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

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Catherine Crouch
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Li Zhao
Eric Mazur

CLEO 2001
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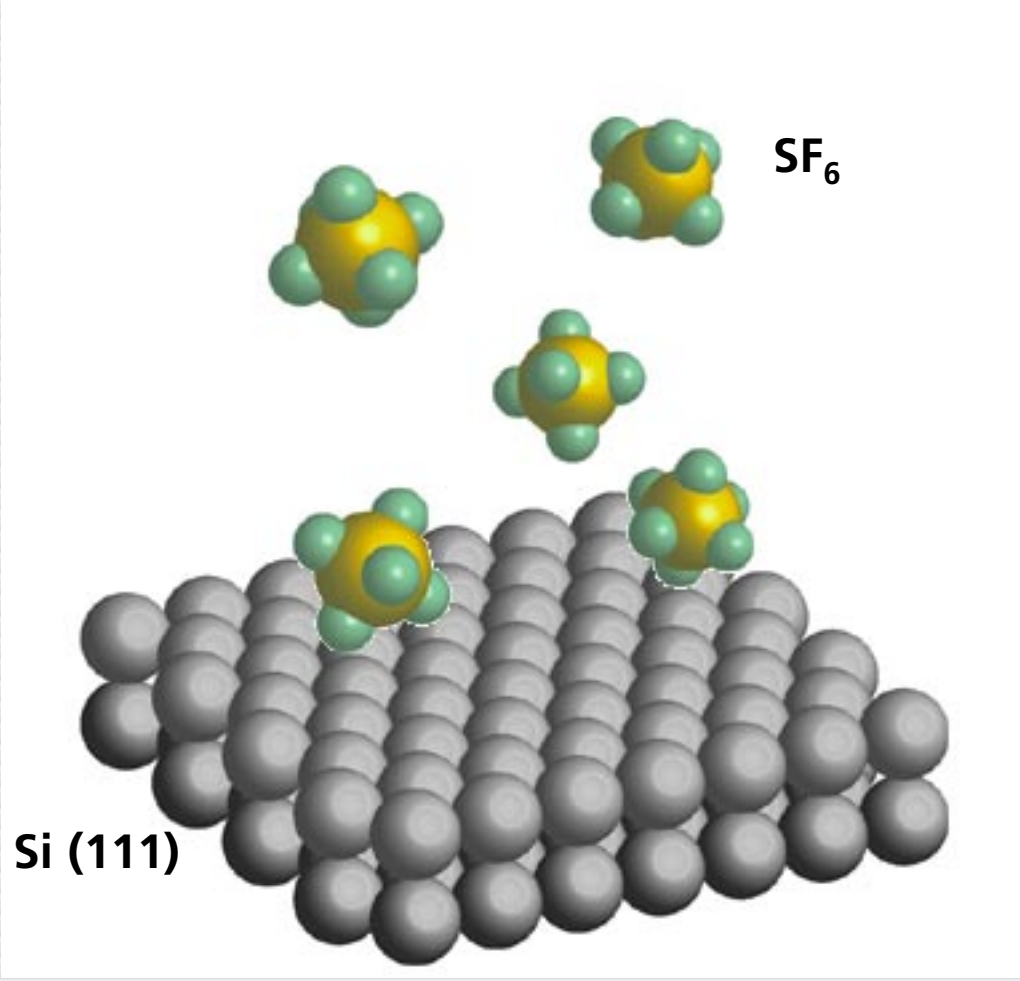
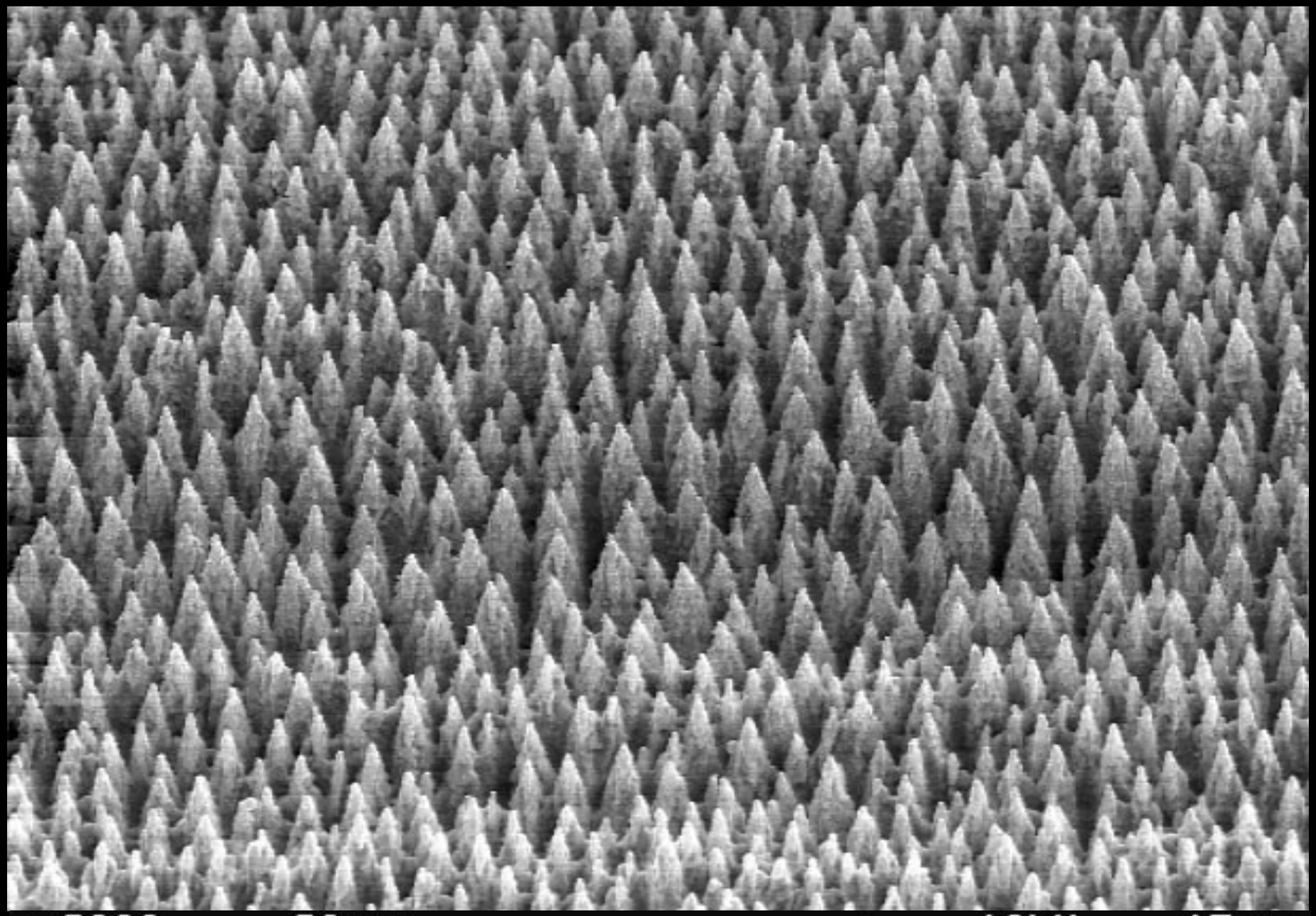
Outline

