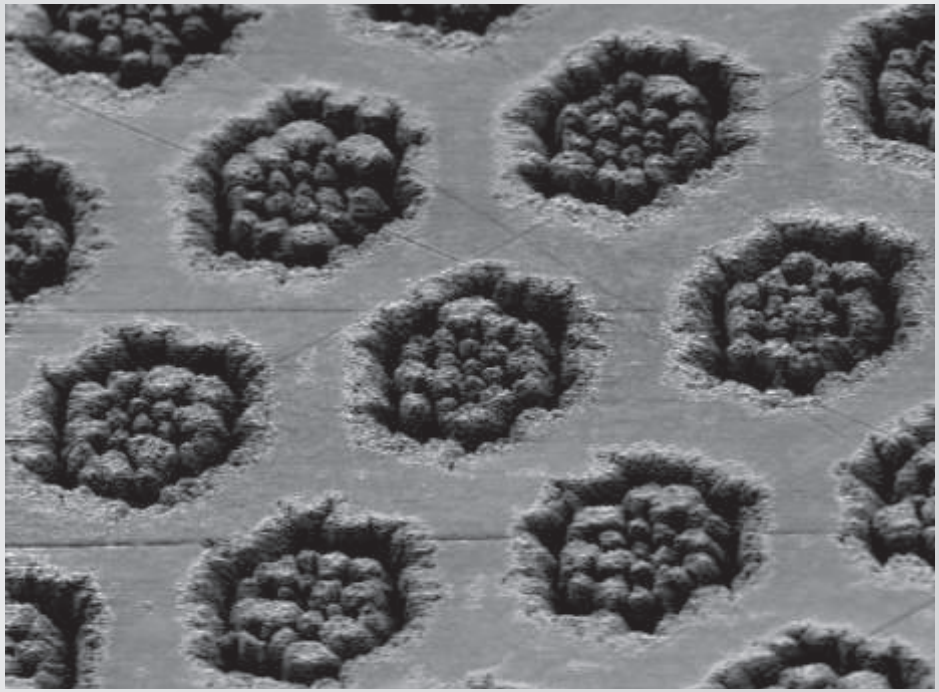
carbon steel





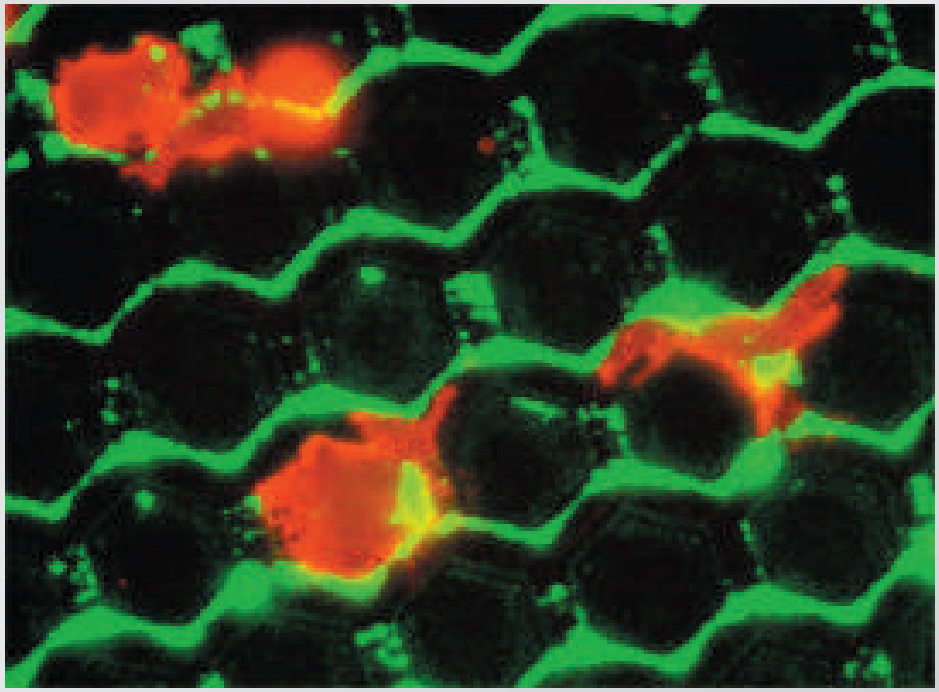
Magnetic microstructures

Co/Fe alloys



Magnetic microstructures

cells on carbon steel



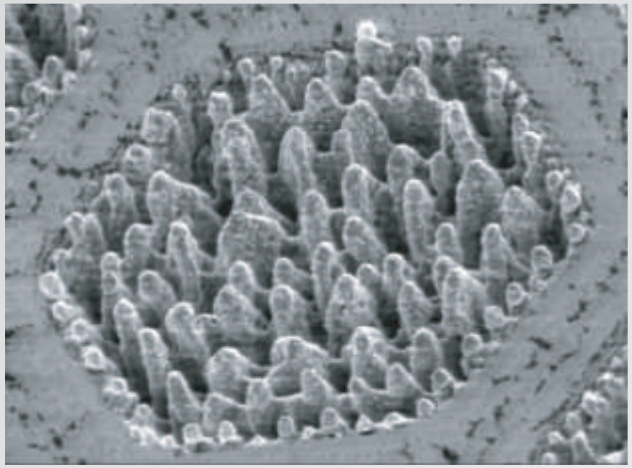
works, but not durable

Magnetic microstructures

alternative approach: coat silicon tips with Co and Au

Magnetic microstructures

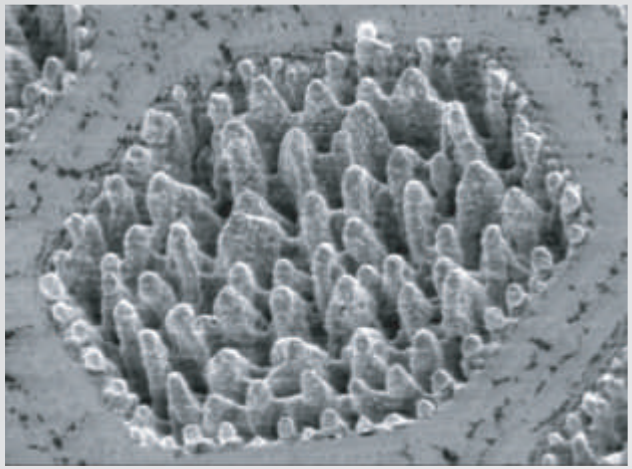
microstructure silicon, then coat with Co and Au



