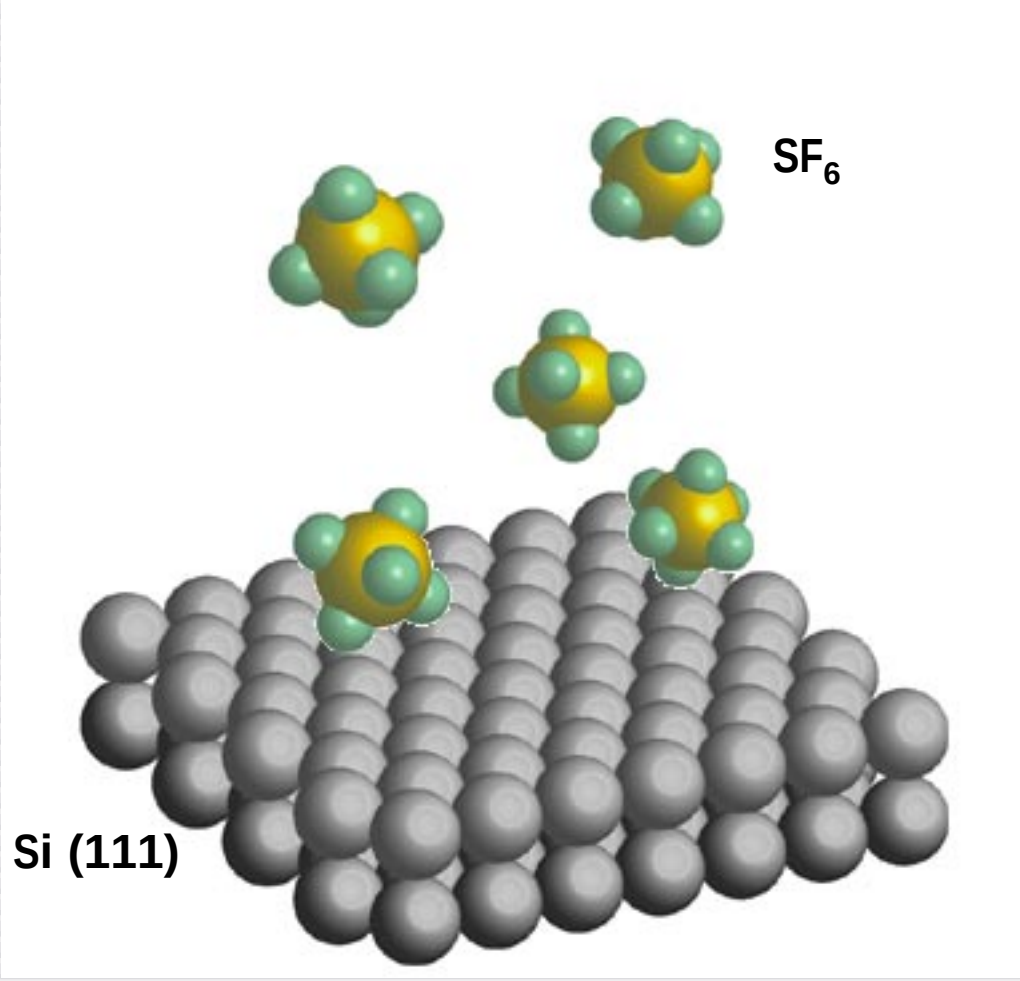
Fabrication of micrometer-sized conical field emitters using femtosecond laser-assisted etching of silicon

Jim Carey
Eric Mazur
Catherine Crouch
Rebecca Younkin

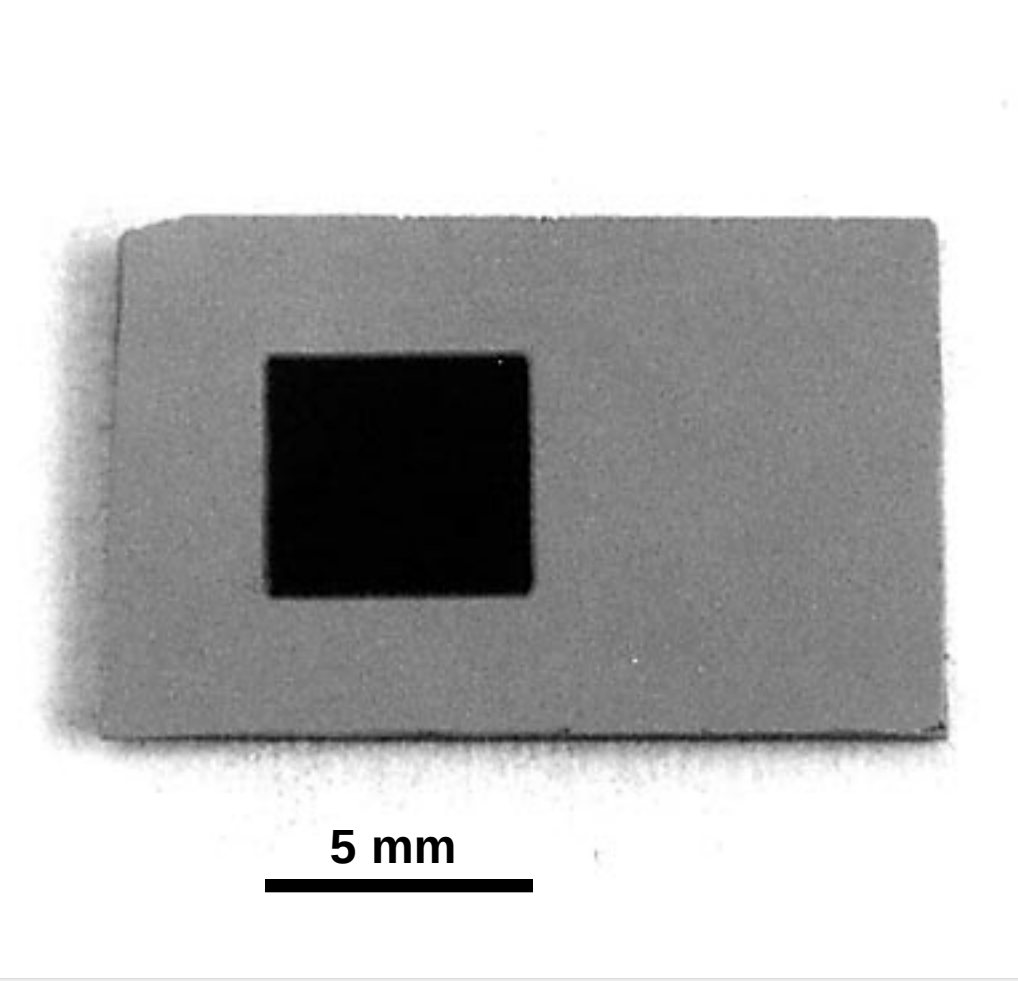
IVMC 2001
UC Davis, 14 August 2001

Introduction



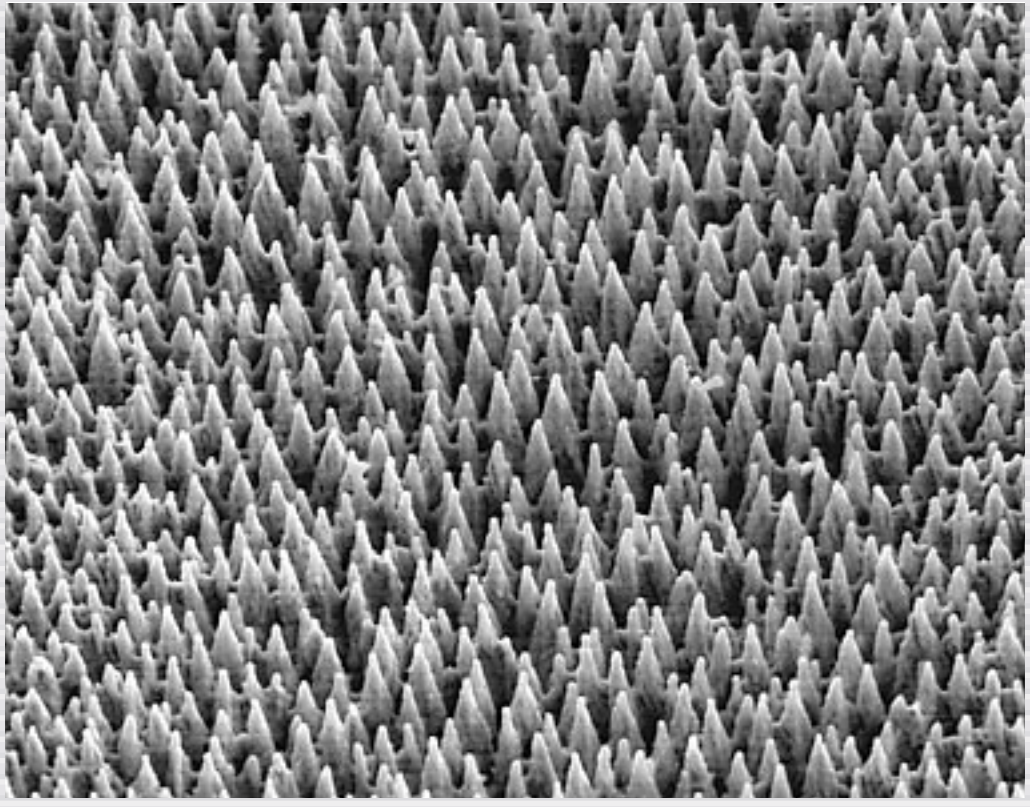
irradiate with 100-fs 10 kJ/m^2 pulses

Introduction



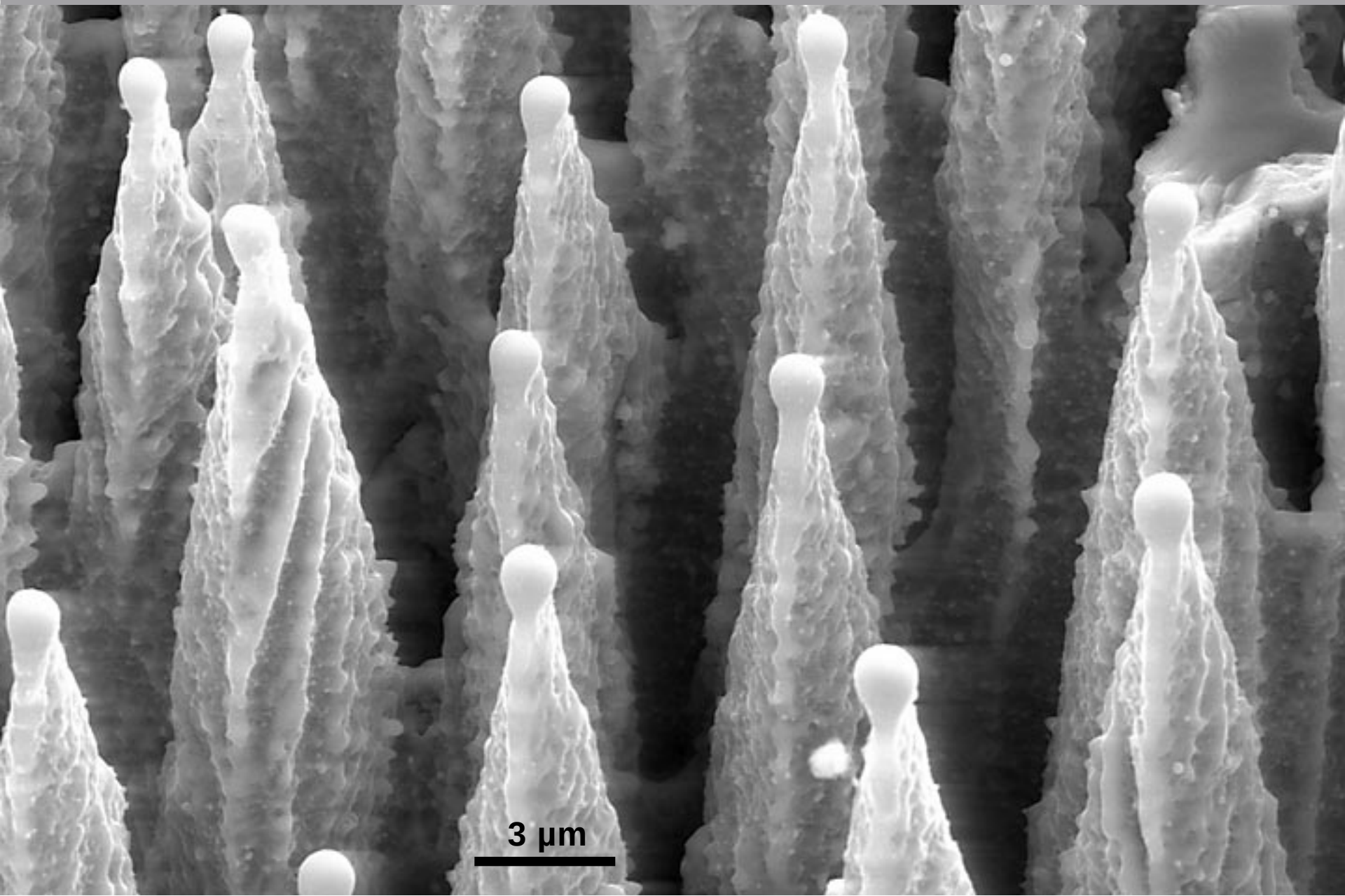
“black silicon”