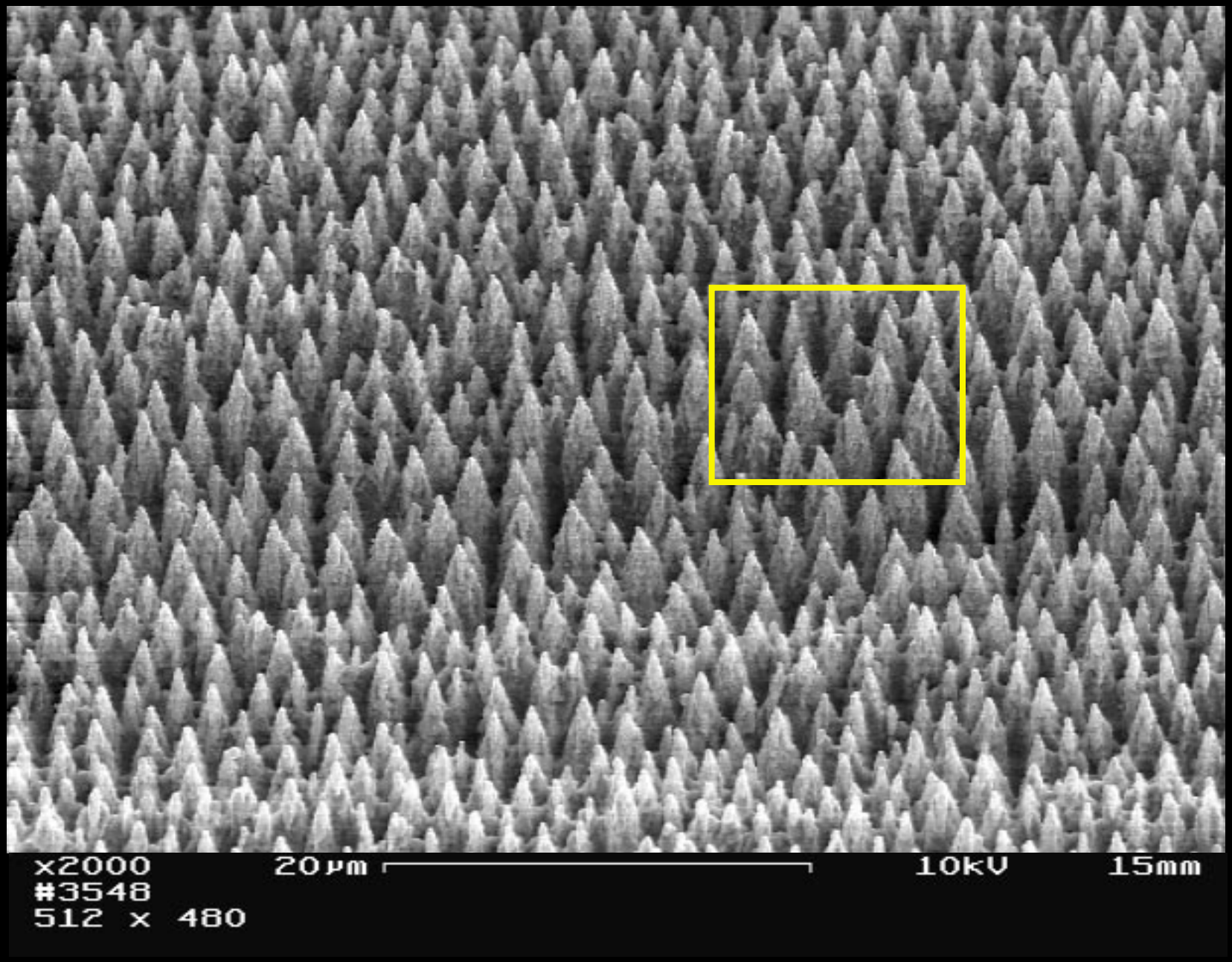
- Background
- Results
- Discussion

Background



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