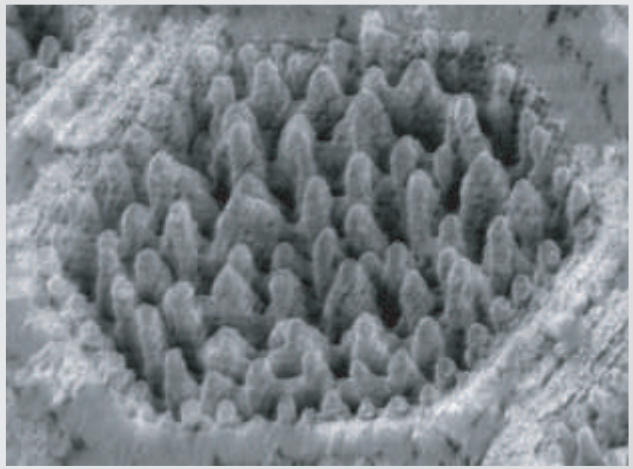
structure silicon

Magnetic microstructures

microstructure silicon, then coat with Co and Au



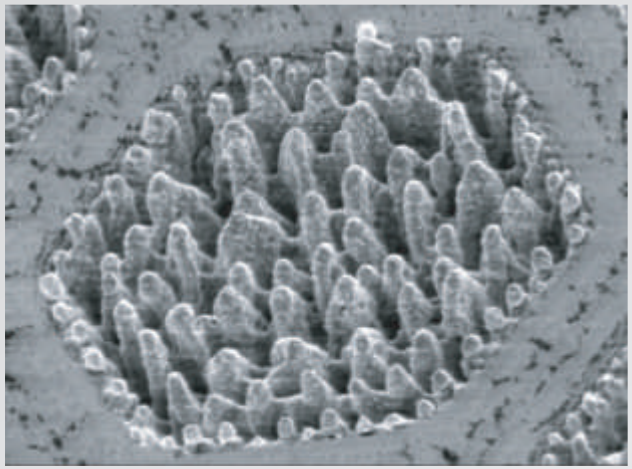
structure silicon



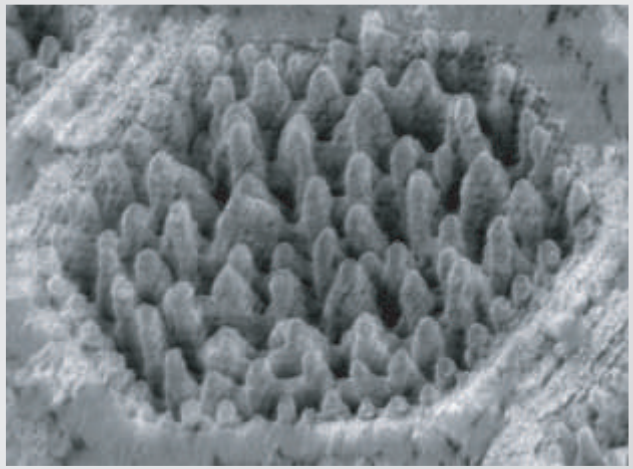
add 50 nm Co

Magnetic microstructures

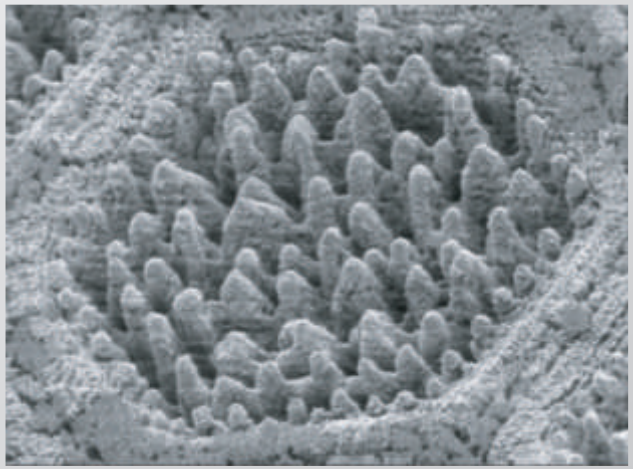
microstructure silicon, then coat with Co and Au



structure silicon



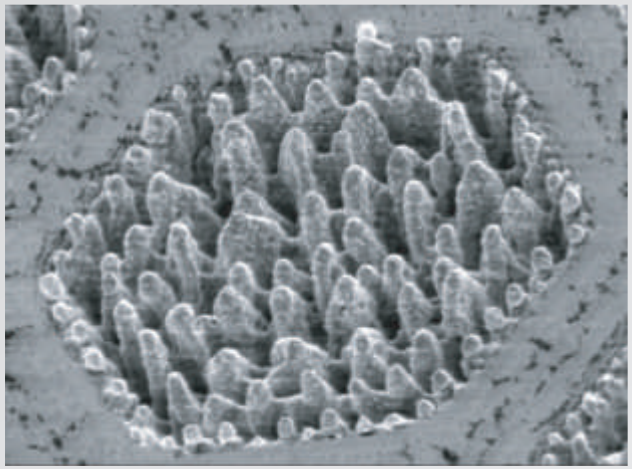
add 50 nm Co



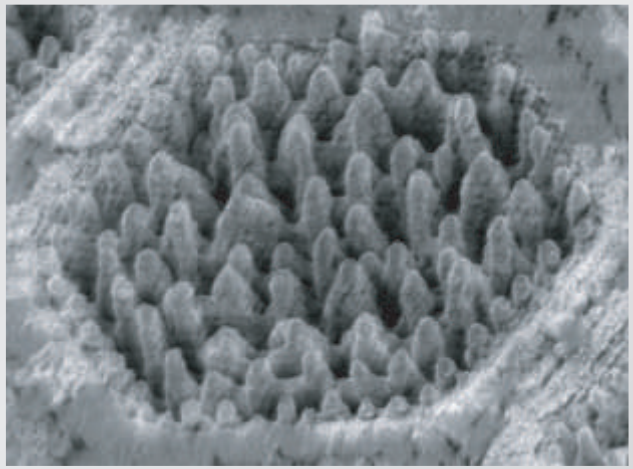
add 5 nm Au

Magnetic microstructures

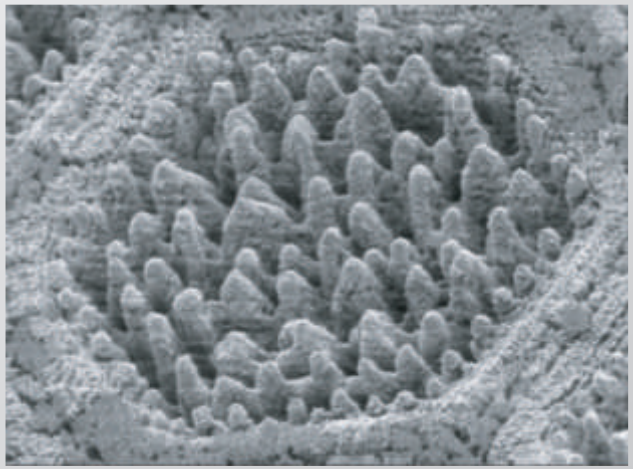
microstructure silicon, then coat with Co and Au