Introduction

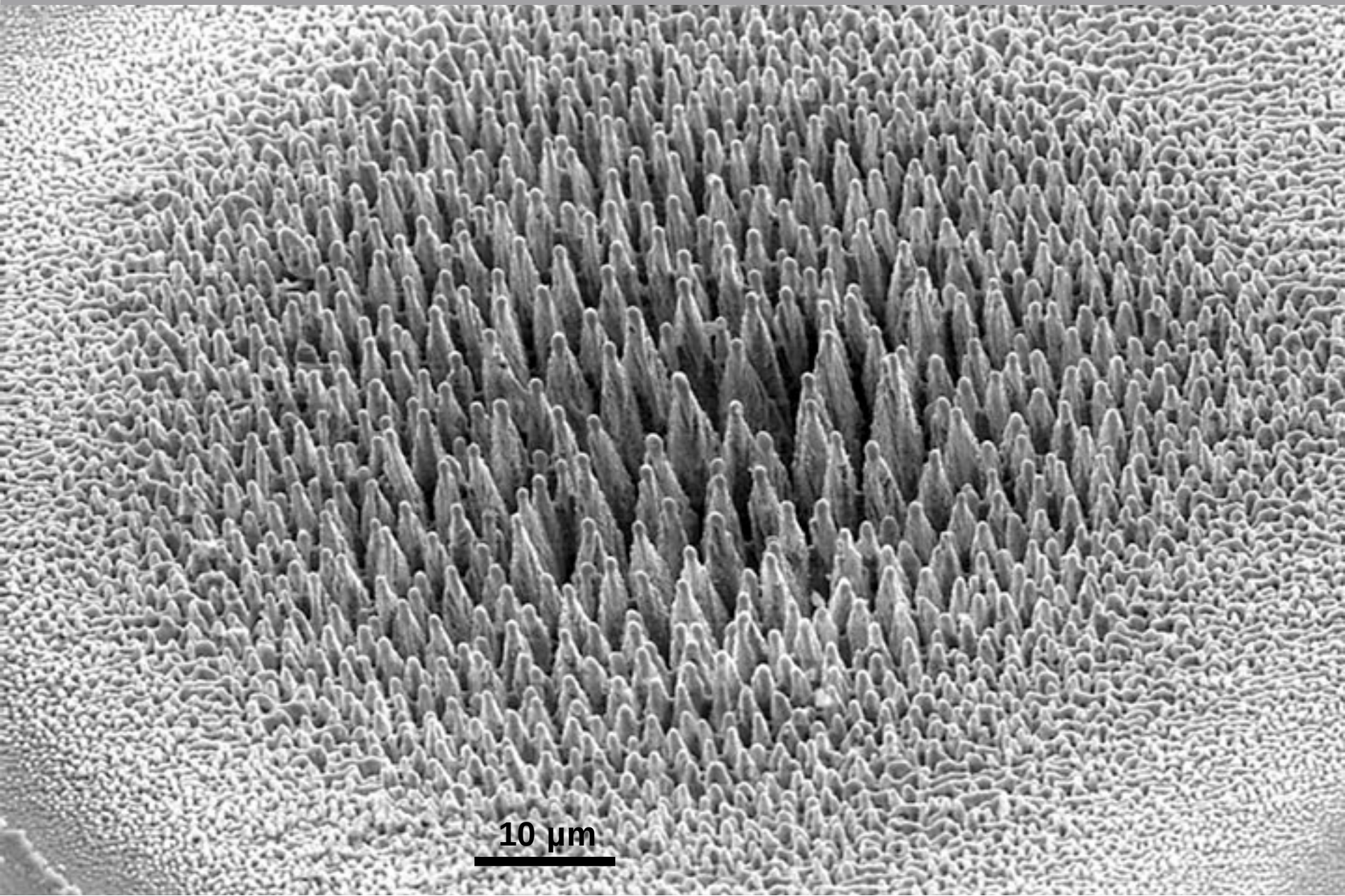


20 µm

Introduction

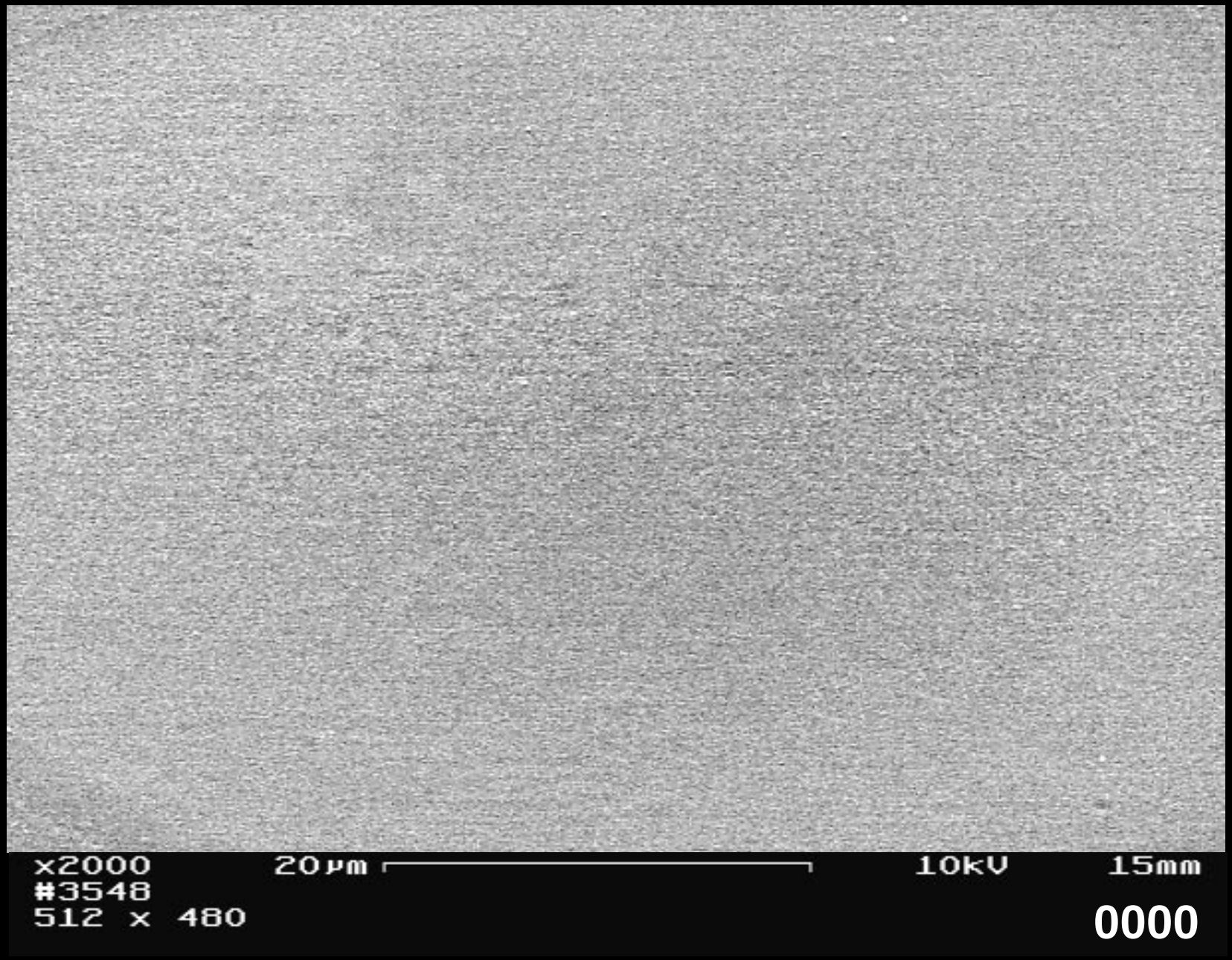


Introduction



Outline

- Background
- Results
- Discussion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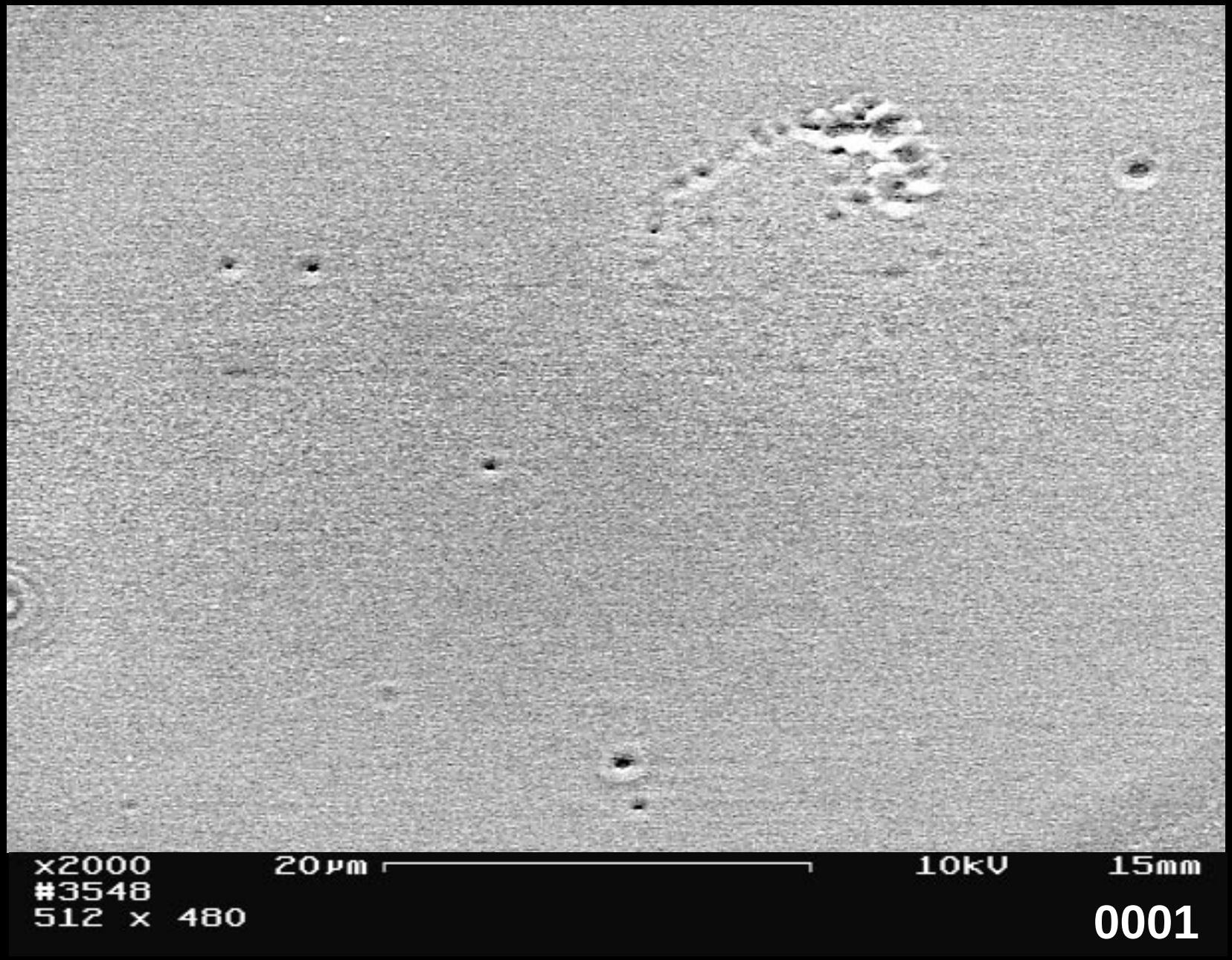
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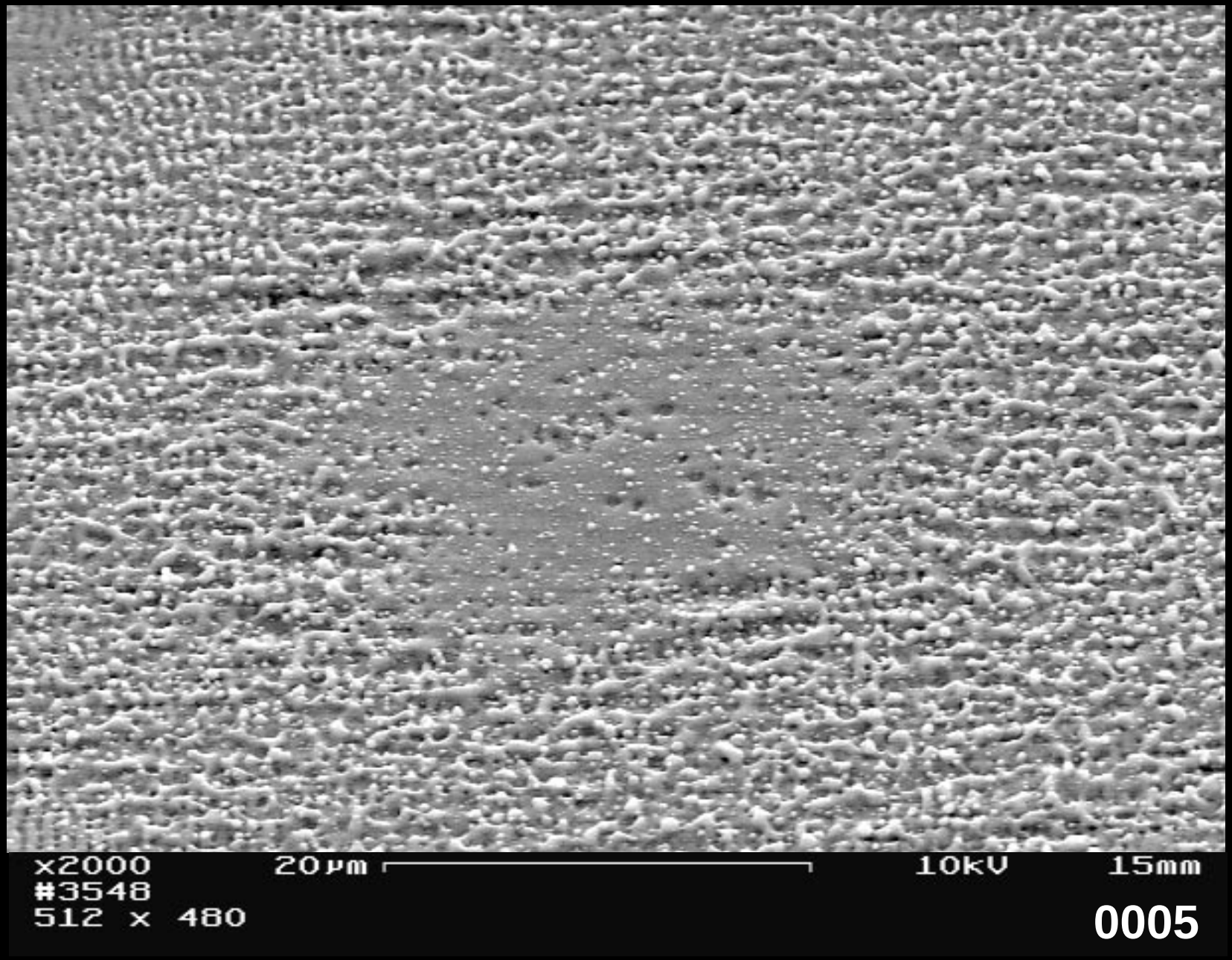
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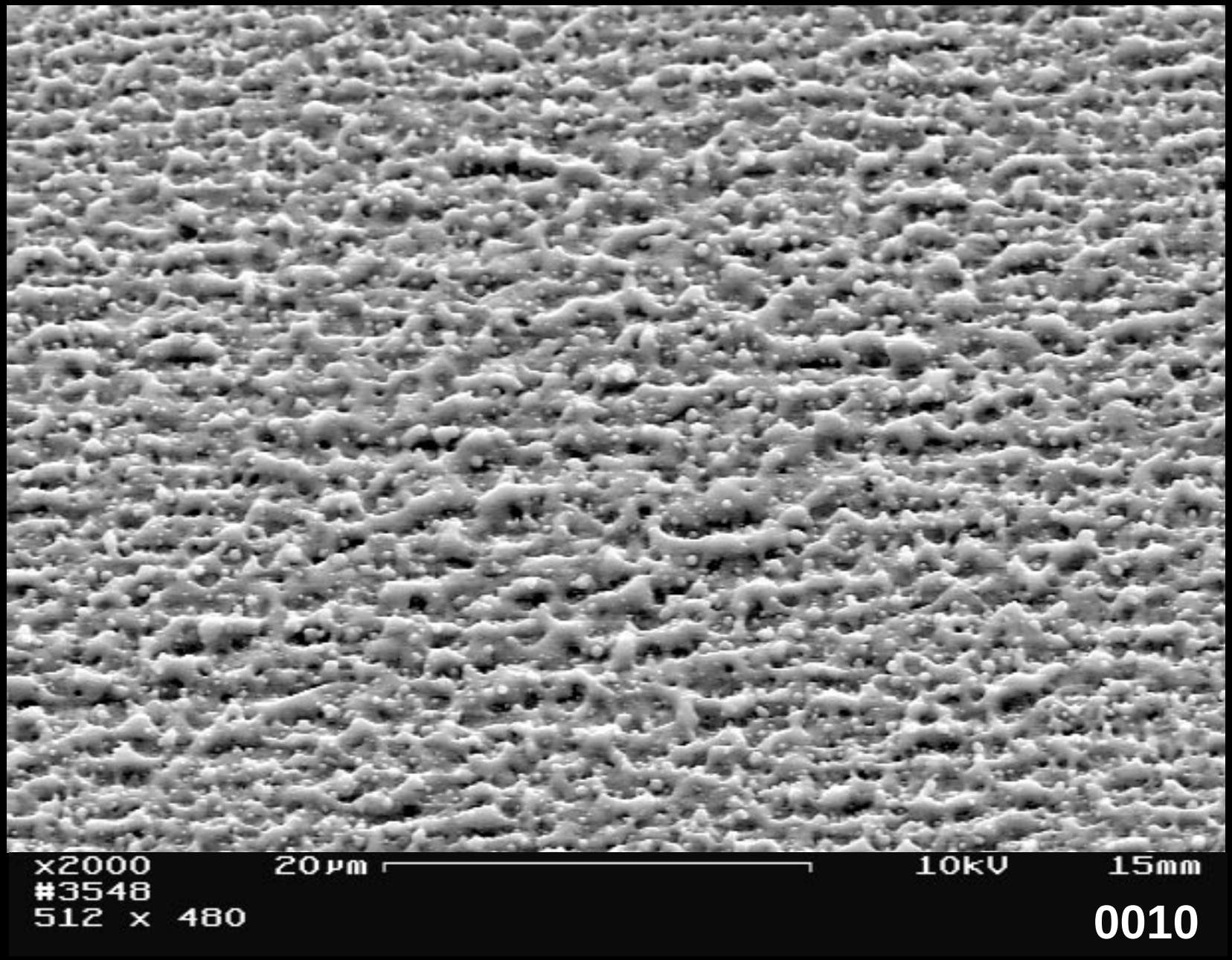
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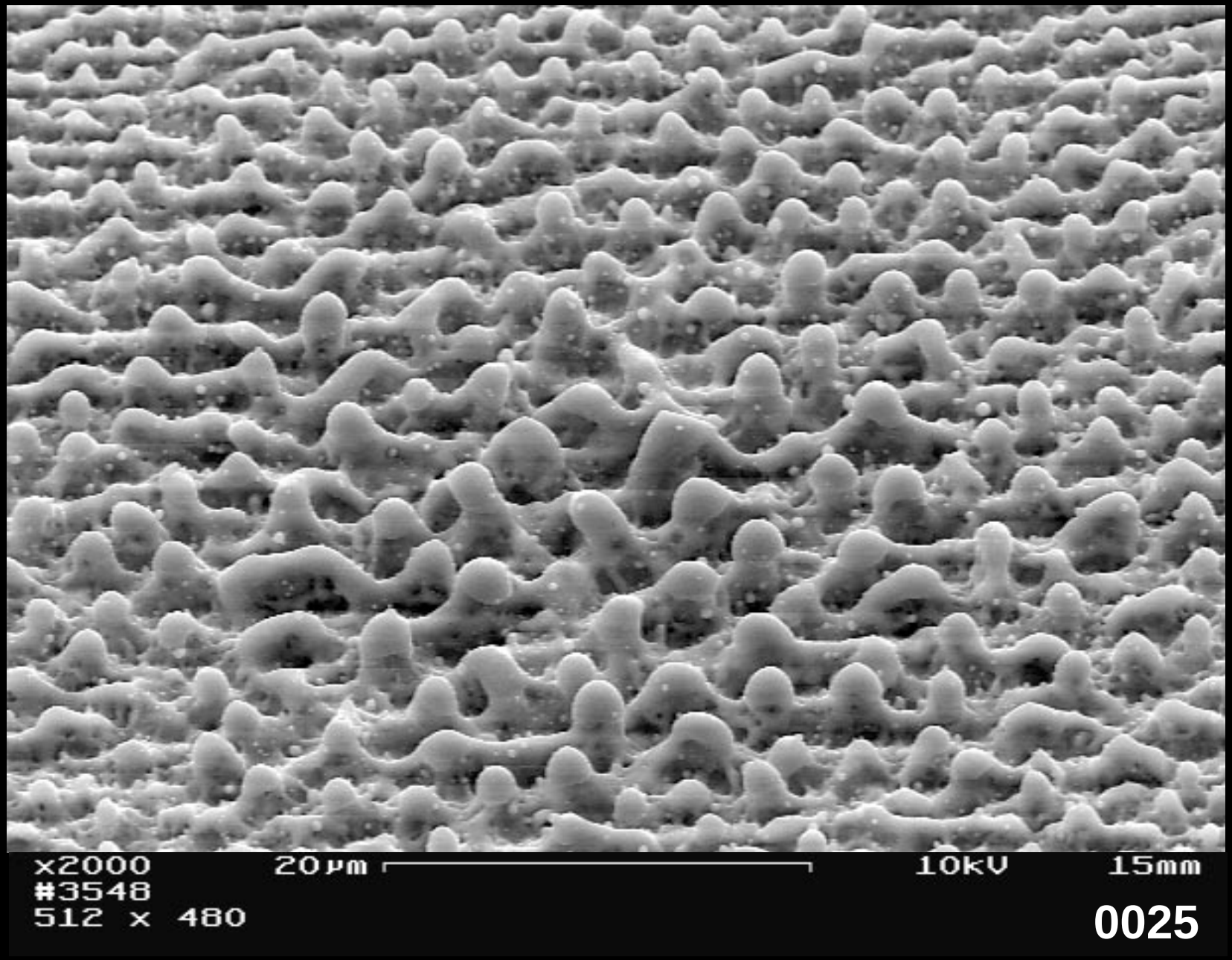
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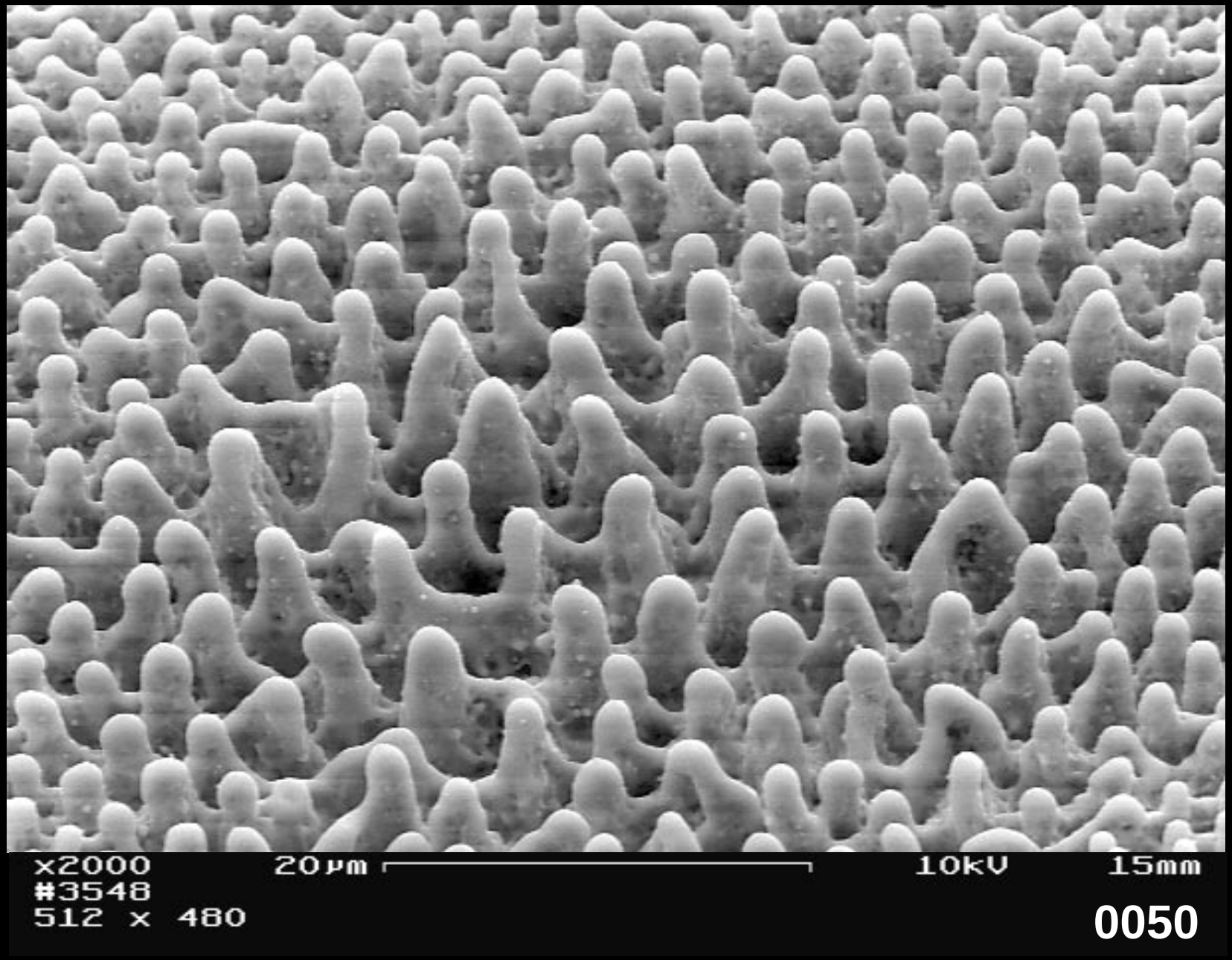
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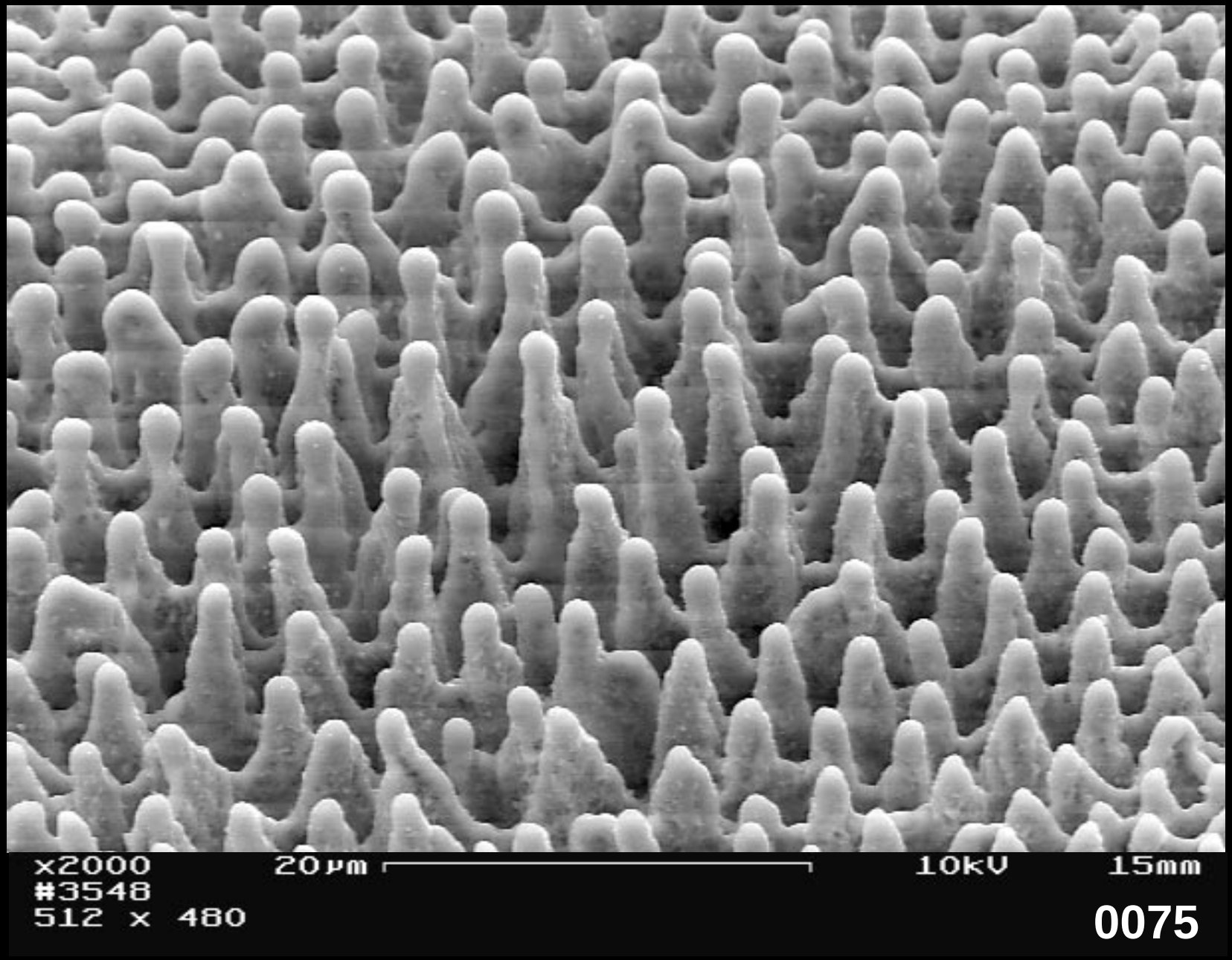
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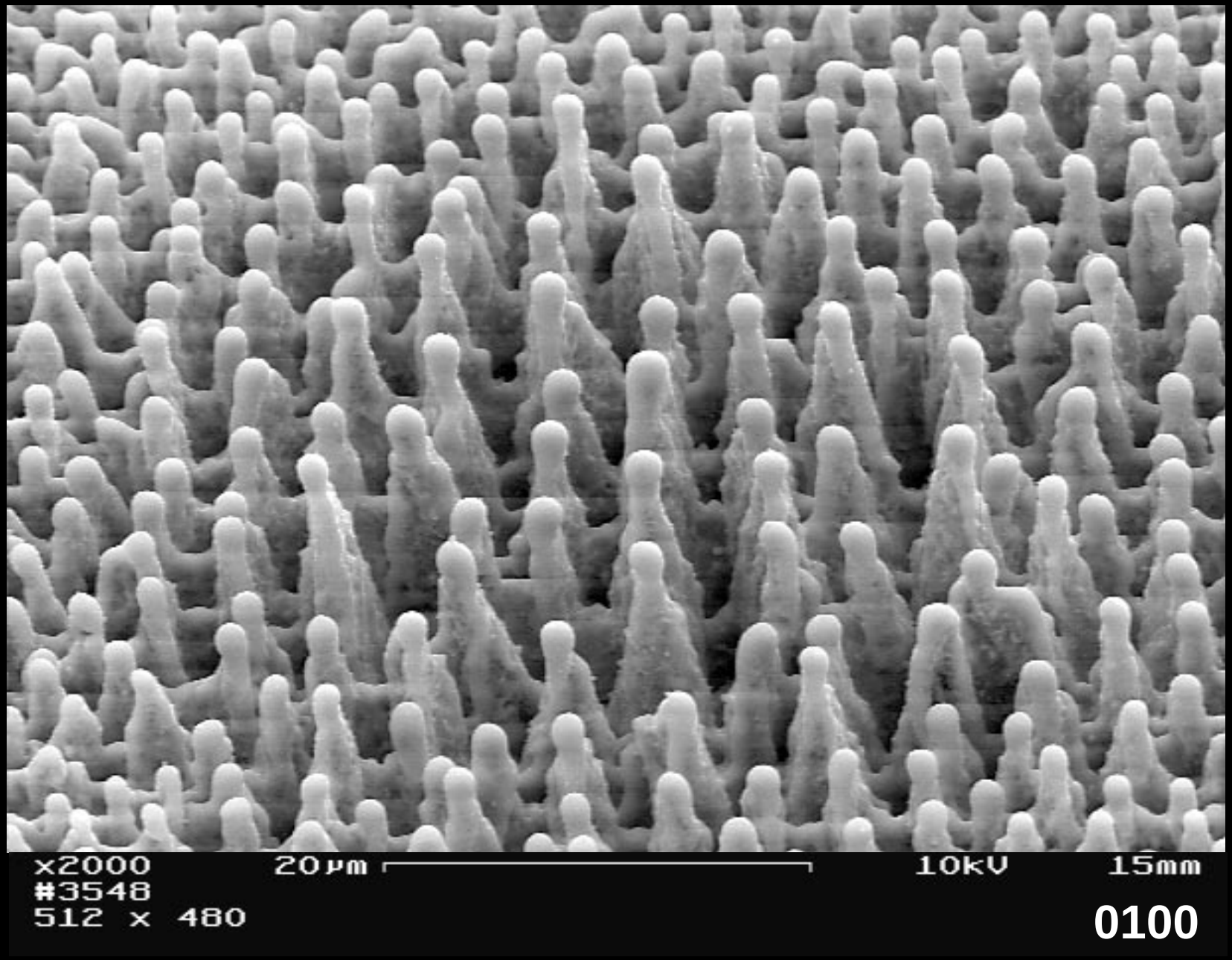
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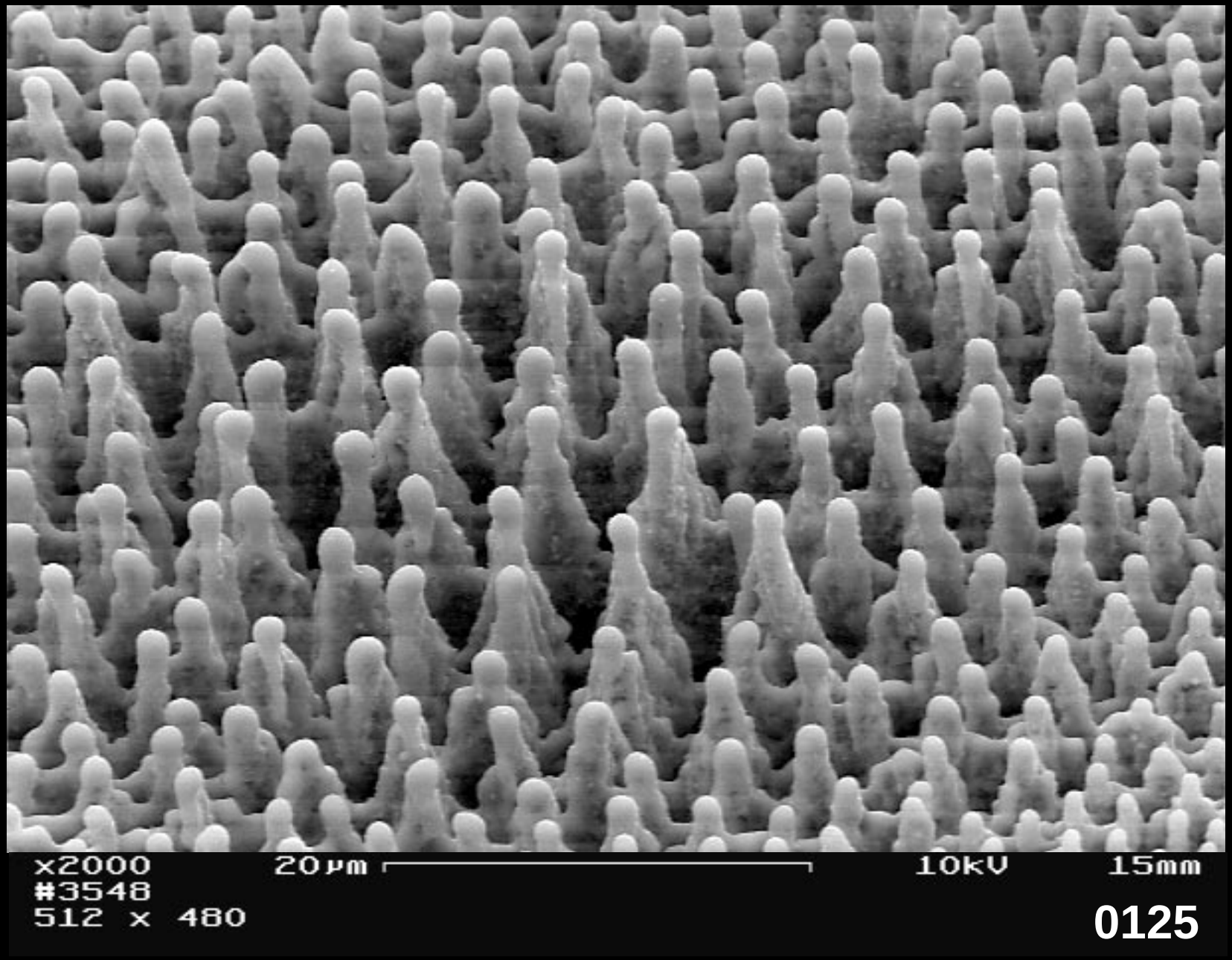
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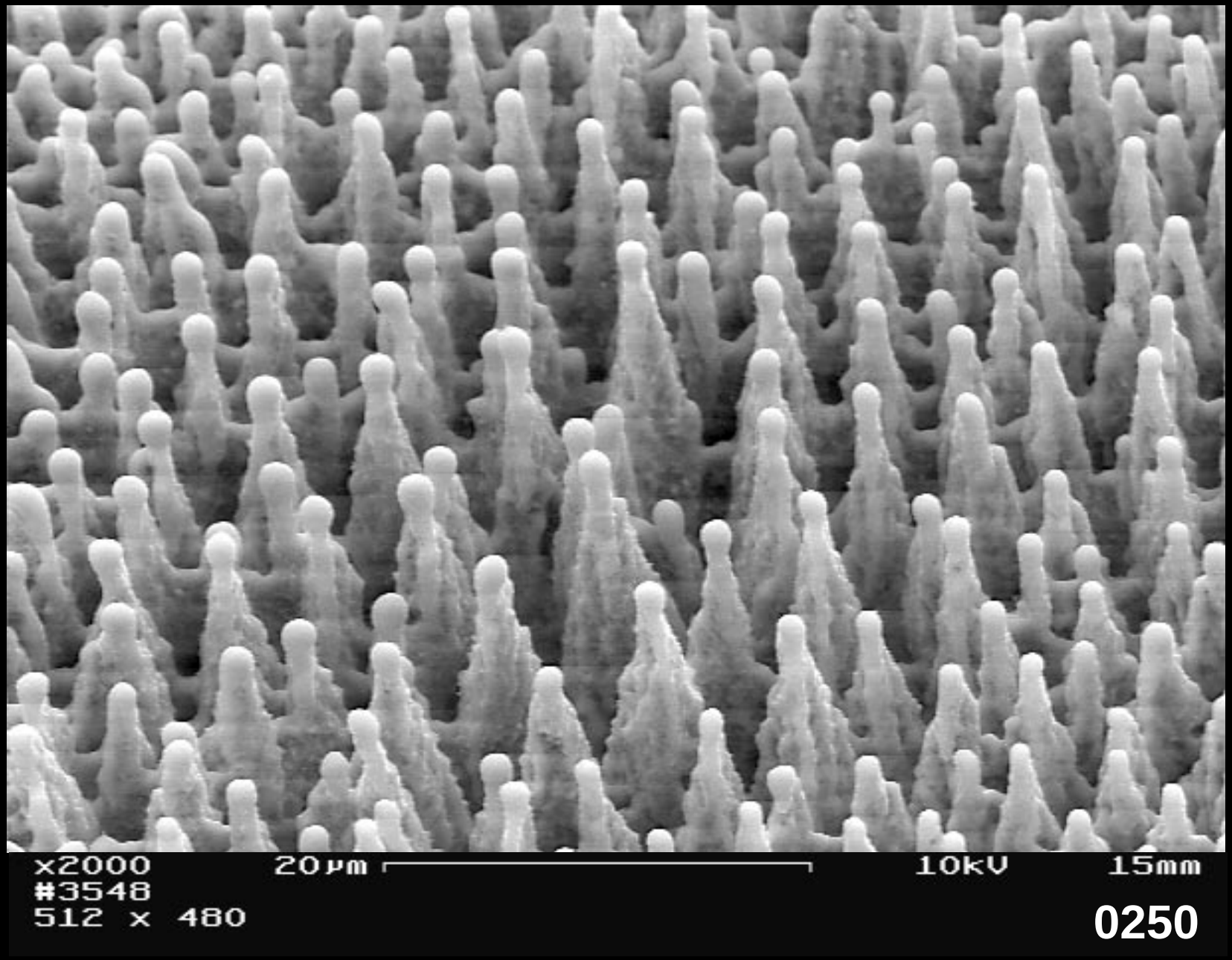
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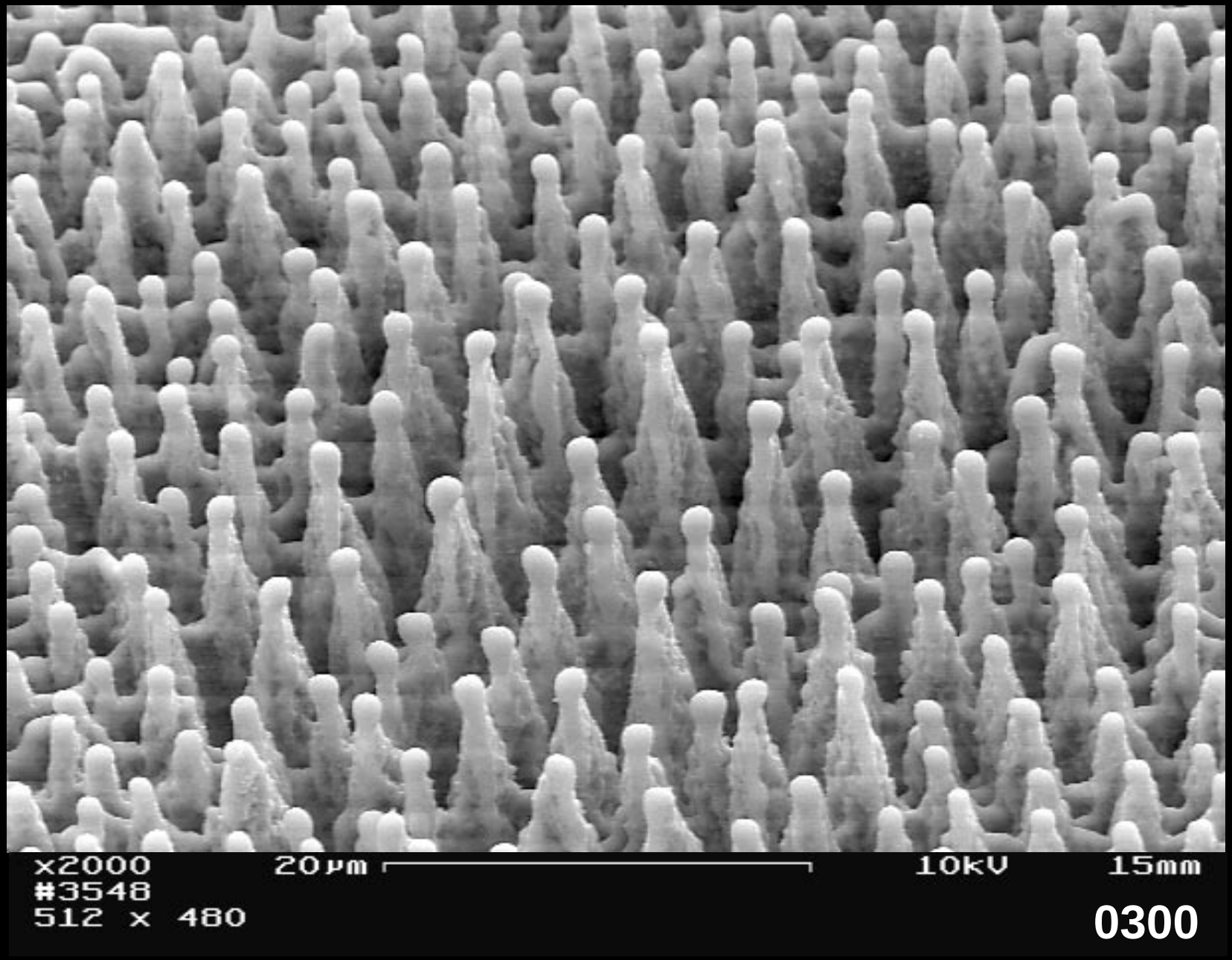
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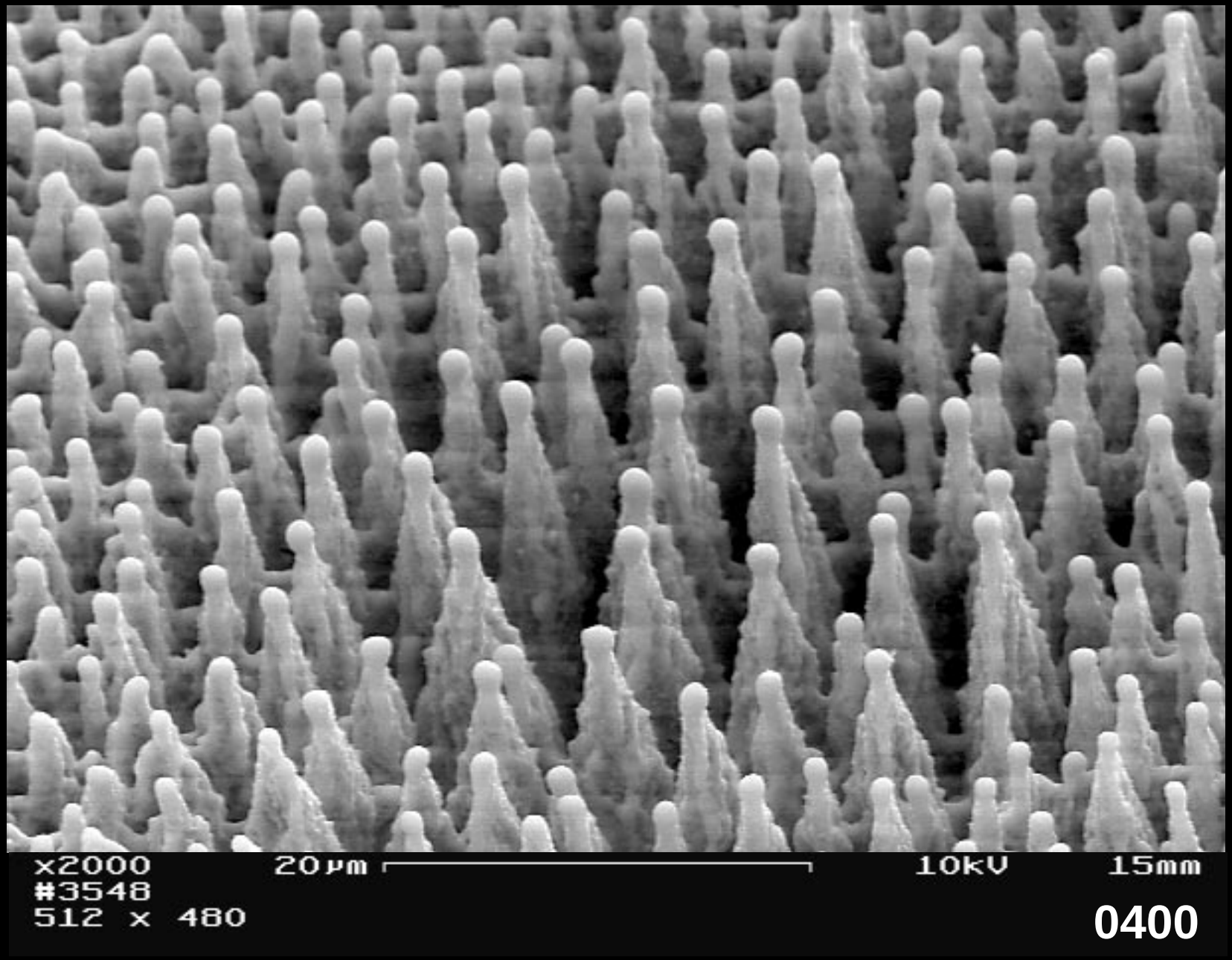
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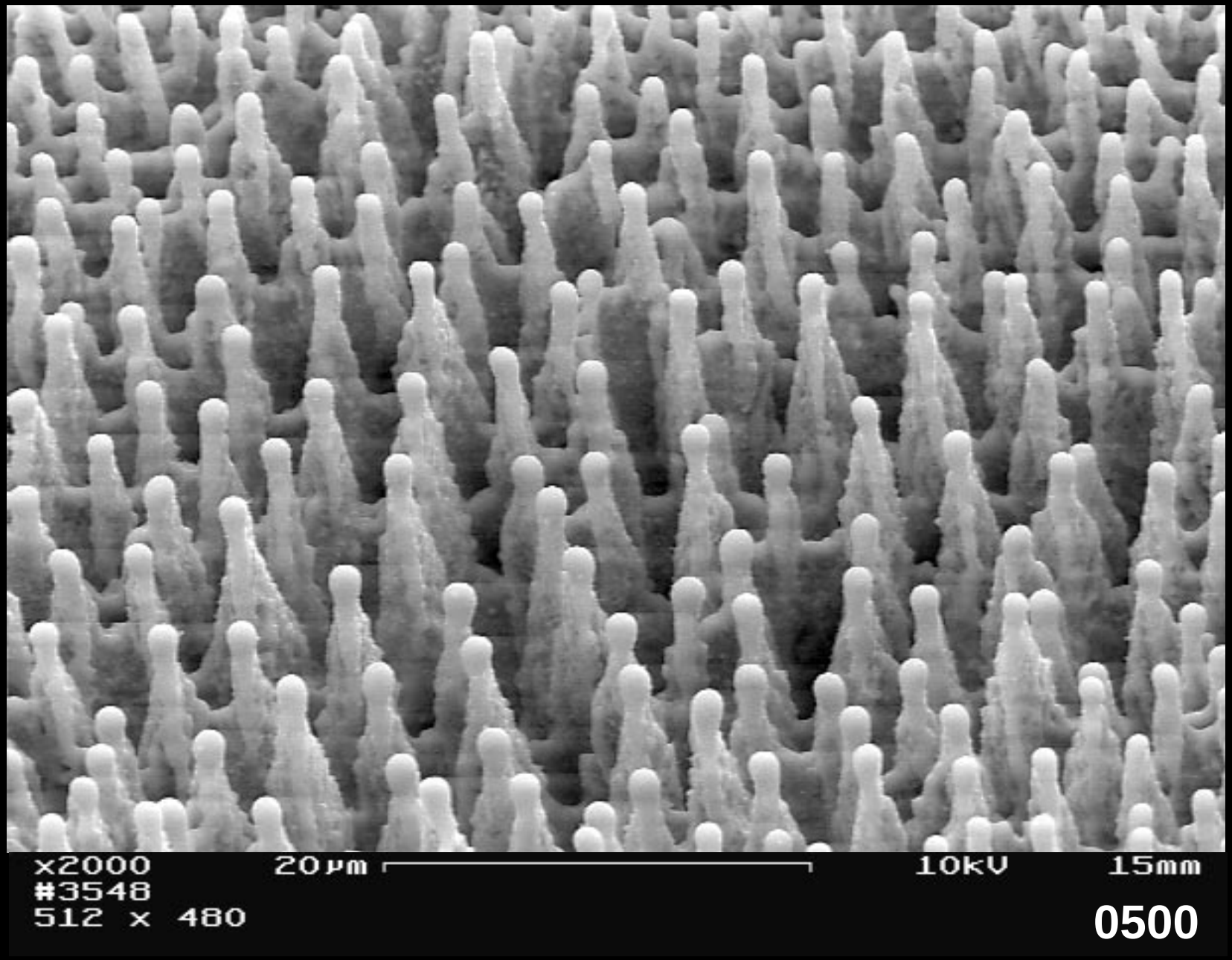
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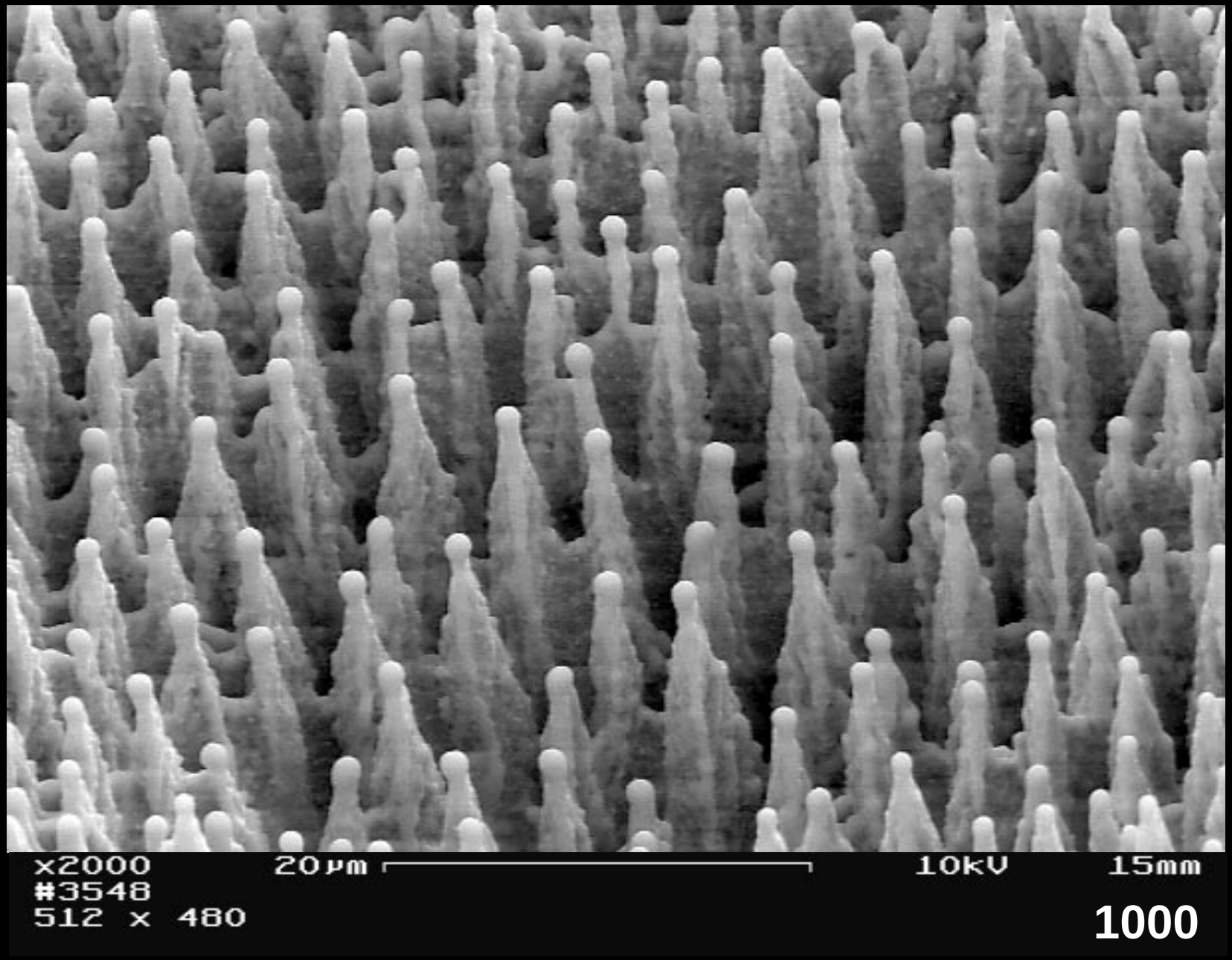
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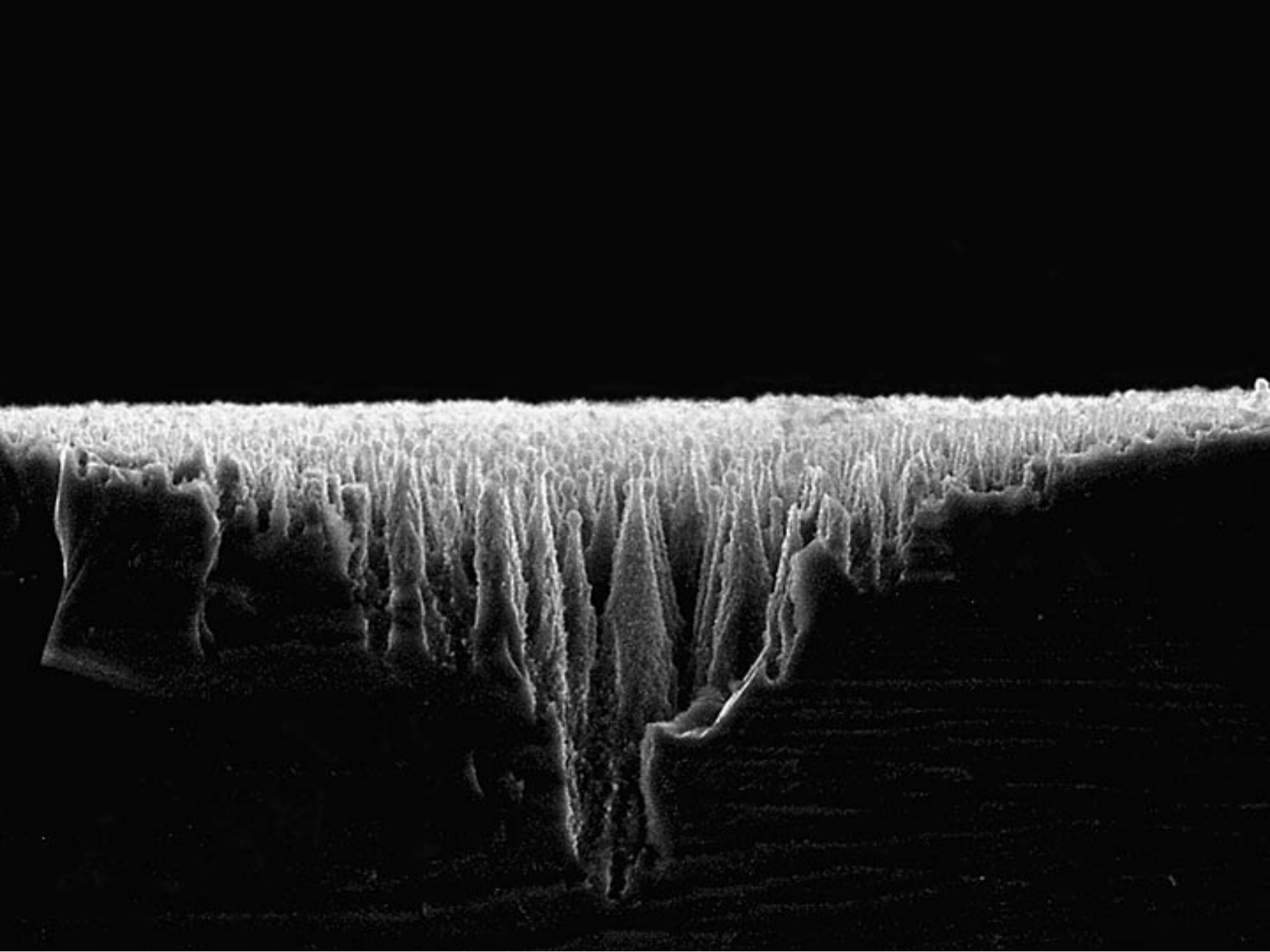