structure silicon



add 50 nm Co

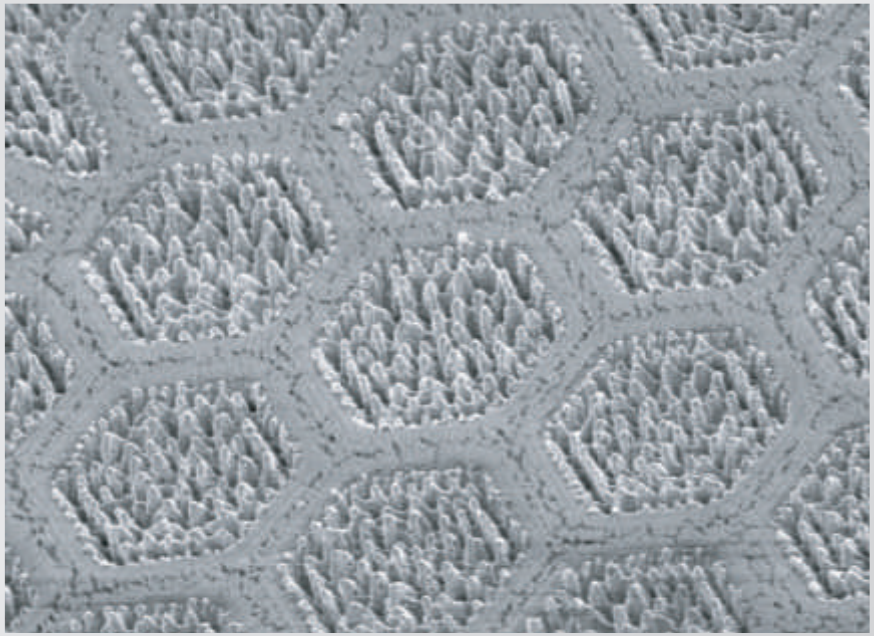


add 5 nm Au

morphology not affected by coating

Magnetic microstructures

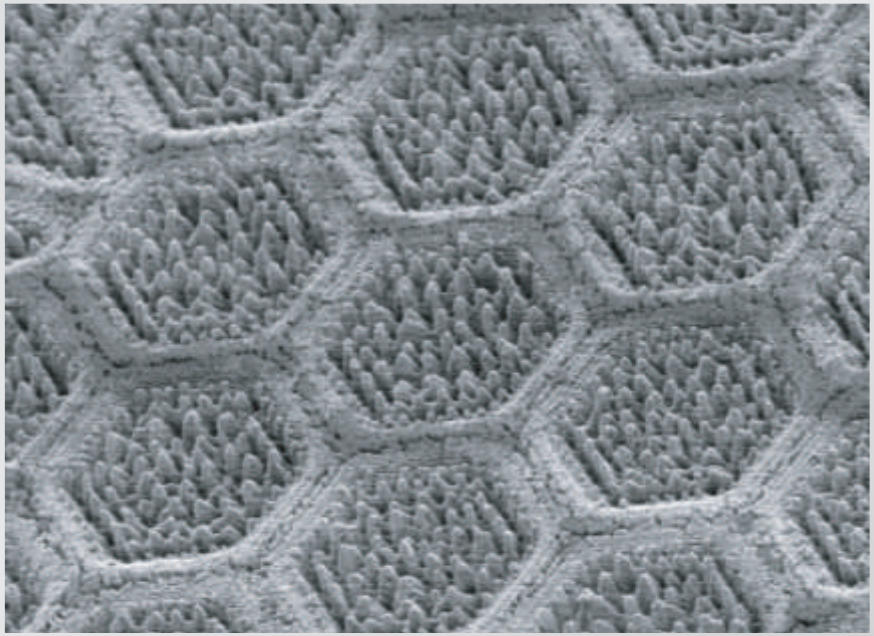
microstructure silicon, then coat with Co and Au



uncoated

Magnetic microstructures

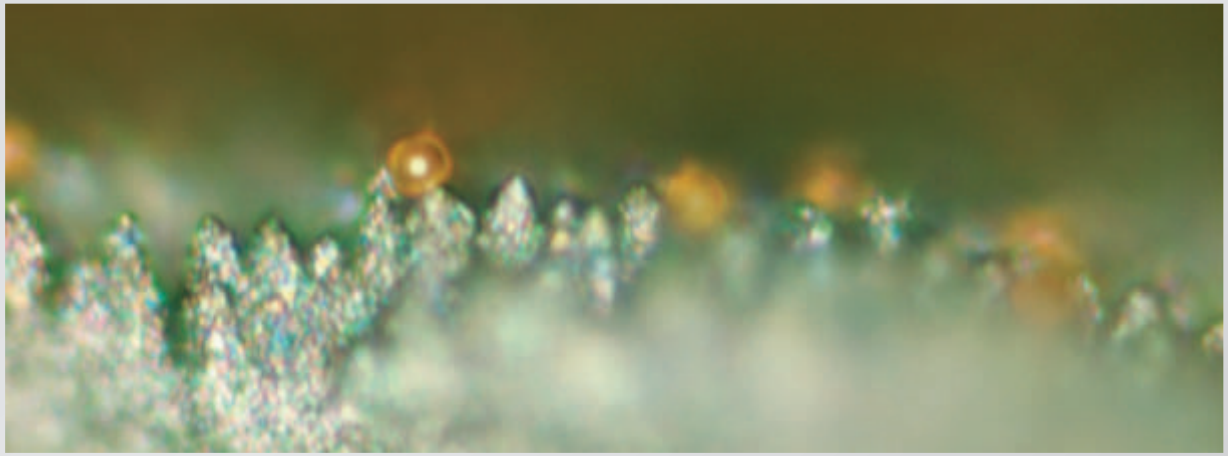
microstructure silicon, then coat with Co and Au