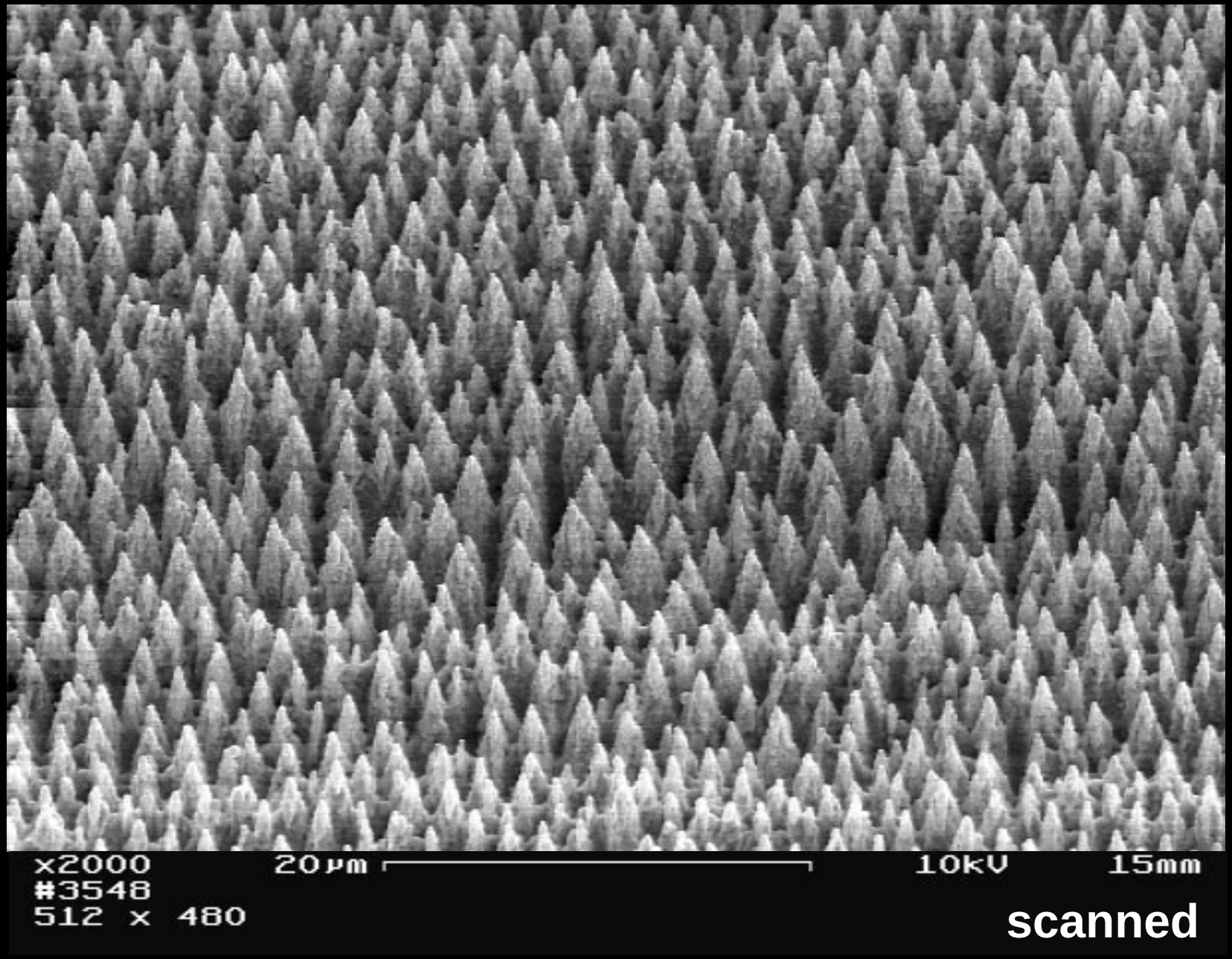
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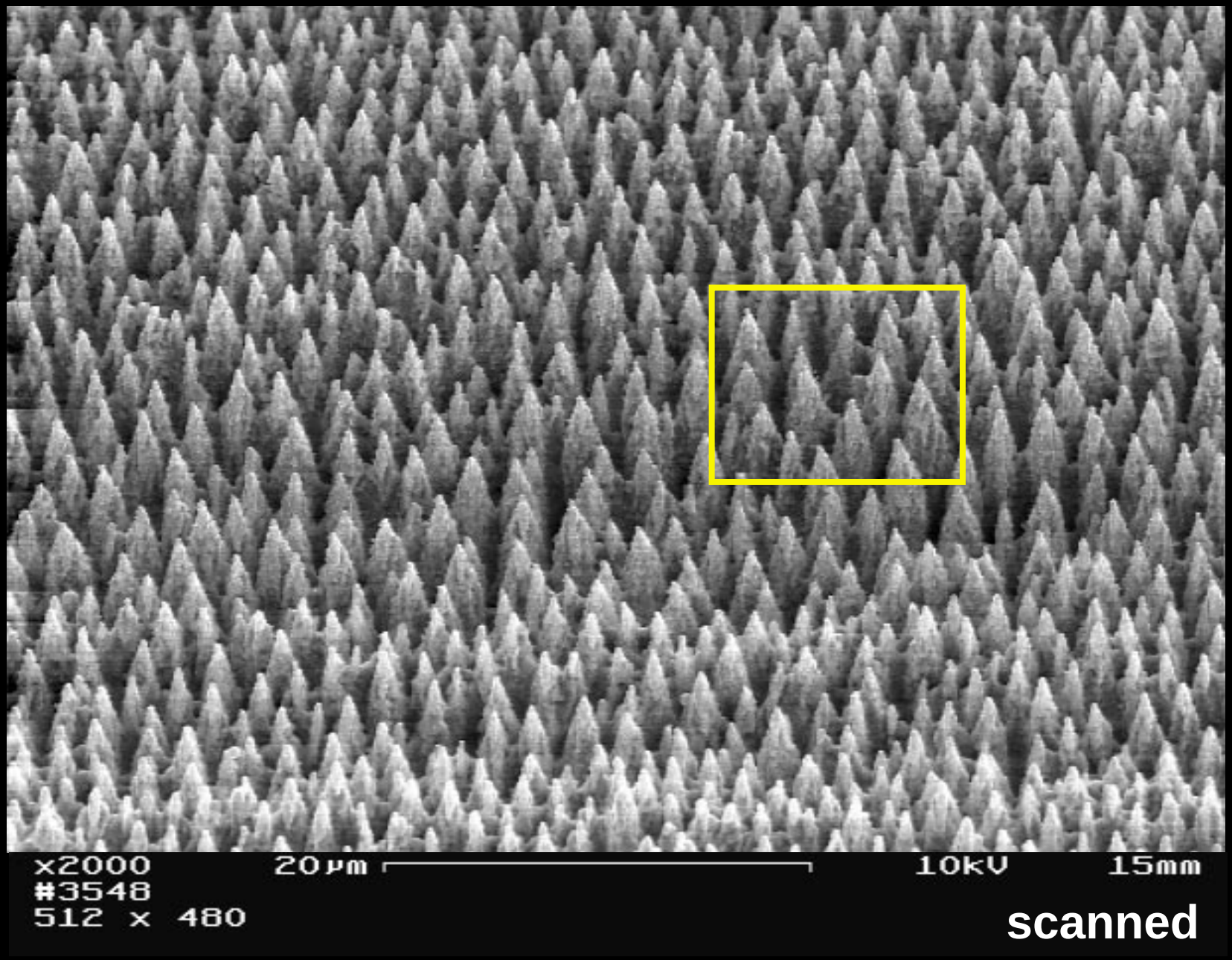
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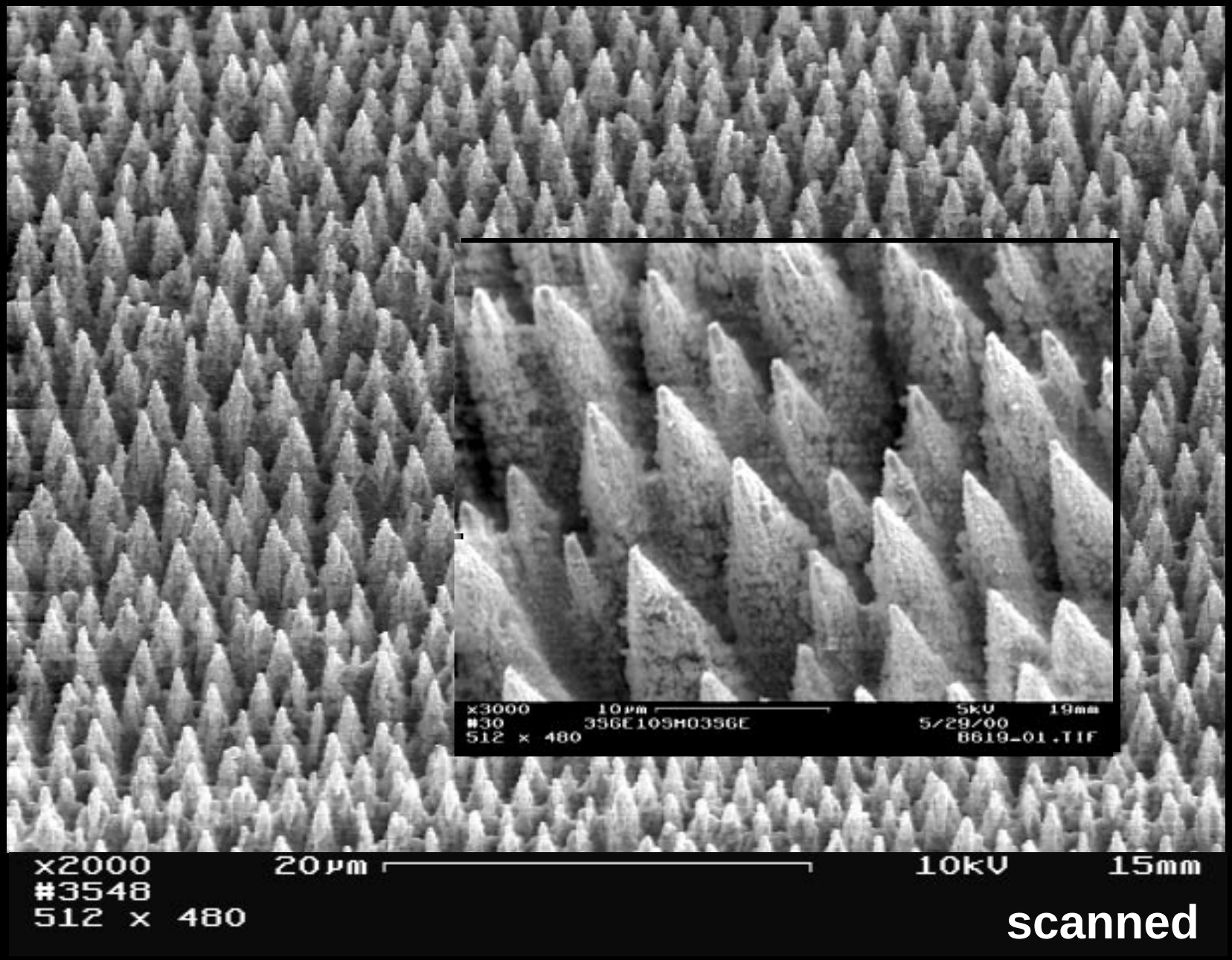
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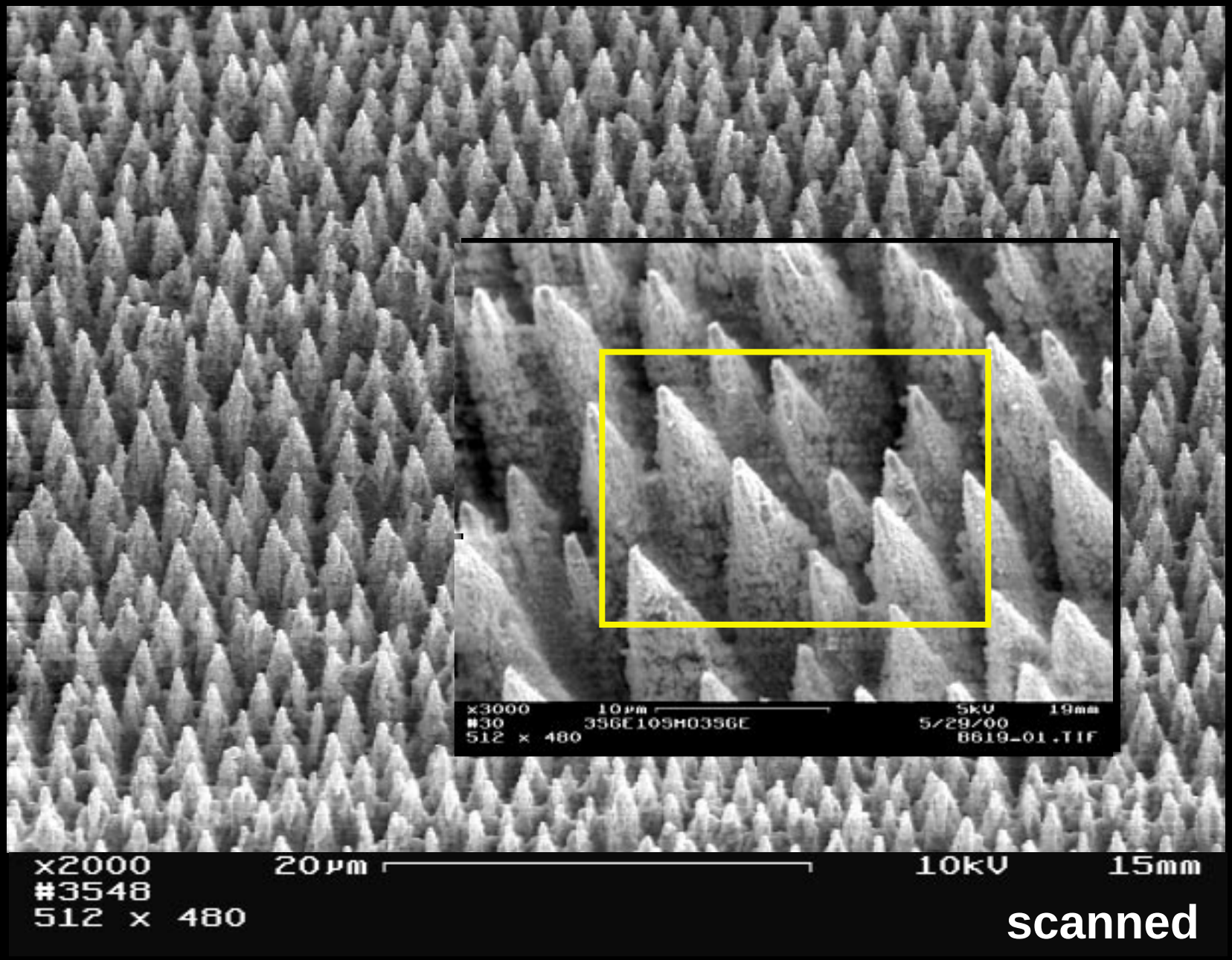
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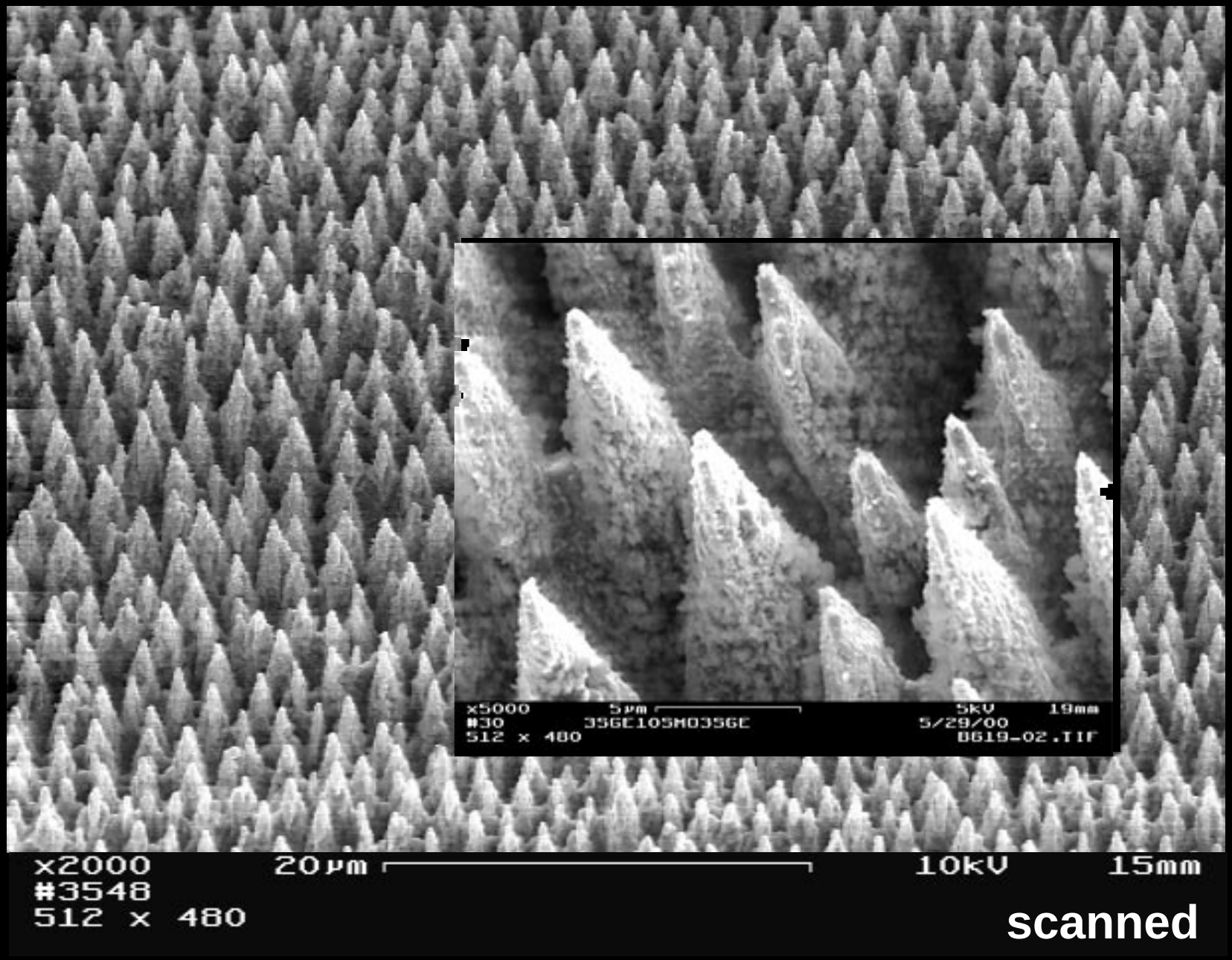
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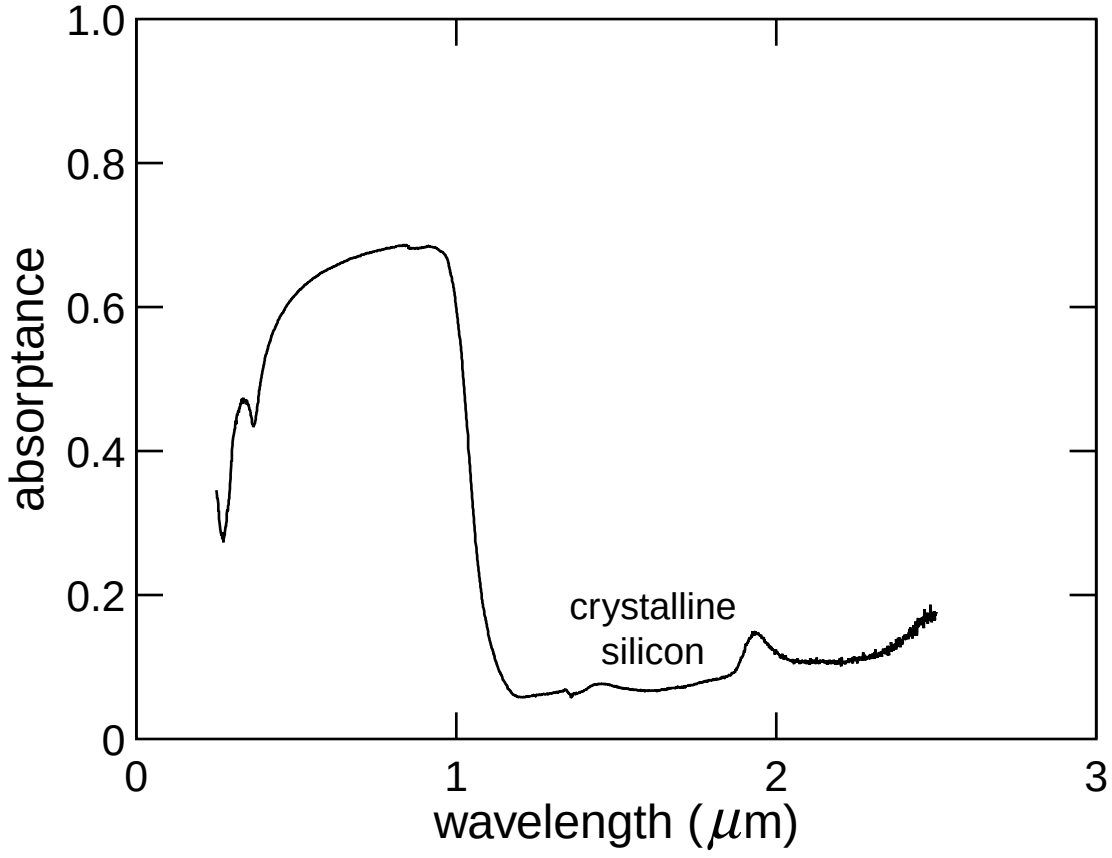
Background

absorptance



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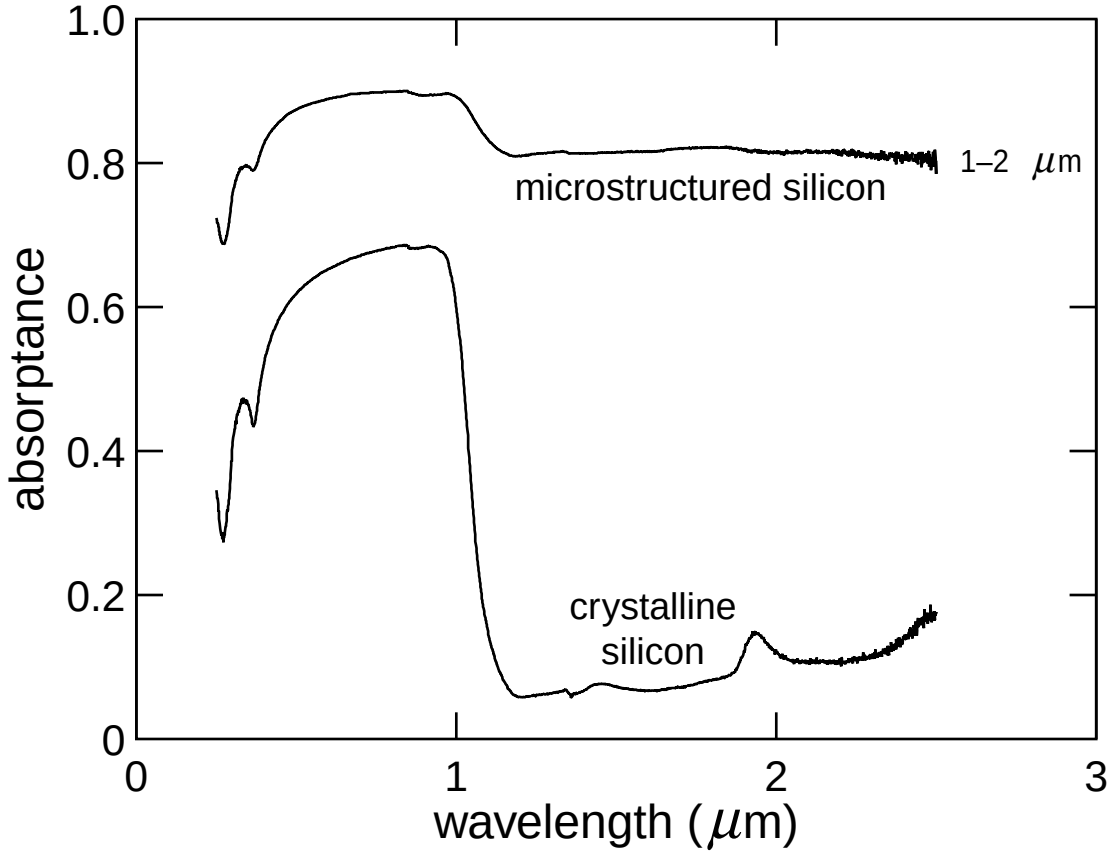
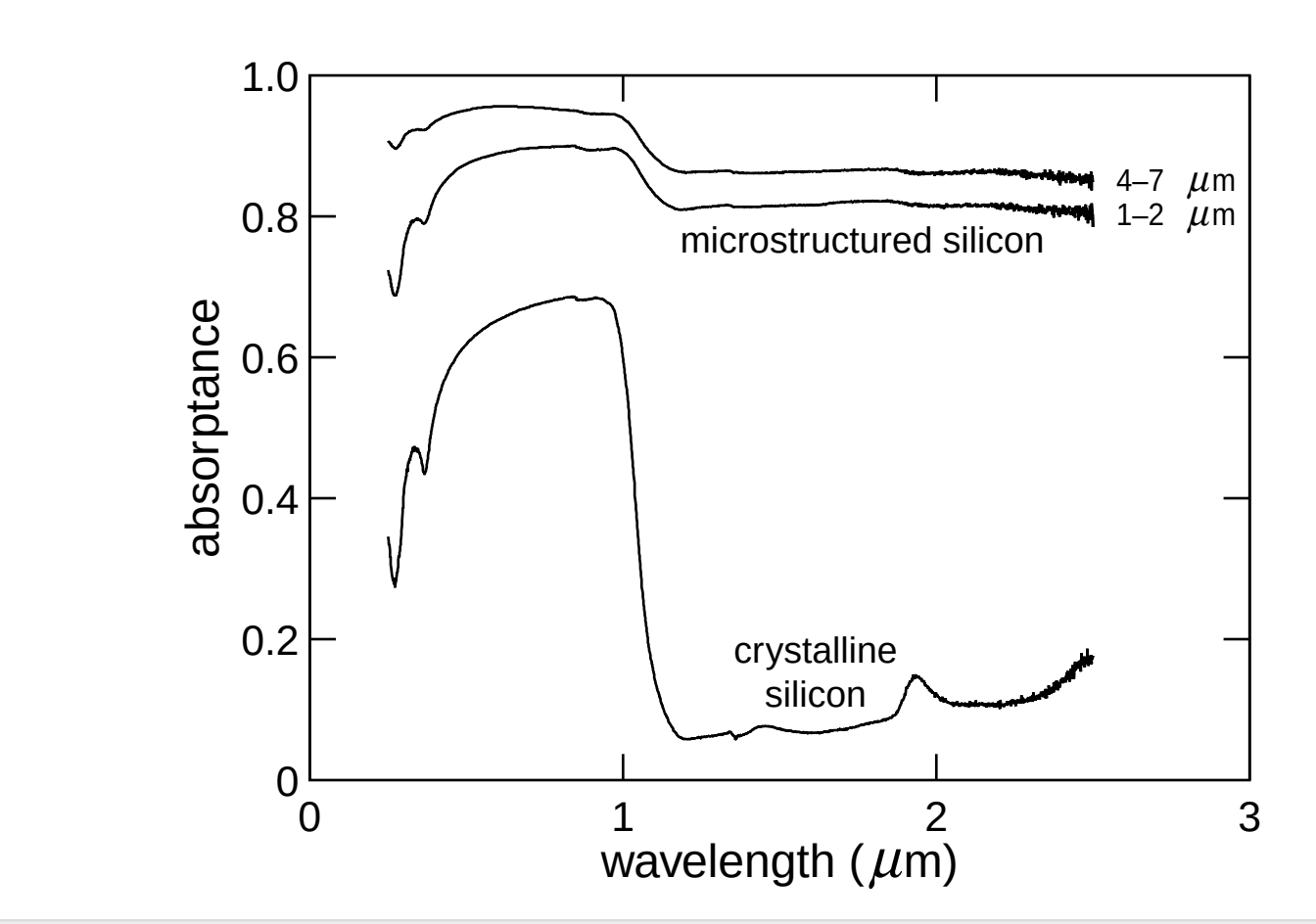
absorptance



C. Wu, *et al.*, *Appl. Phys. Lett*. 78, 1850 (2001)

Background

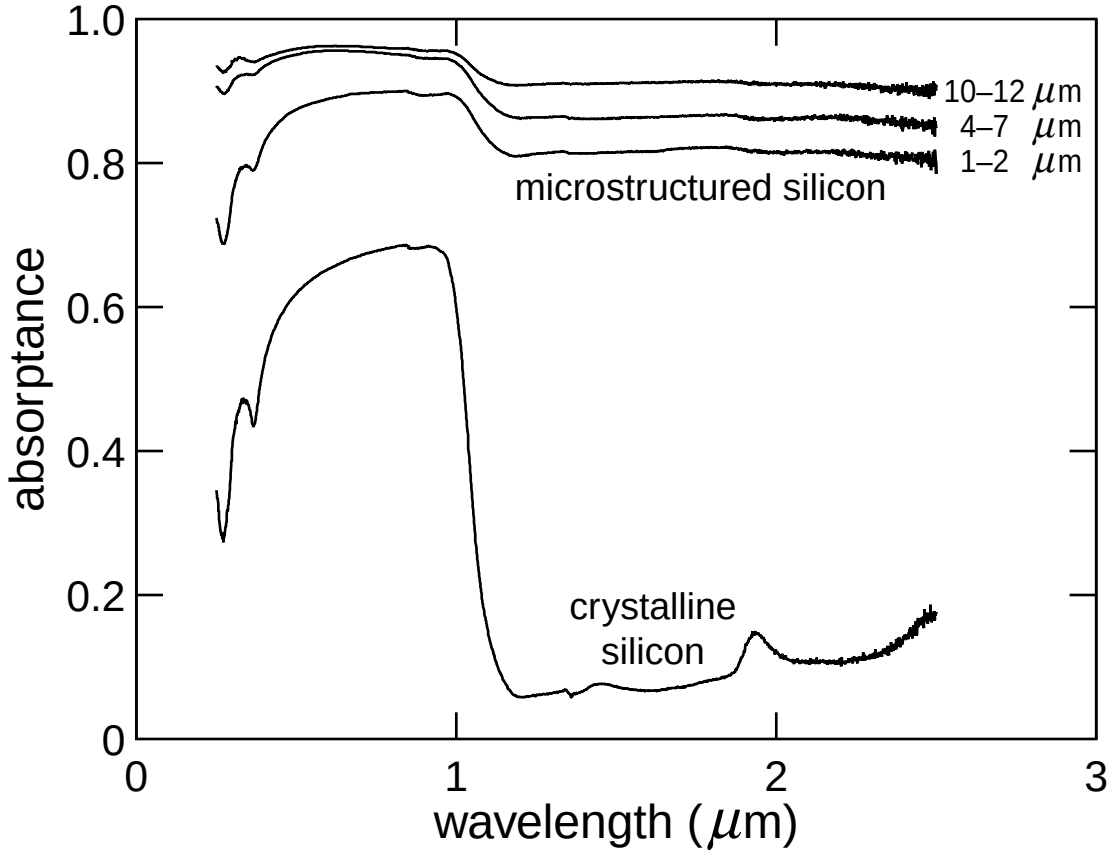
absorptance



C. Wu, *et al.*, *Appl. Phys. Lett.* **78**, 1850 (2001)

Background

absorptance



C. Wu, *et al.*, *Appl. Phys. Lett*. 78, 1850 (2001)

Background

Points to keep in mind:

- **one-step, maskless process**
- **large area with uniform high density of spikes**
- **band structure change**

Outline

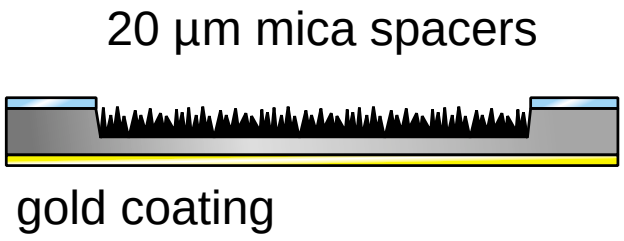
- Background
- **Results**
- Discussion

Setup

Setup

gold coating

Setup



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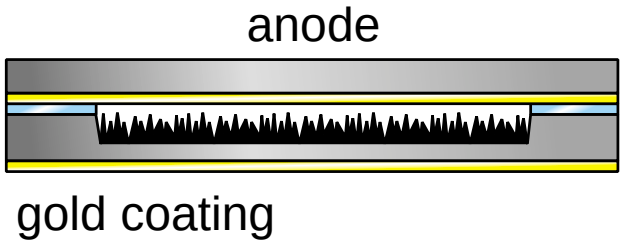

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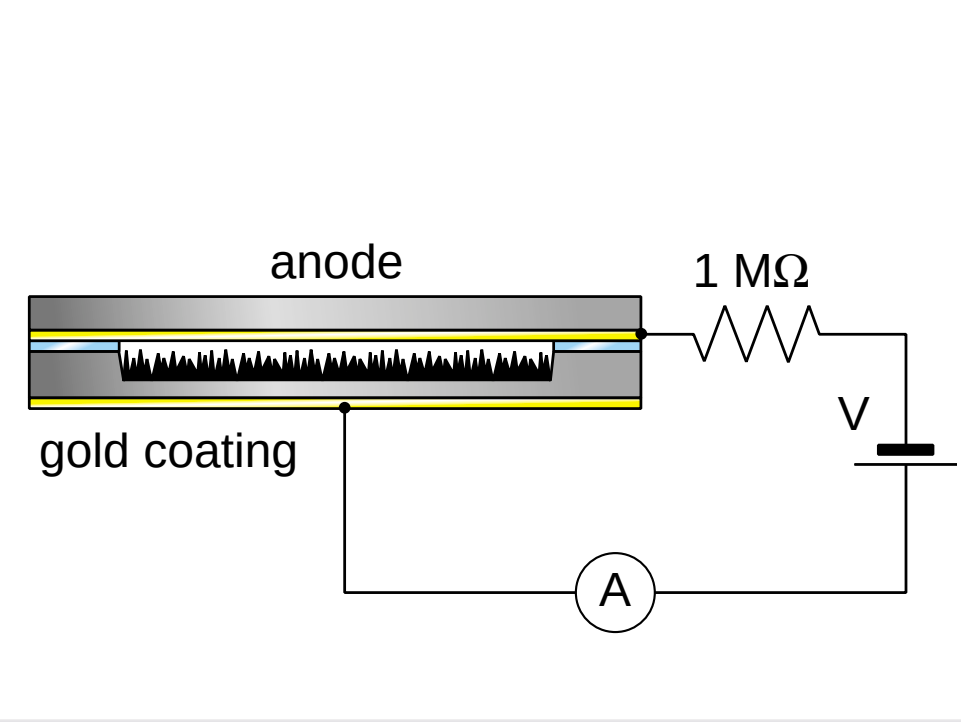
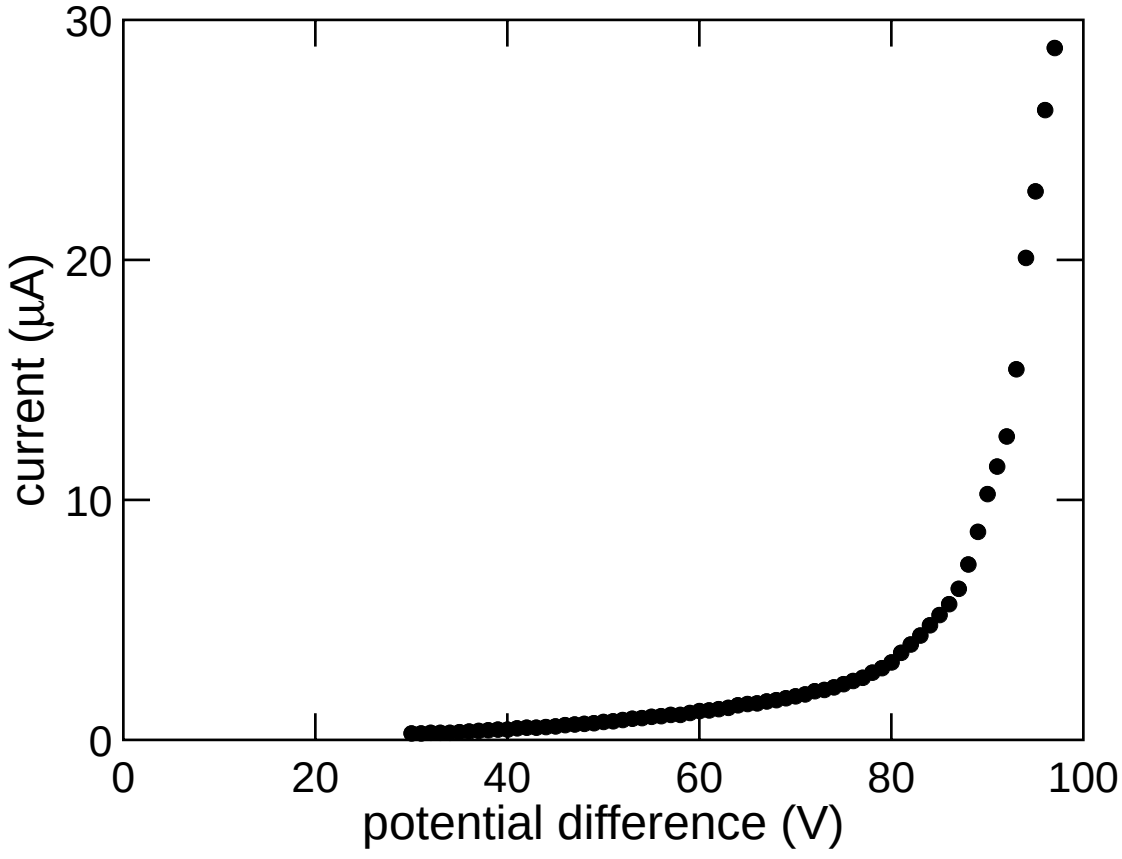


Results



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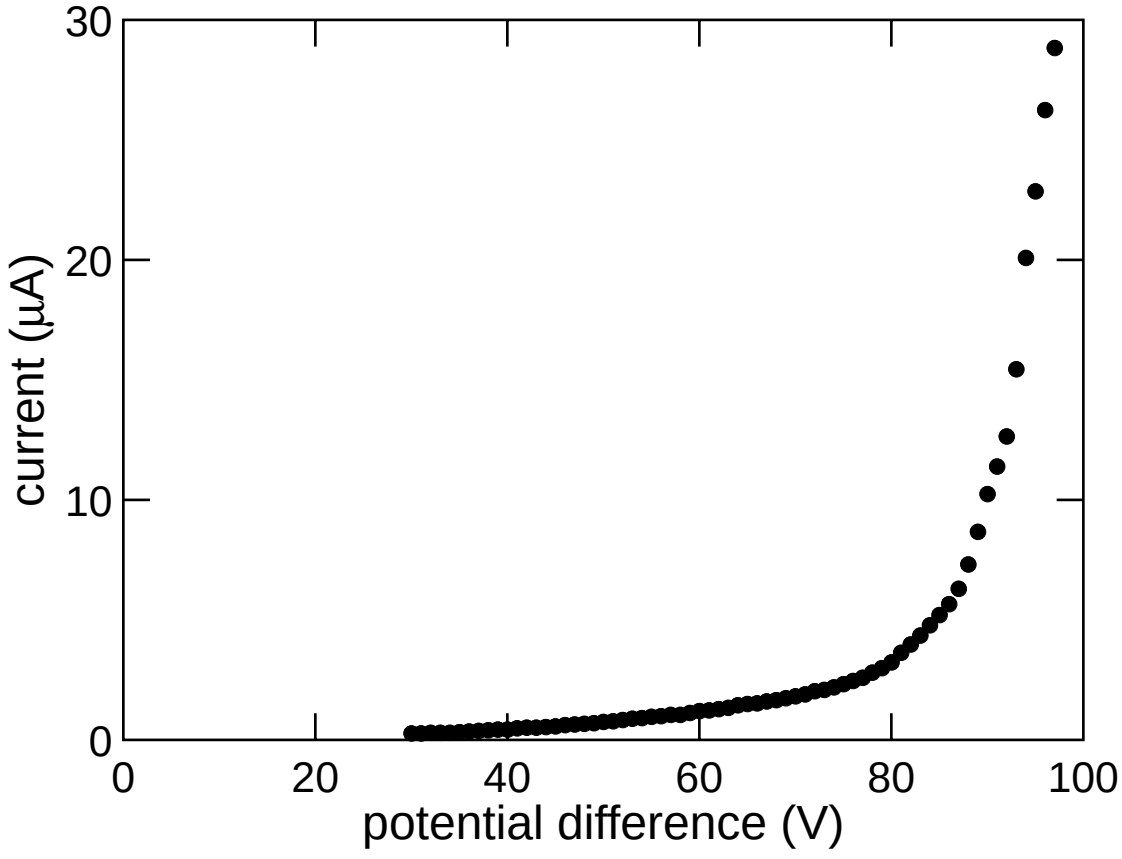
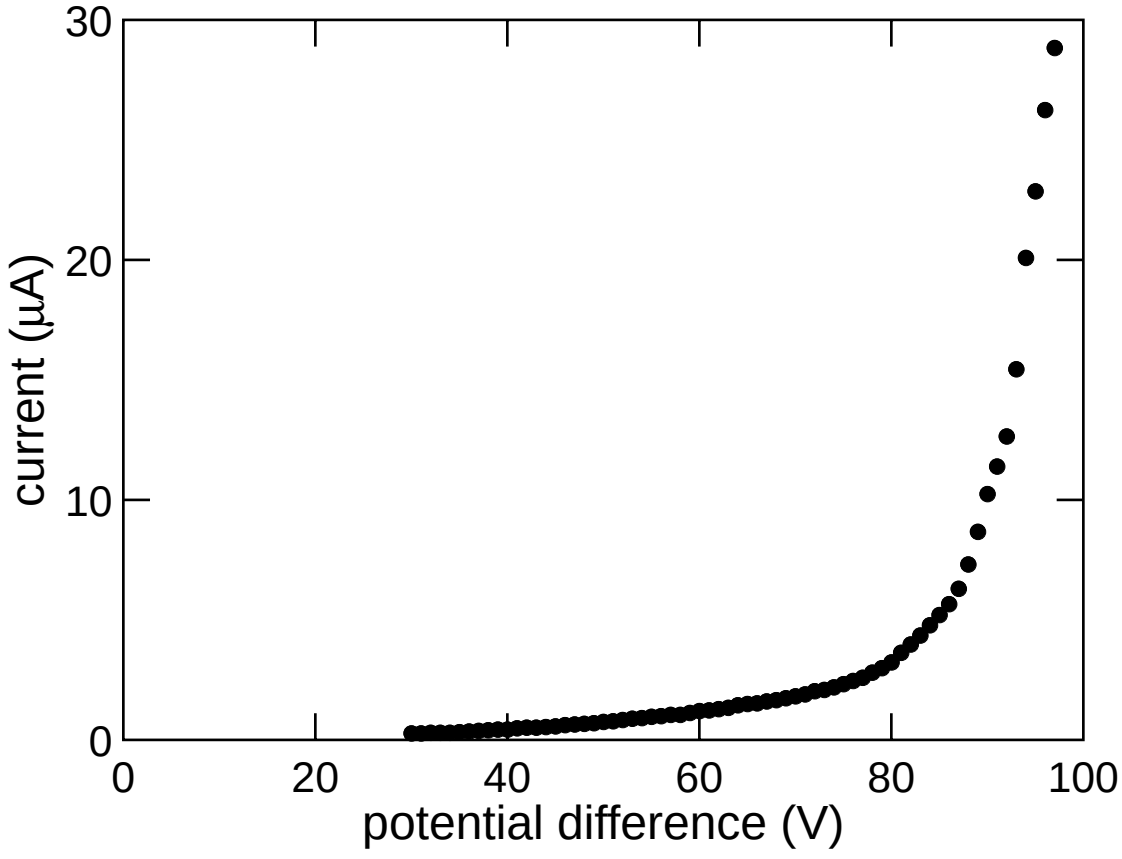


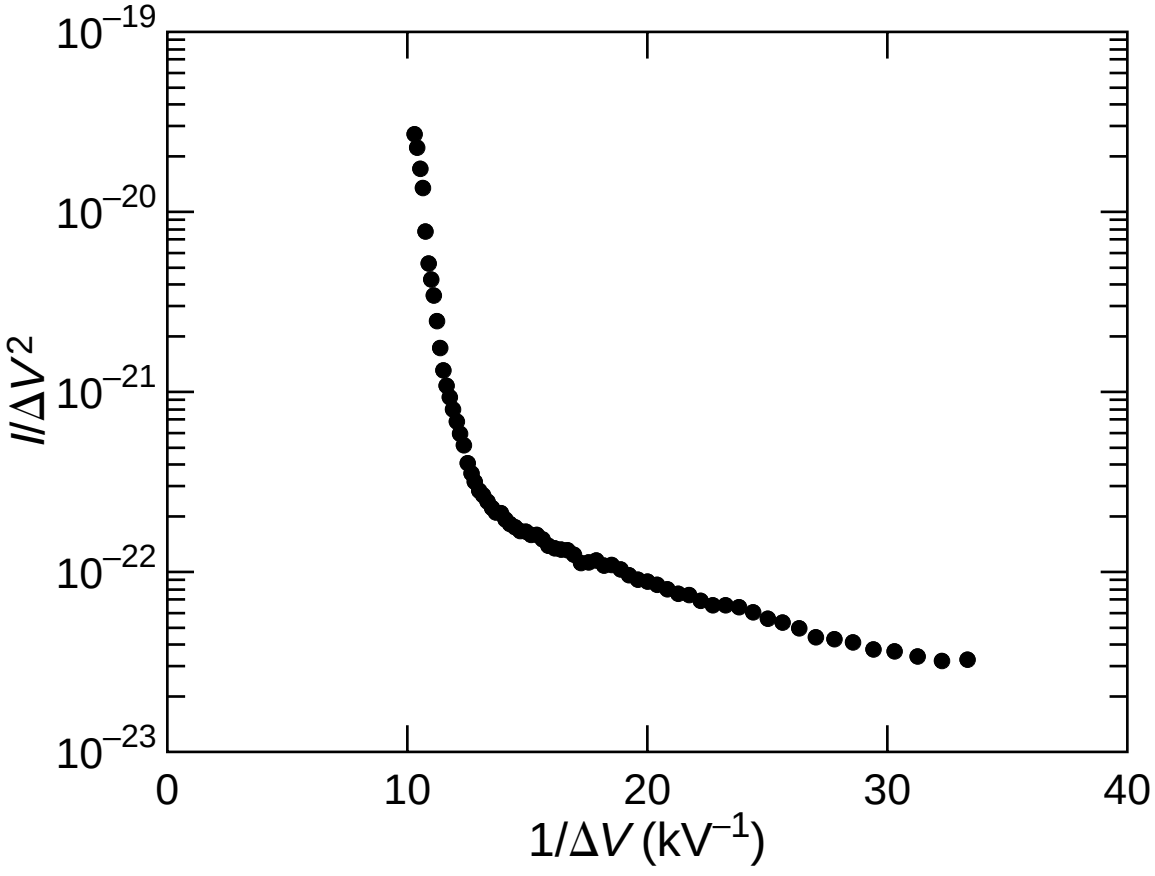
turn-on field (1 μA/cm^2): 1.2 V/μm

Results



threshold field (10 μA/cm^2): 2.1 V/μm

Results



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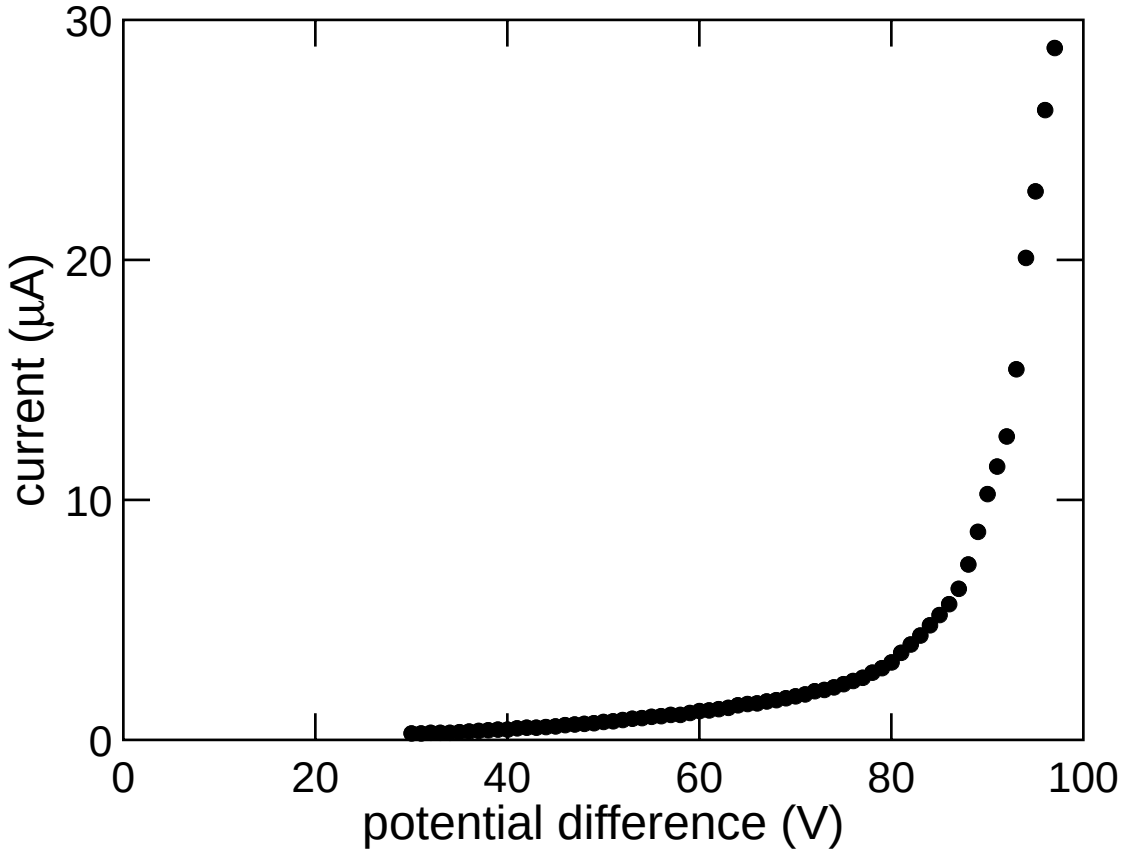