Co/Au coated

Magnetic microstructures

magnetic bead (red) attracted to magnetized spike

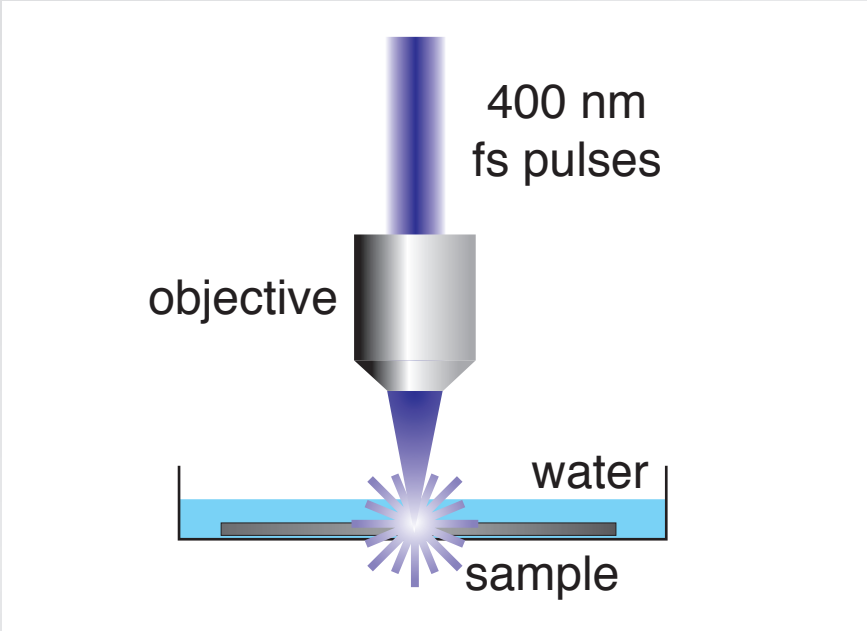


Outline

- silicon microstructures
- magnetic microstructures
- nanomagnetics

Nanomagnetics

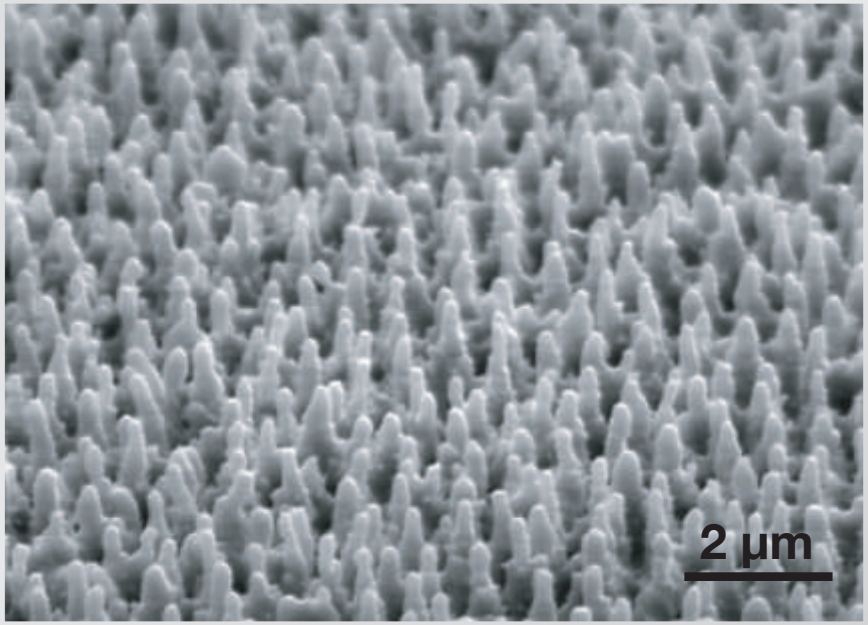
structure silicon in water



***Appl. Phys. Lett.*, 85, 5694 (2004)**

Nanomagnetics

structure silicon in water

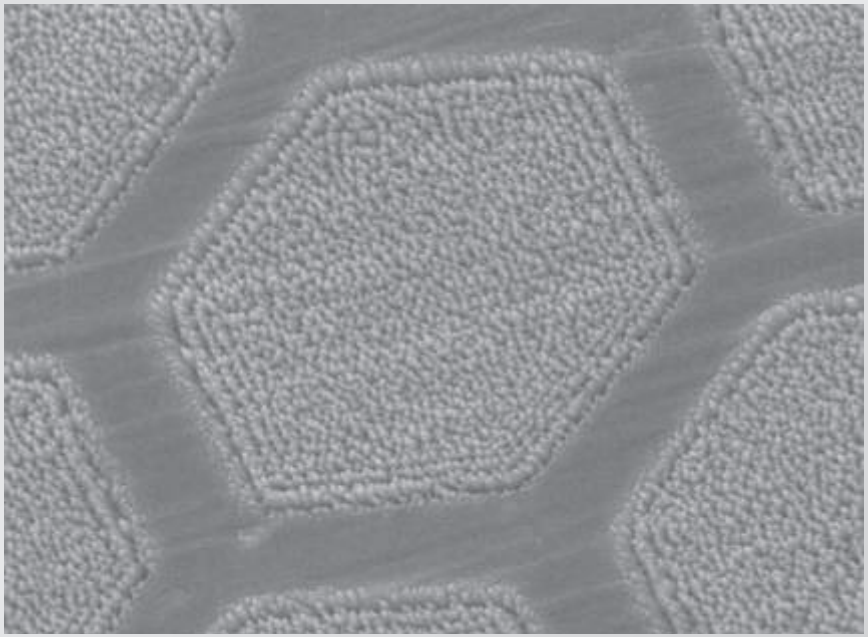


yields nanoscale structure!