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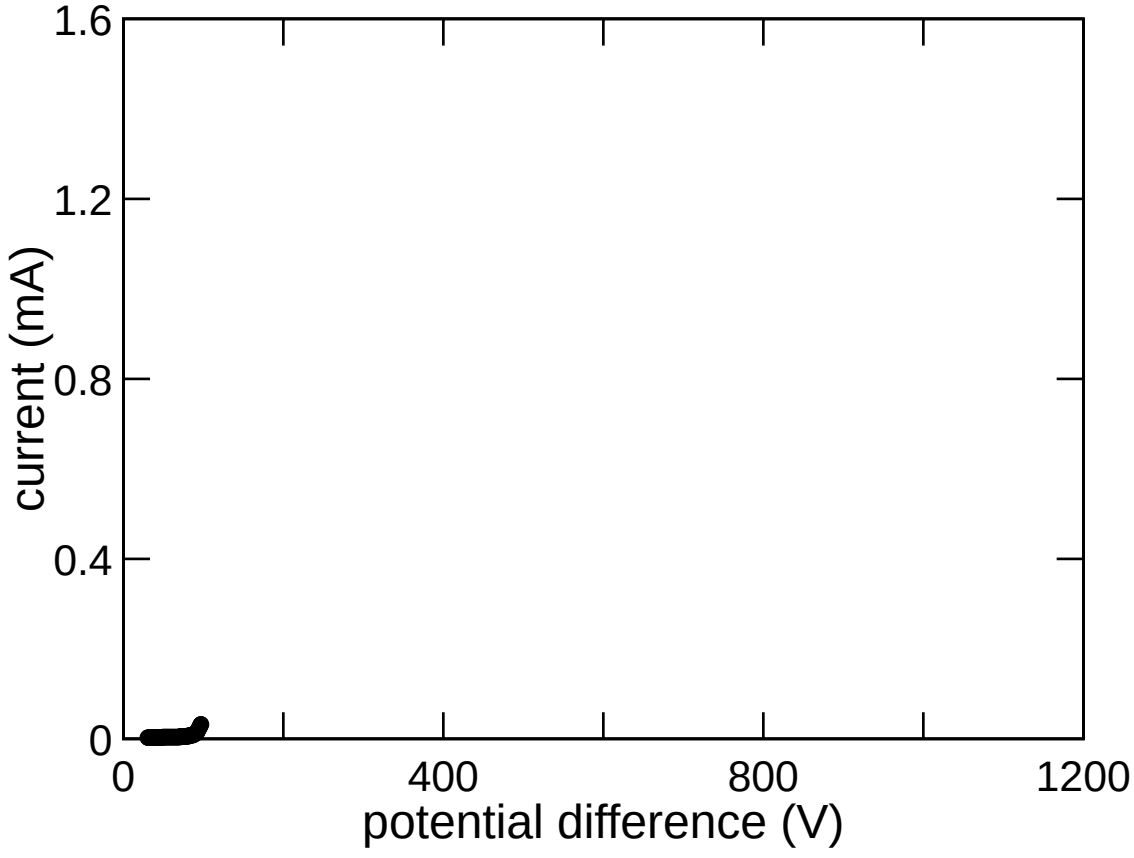

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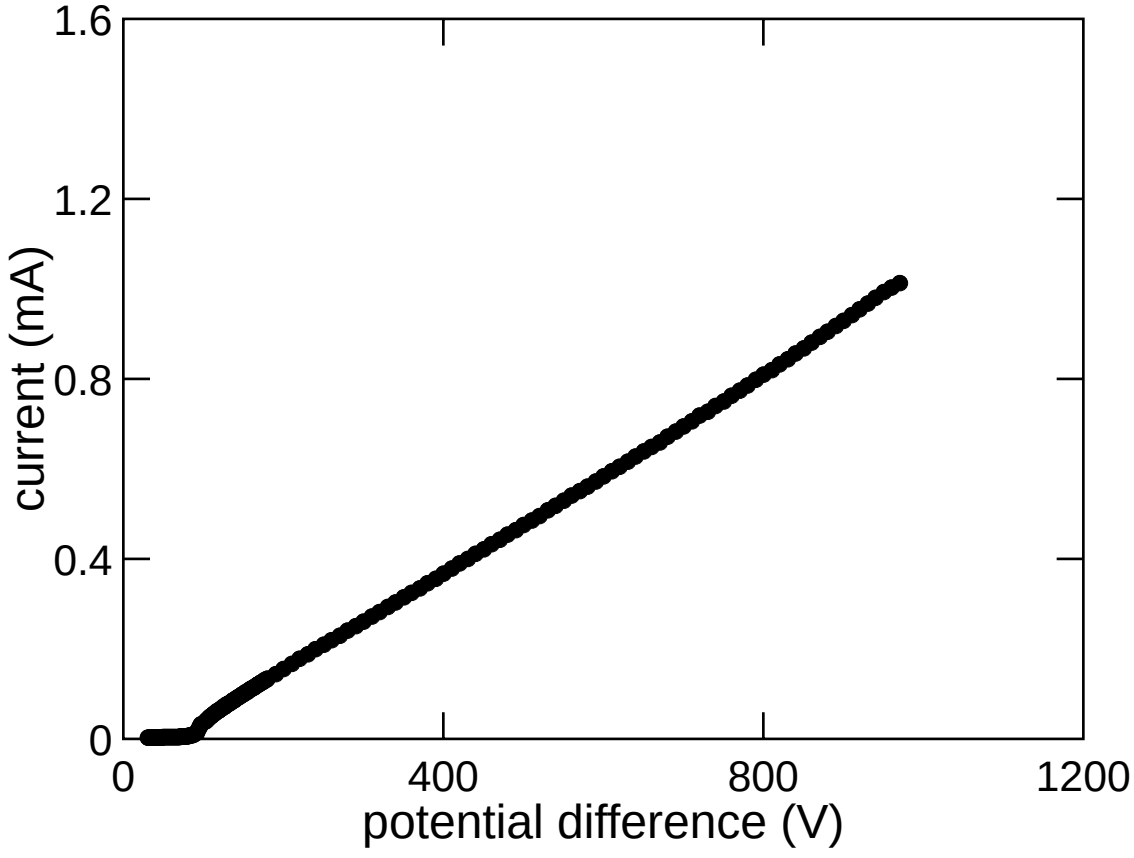

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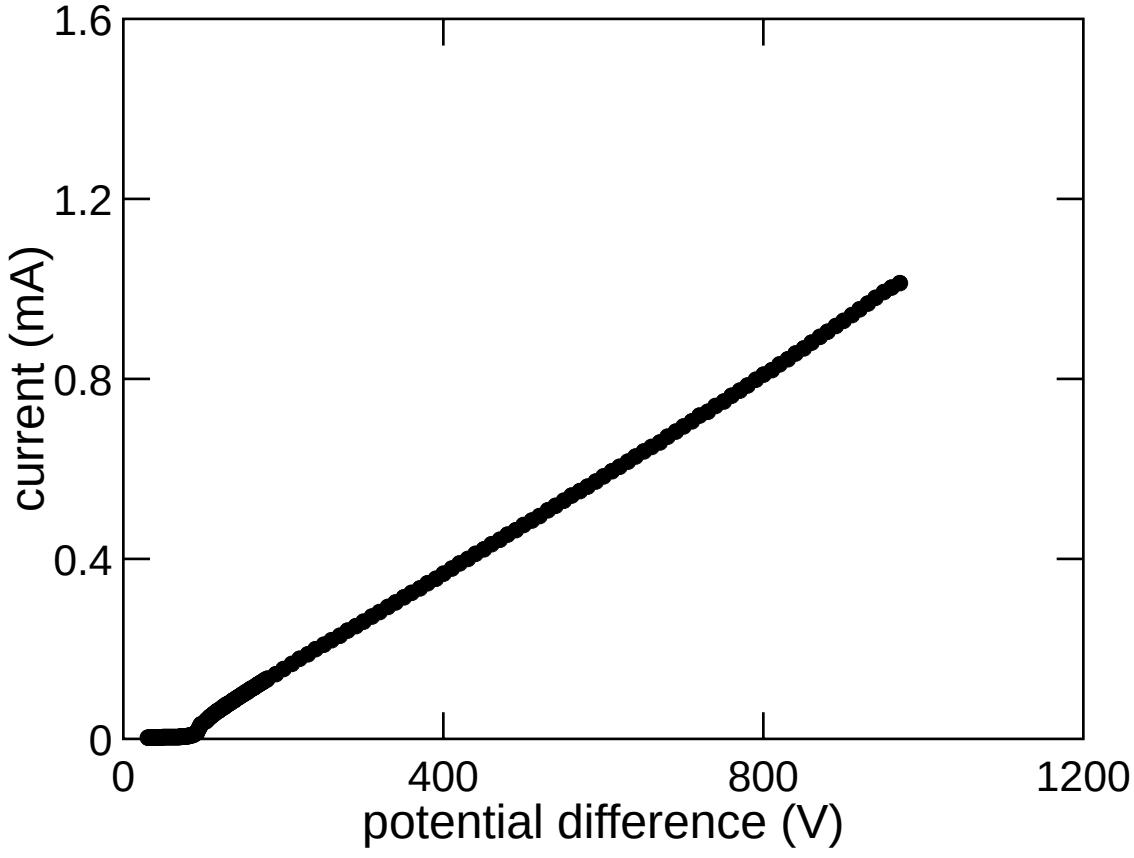
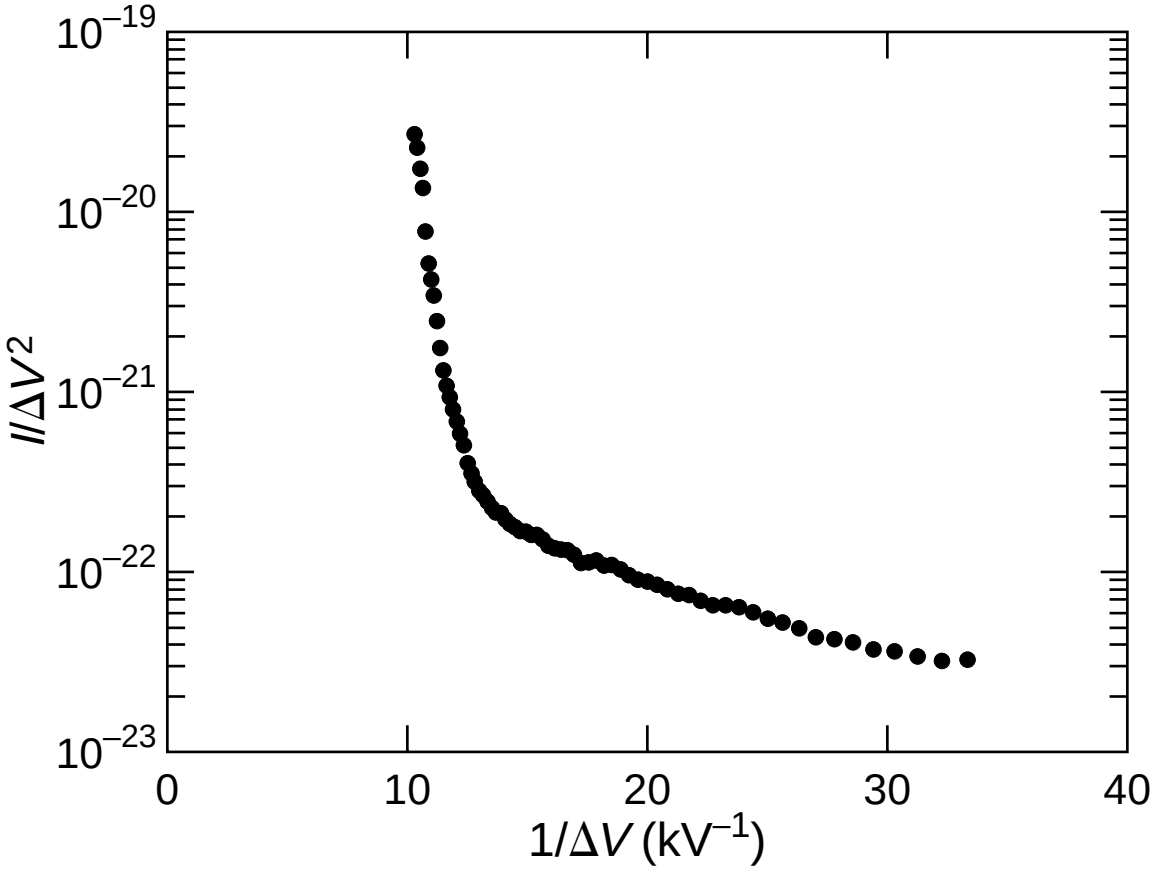


maximum current: 15 mA (4 mm^2 sample)

Results



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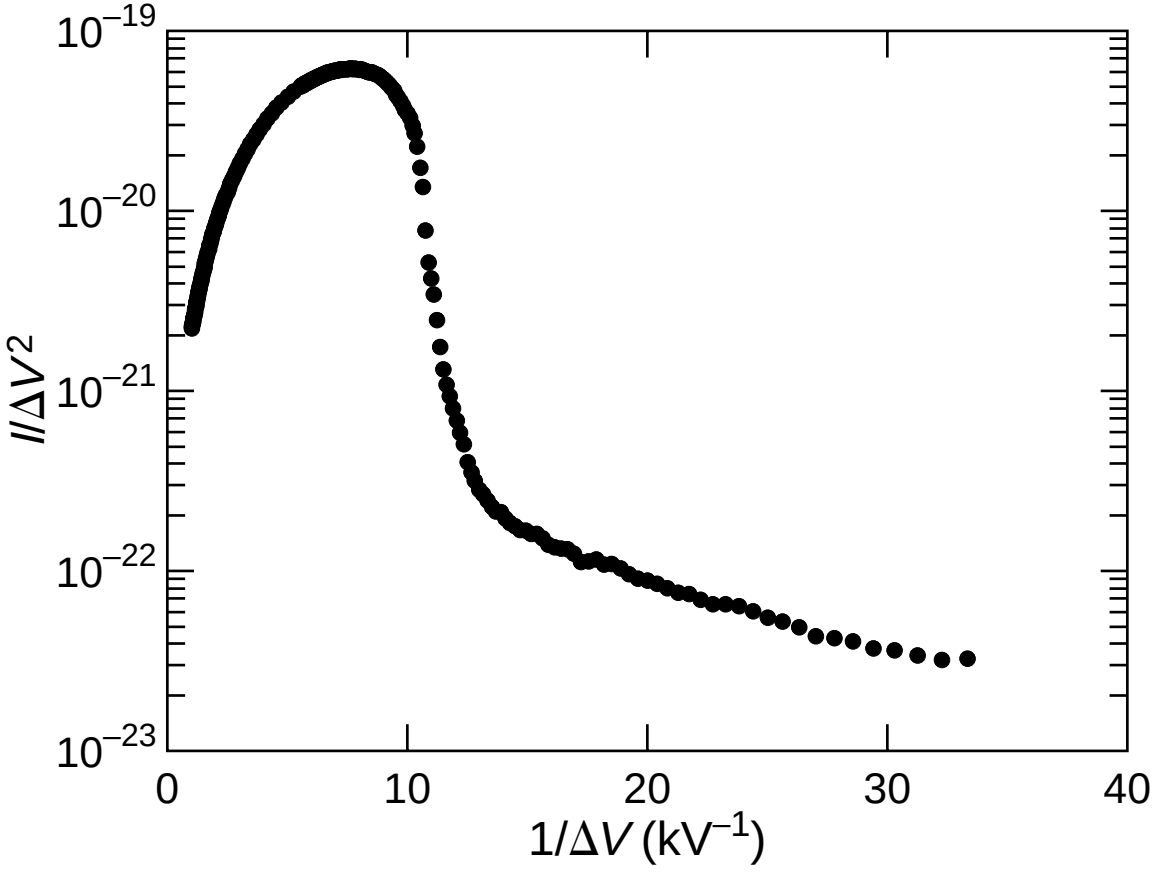


Outline

- Background
- Results
- **Discussion**

Discussion

Ion channeling and electron backscattering

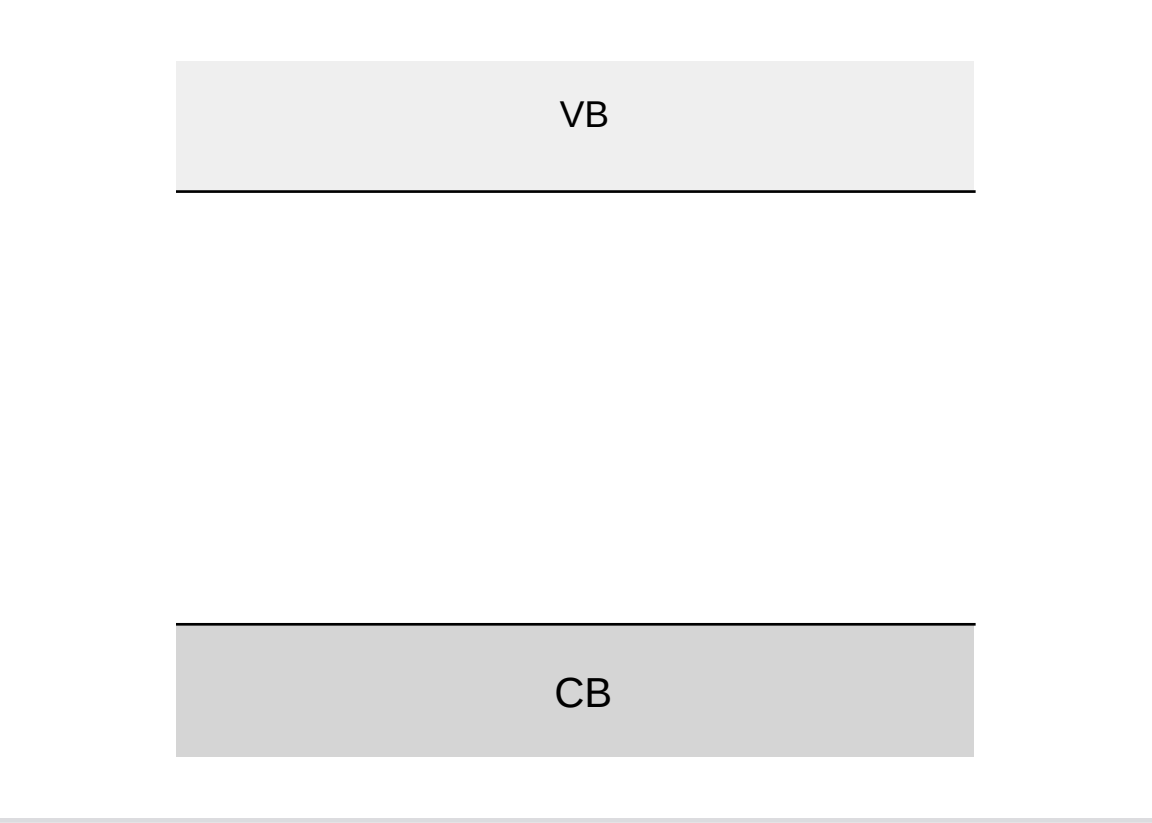
- **spikes retain crystalline order**
- **high density of defects**

Discussion

Secondary ion mass spectrometry:

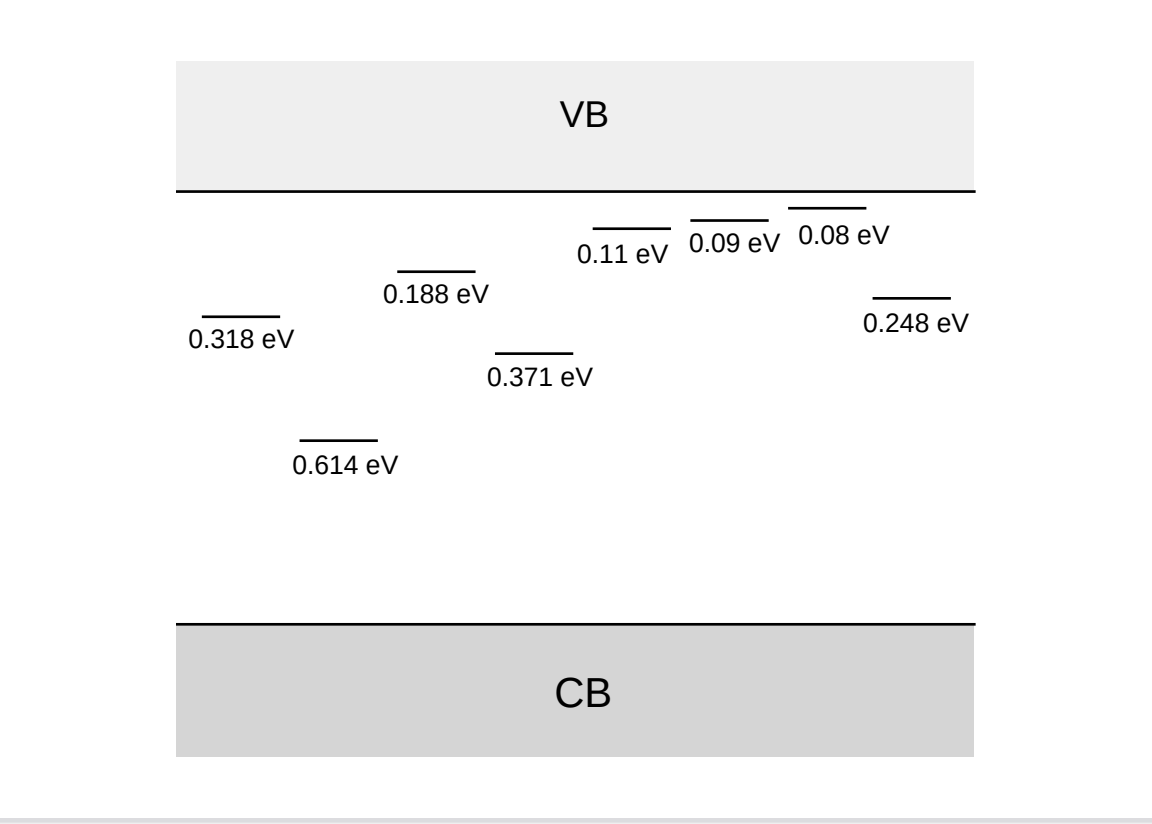
- **10^{20} cm^{-3} sulfur**
- **10^{17} cm^{-3} fluorine**

Discussion



Discussion

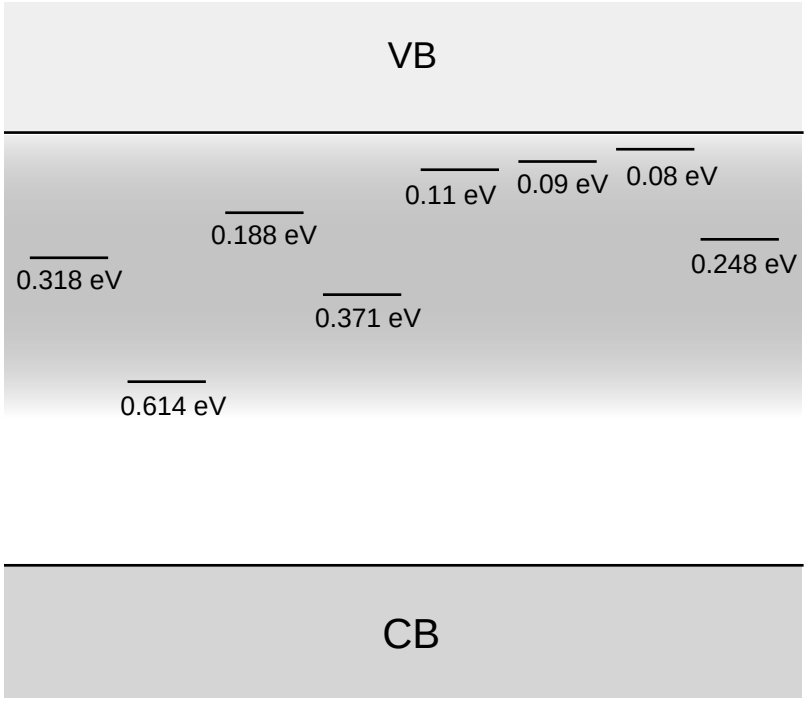
sulfur introduces states in the gap



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

Discussion

states broaden into a band



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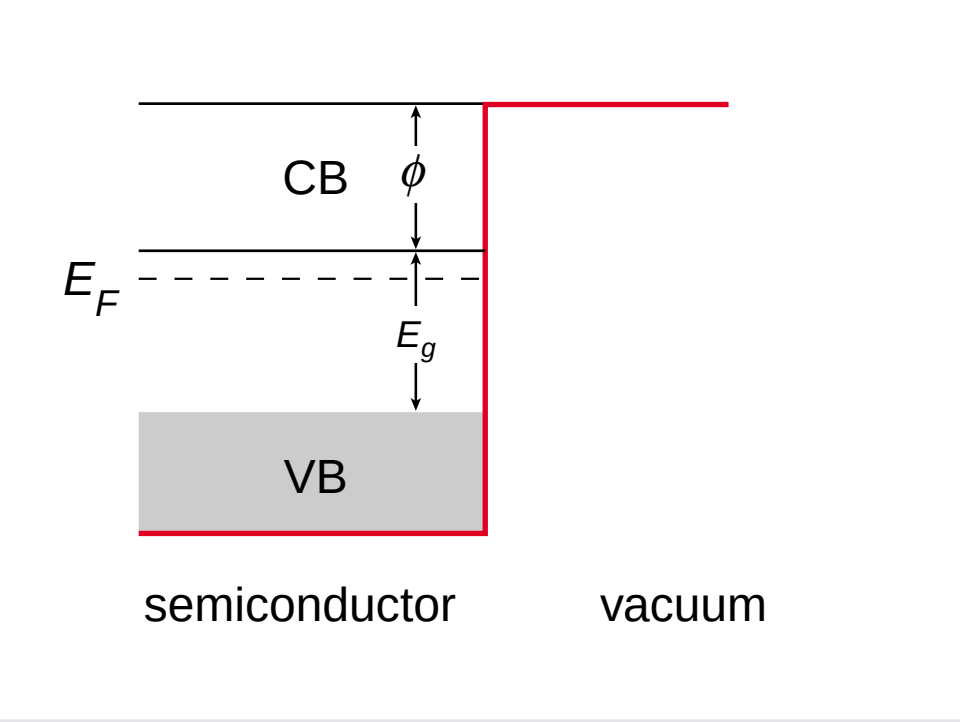
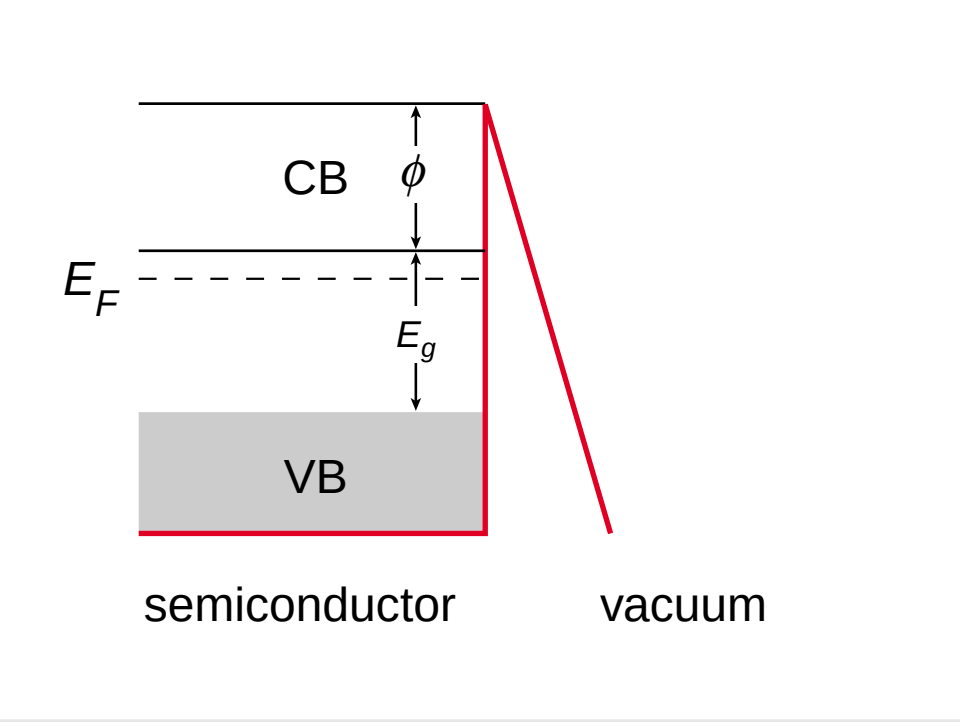


Field emission



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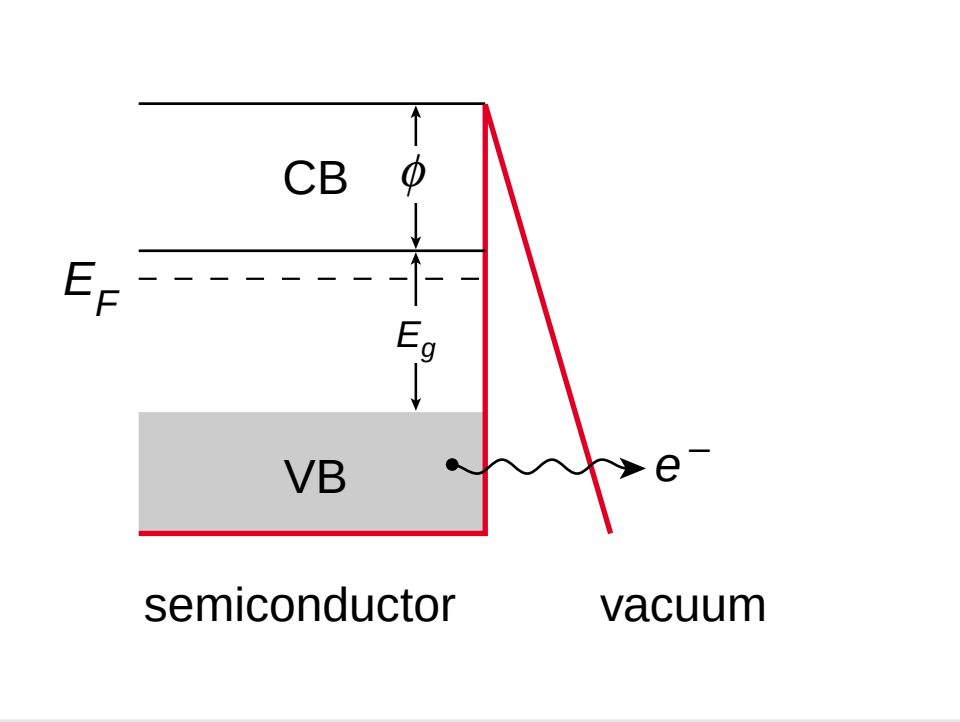
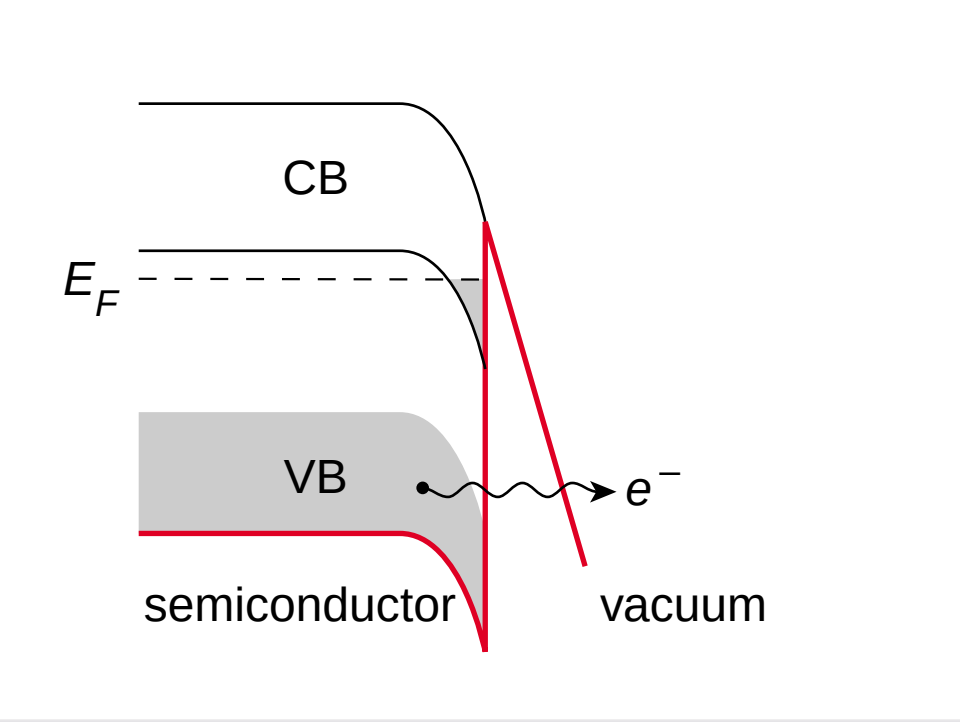


Field emission



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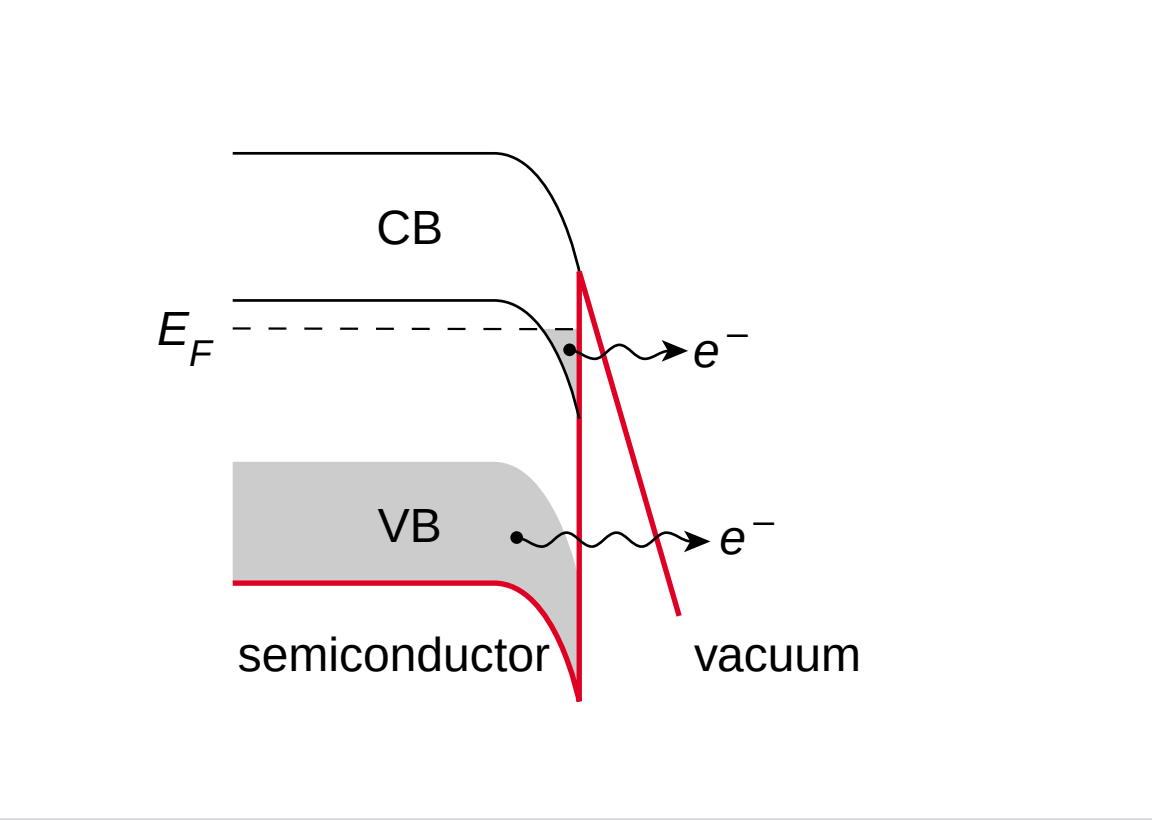
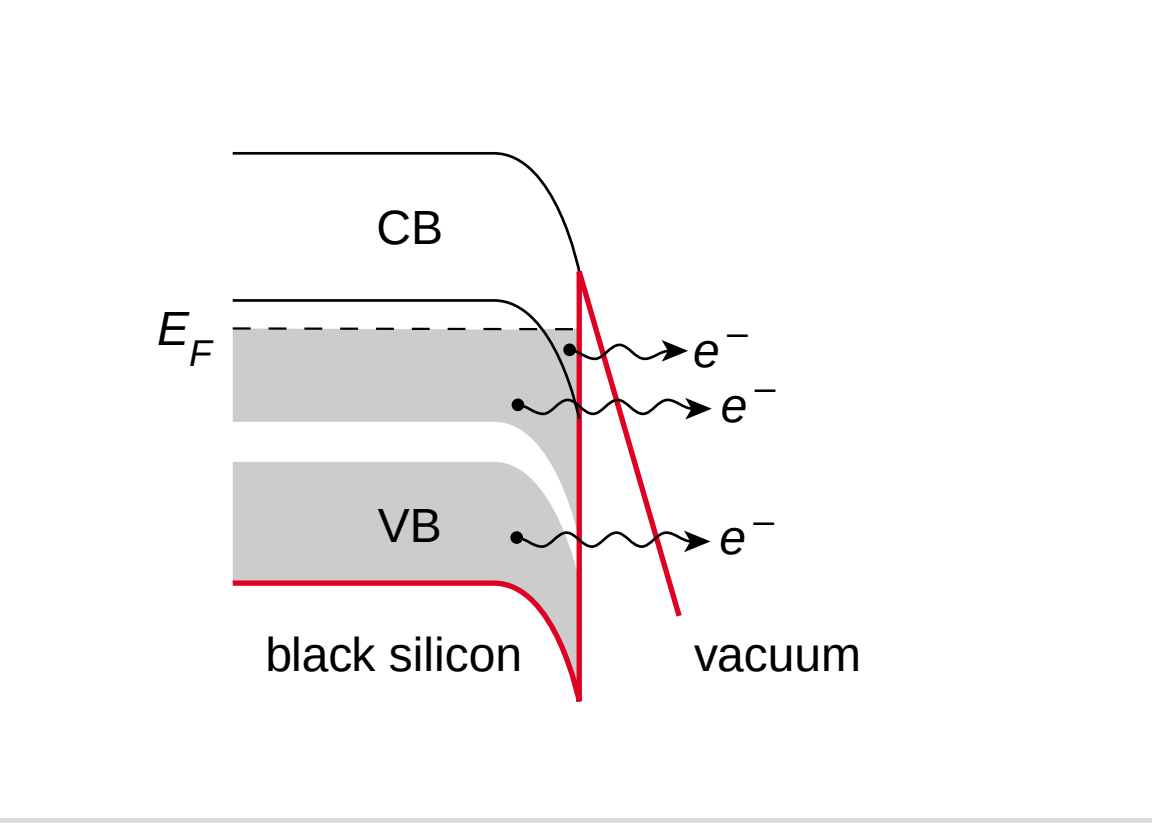


Discussion

sulfur band provides additional electrons



Summary

Microstructured silicon

- **fabricated by simple, maskless process**

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- **fabricated by simple, maskless process**
- **can be integrated with microelectronics**

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Microstructured silicon

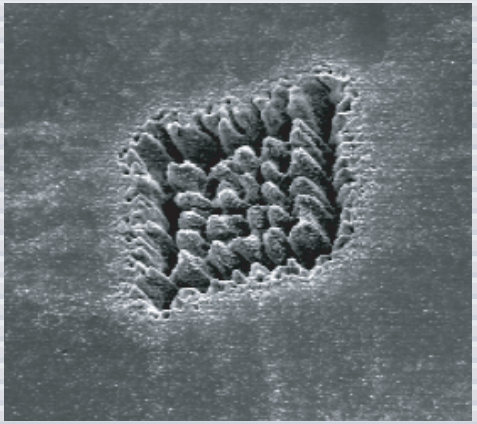
- **fabricated by simple, maskless process**
- **can be integrated with microelectronics**
- **provides stable, high field-emission current**

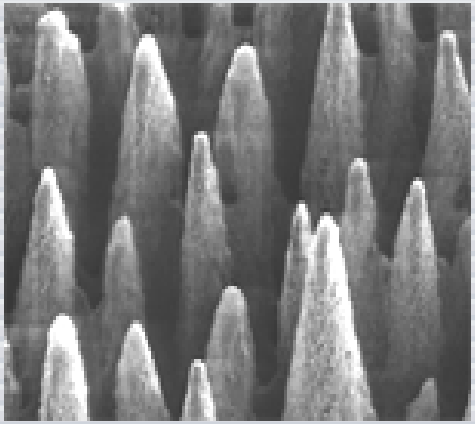
Summary

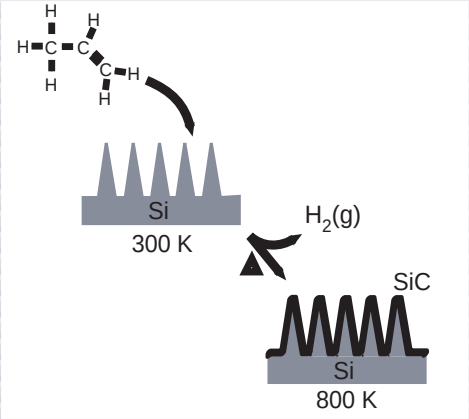
Microstructured silicon

- **fabricated by simple, maskless process**
- **can be integrated with microelectronics**
- **provides stable, high field-emission current**
- **is durable**

Future Directions







- **Ordered arrays**
- **Other gases**
- **Functionalizing**
- **Emission mechanism**

Acknowledgements

Rebecca Younkin, Mike Sheehy, Catherine Crouch, Josh Levinson, and the Mazur group

Li Zhao, Fudan University, Shanghai, China

funding: ARO, NSF, NDSEG

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