Appl. Phys. Lett., 85, 5694 (2004)

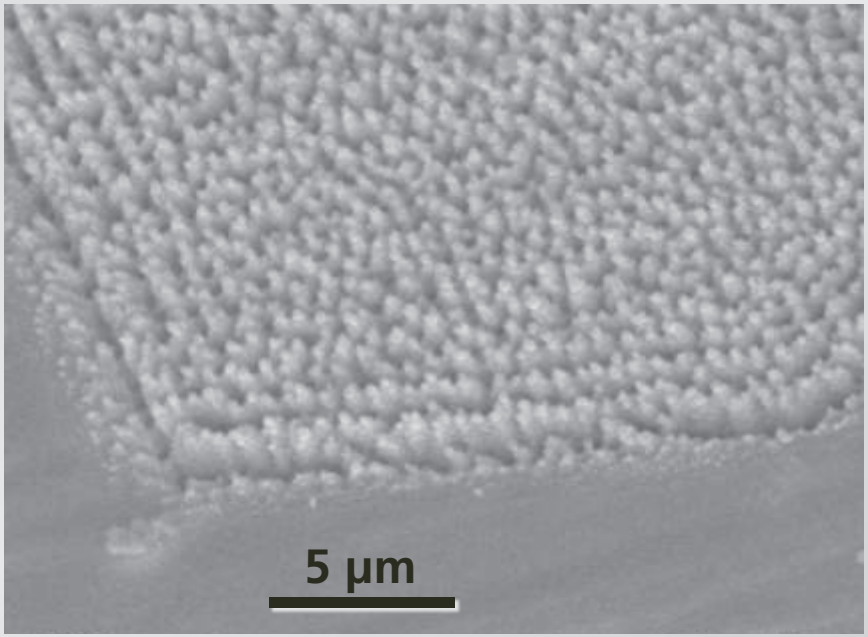
Nanomagnetics

also works on stainless steel



Nanomagnetics

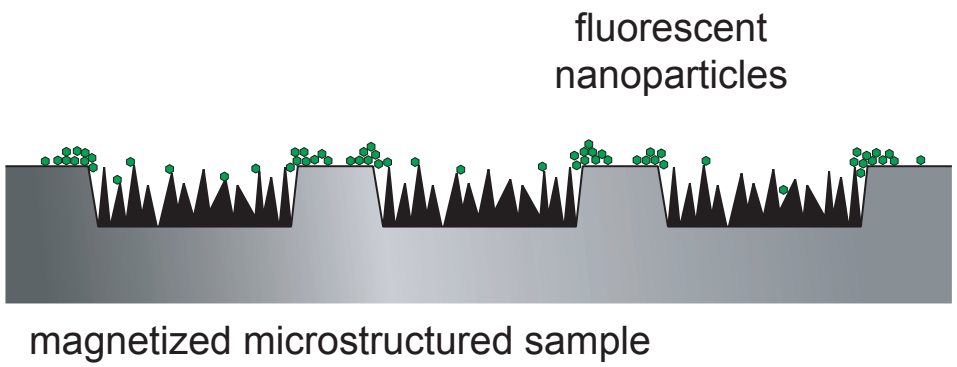
also works on stainless steel



nanoscale spikes!

Nanomagnetics

but how can we get rid of the high edges?



Nanomagnetics

micromachine 95 µm grid on stainless steel

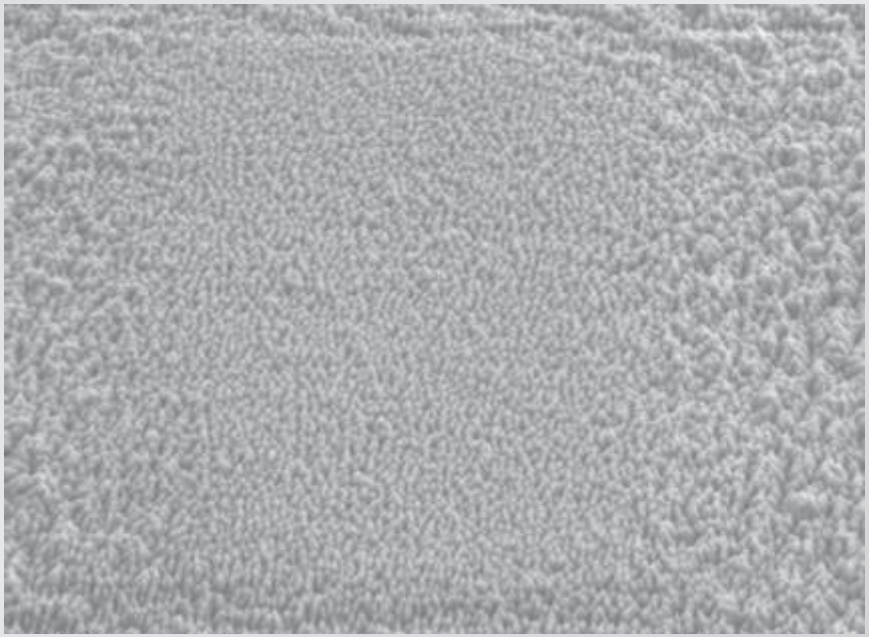
Nanomagnetics

micromachine 95 μm grid on stainless steel

then lightly polish and nanostructure squares

Nanomagnetics

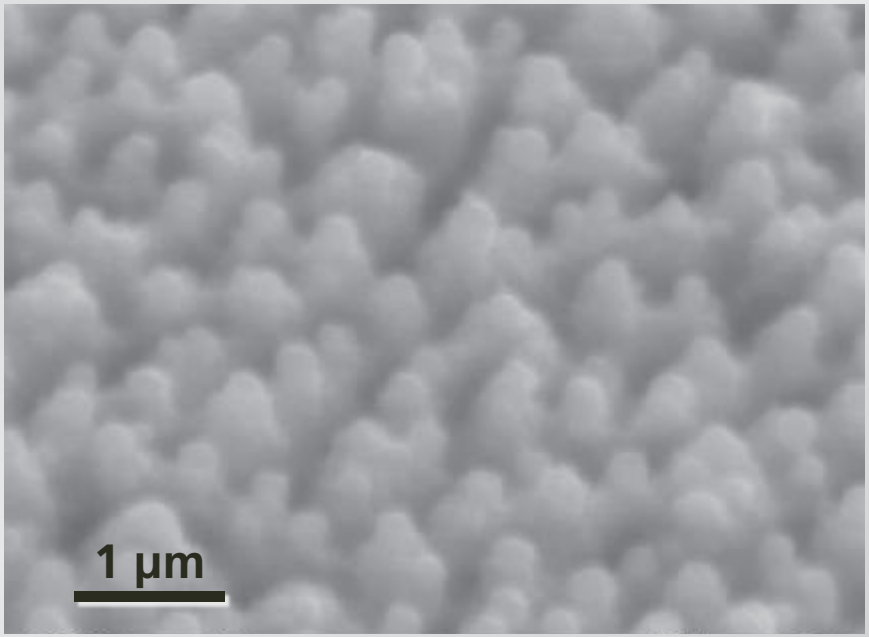
micromachine 95 μm grid on stainless steel



then lightly polish and nanostructure squares

Nanomagnetics

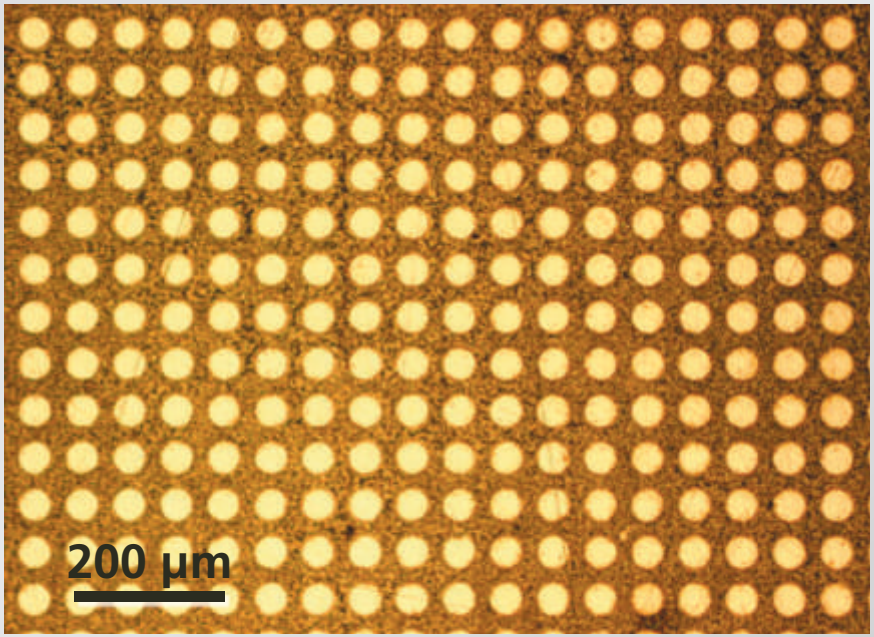
micromachine 95 μm grid on stainless steel



then lightly polish and nanostructure squares

Nanomagnetics

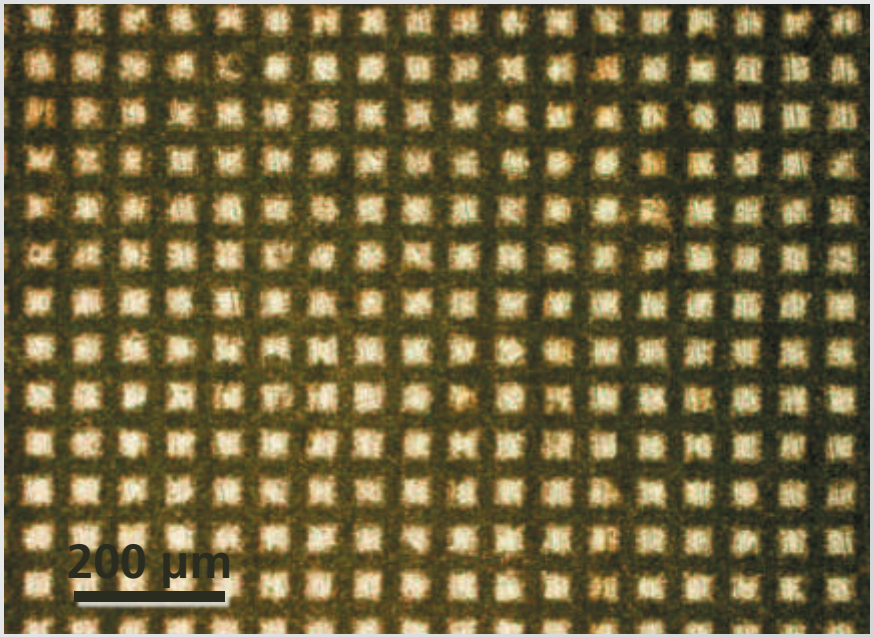
alternatively: use photolithography to create throughs



circular islands

Nanomagnetics

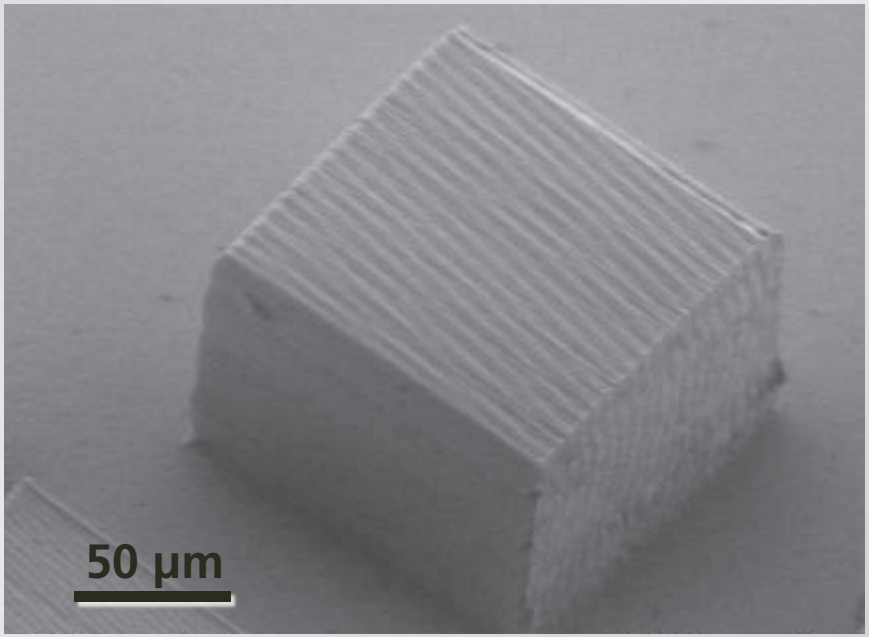
alternatively: use photolithography to create throughs



square islands

Nanomagnetics

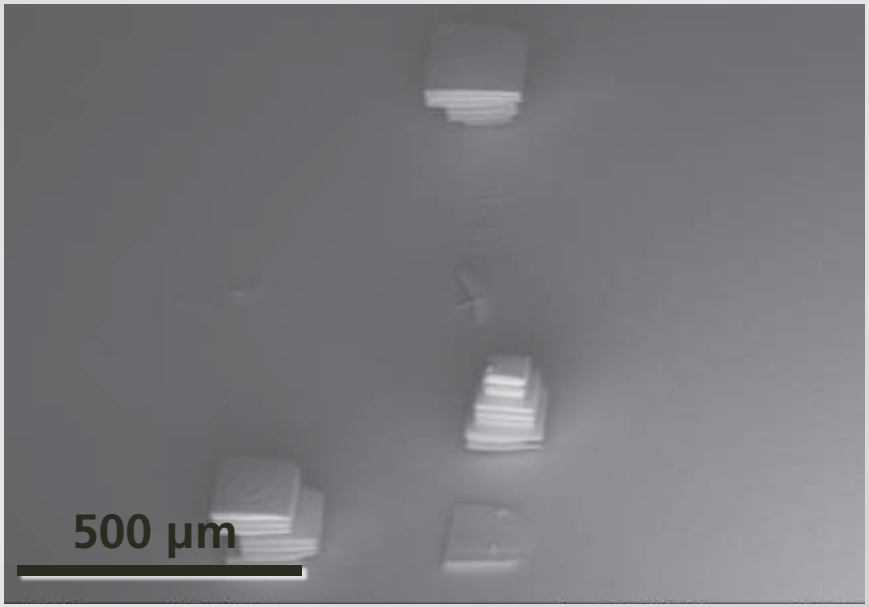
coming year: combine with 2-photon photopolymerization



create 3D microstructures for microfluidics

Nanomagnetics

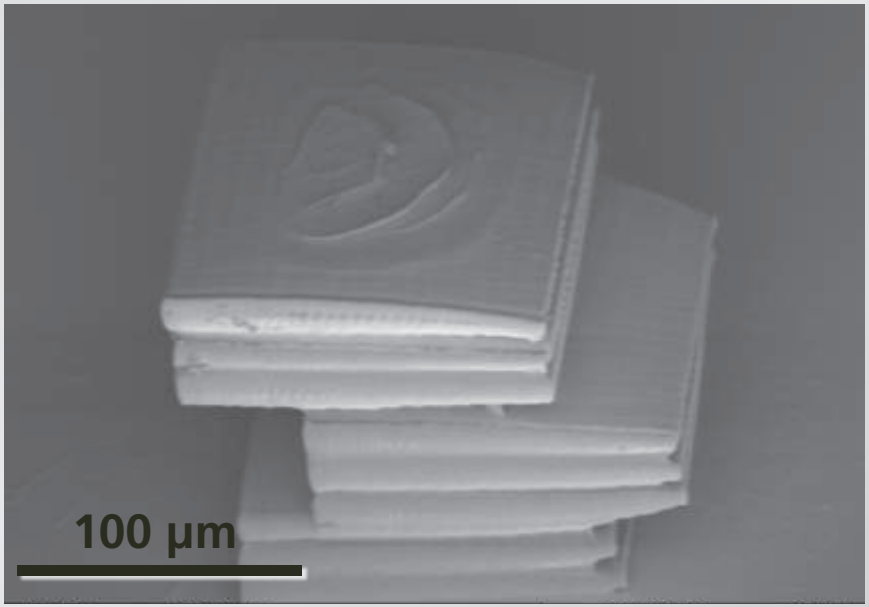
coming year: combine with 2-photon photopolymerization



create 3D microstructures for microfluidics

Nanomagnetics

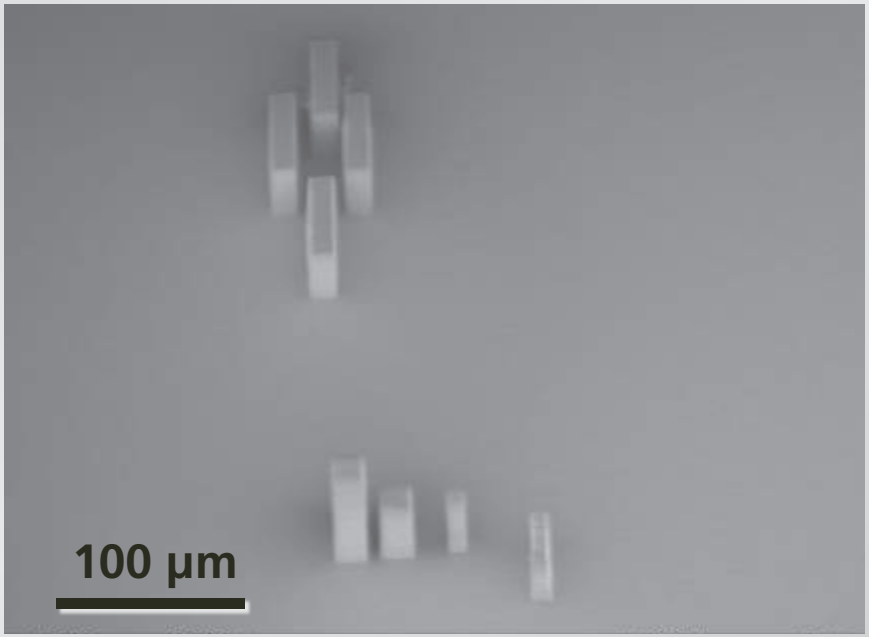
coming year: combine with 2-photon photopolymerization



create 3D microstructures for microfluidics

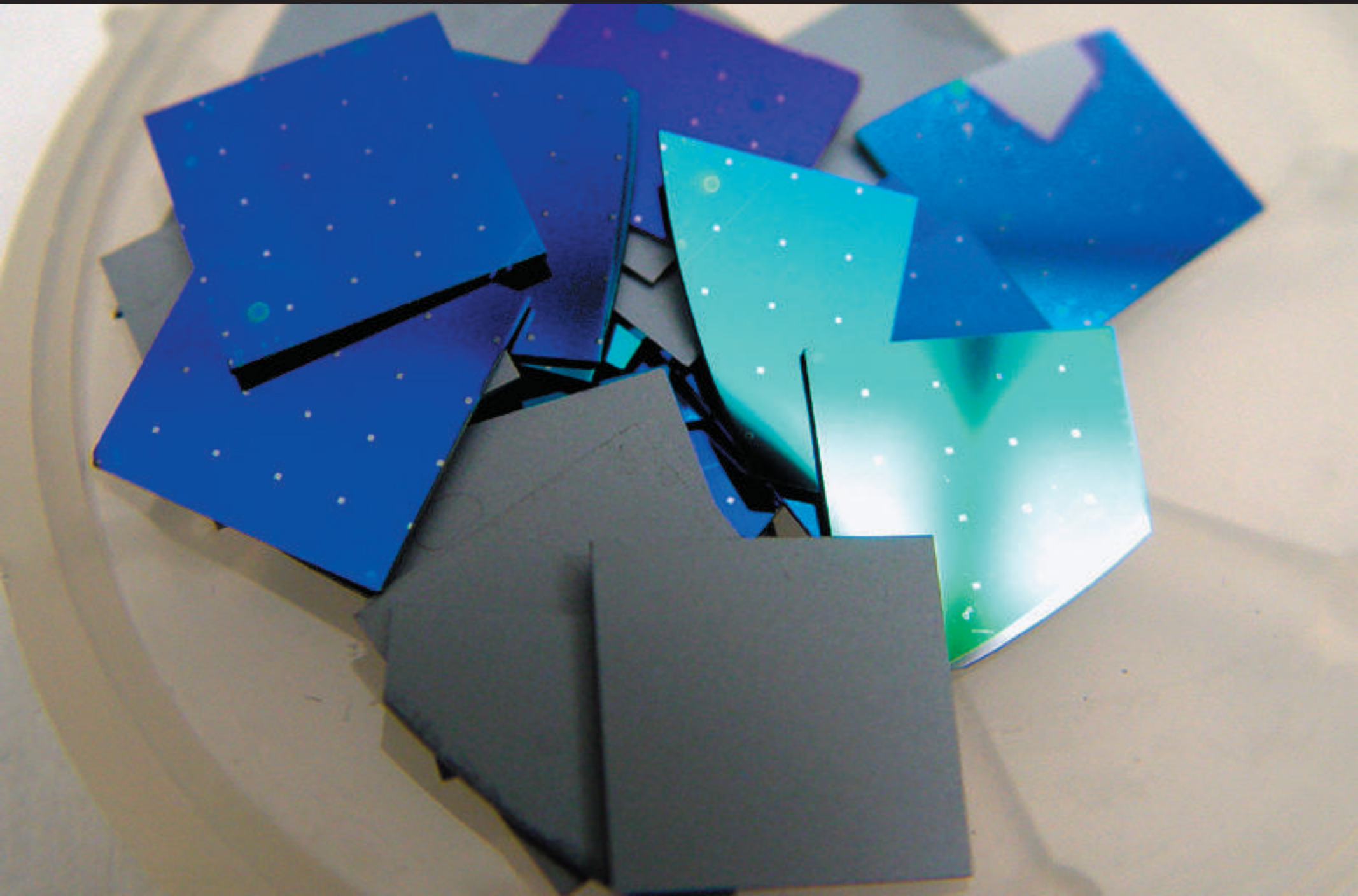
Nanomagnetics

coming year: combine with 2-photon photopolymerization

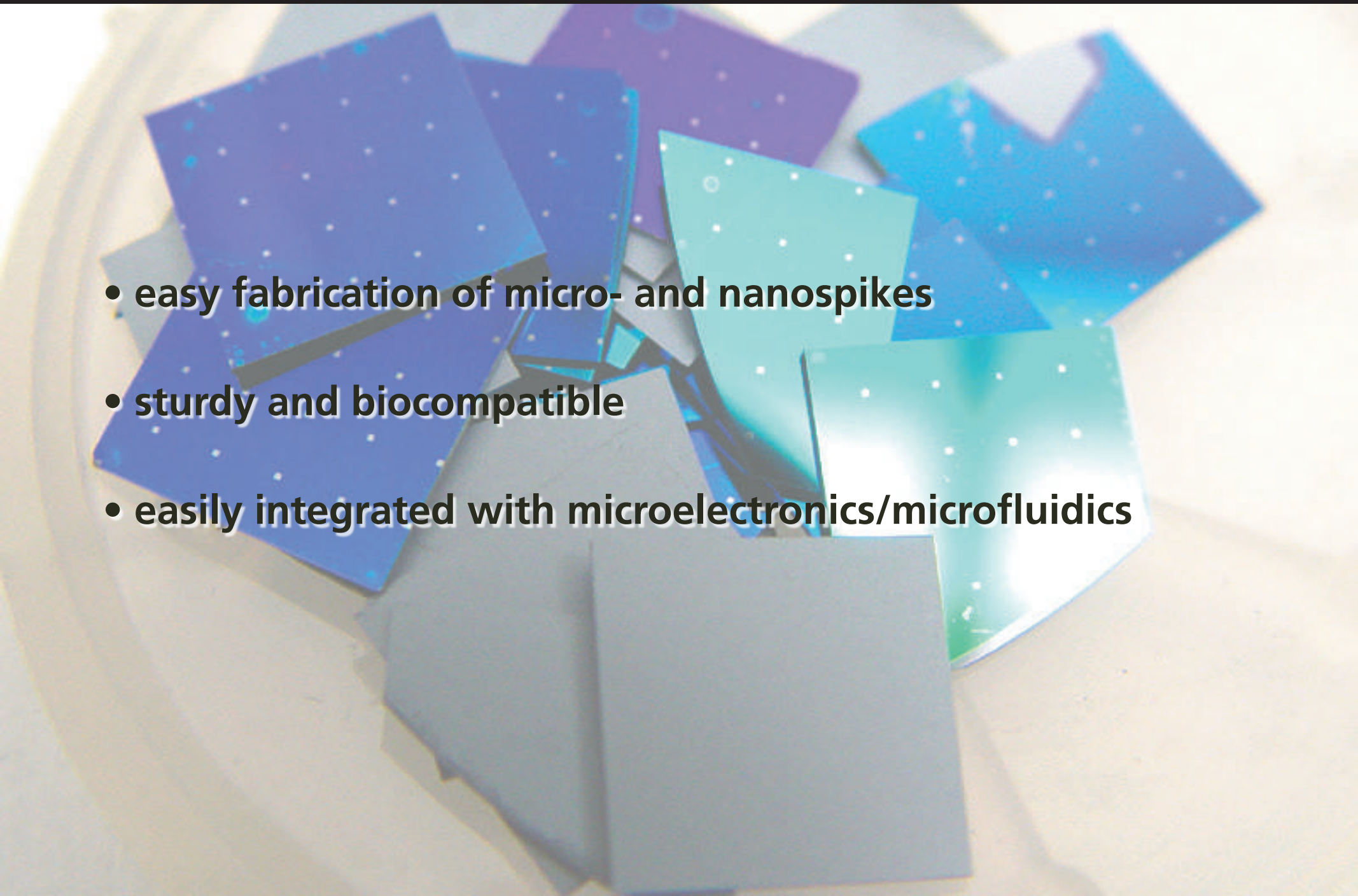


create 3D microstructures for microfluidics

Summary



Summary



- easy fabrication of micro- and nanospikes
- sturdy and biocompatible
- easily integrated with microelectronics/microfluidics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