x2000
20μm
10kV
15mm
#3548
512 x 480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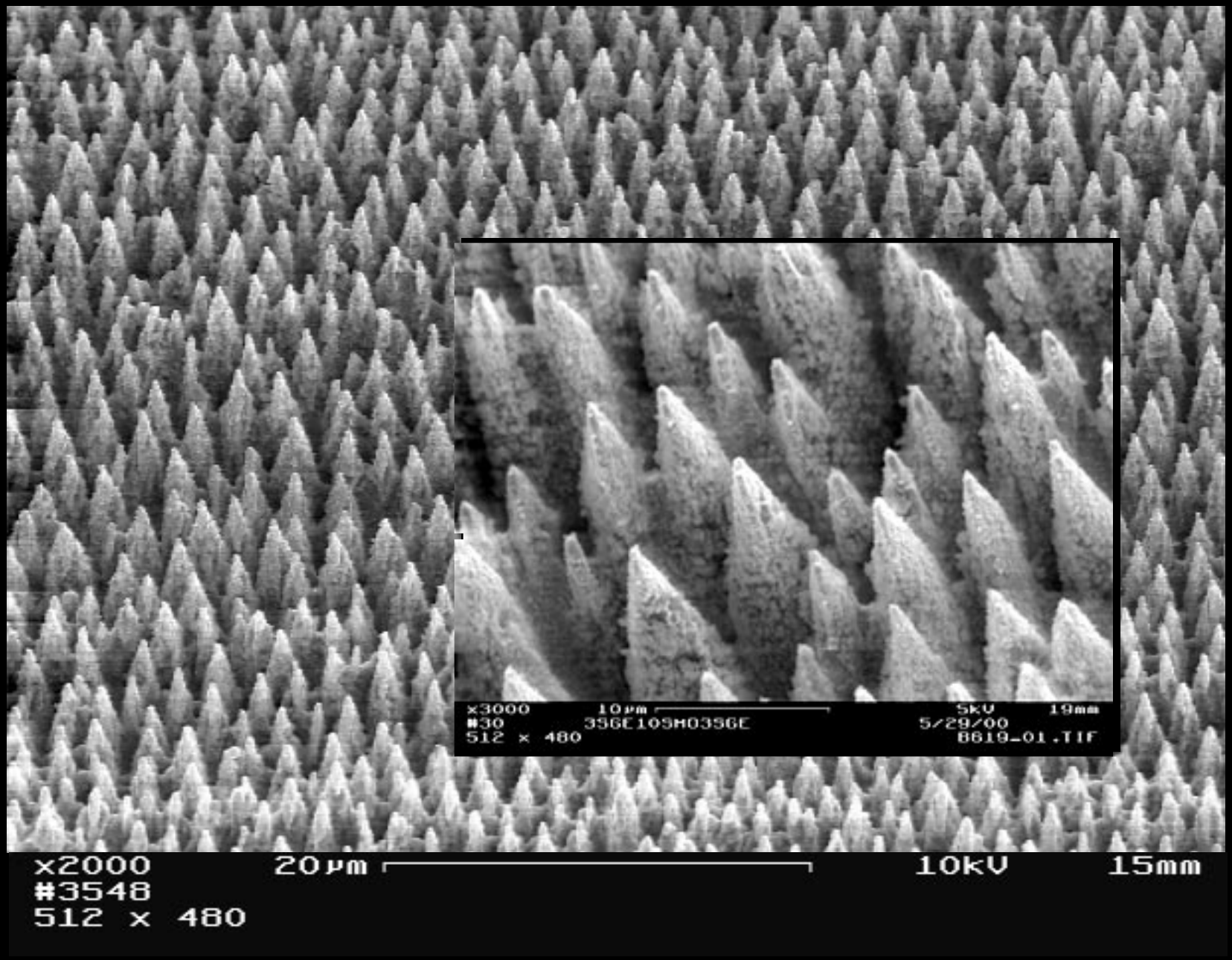
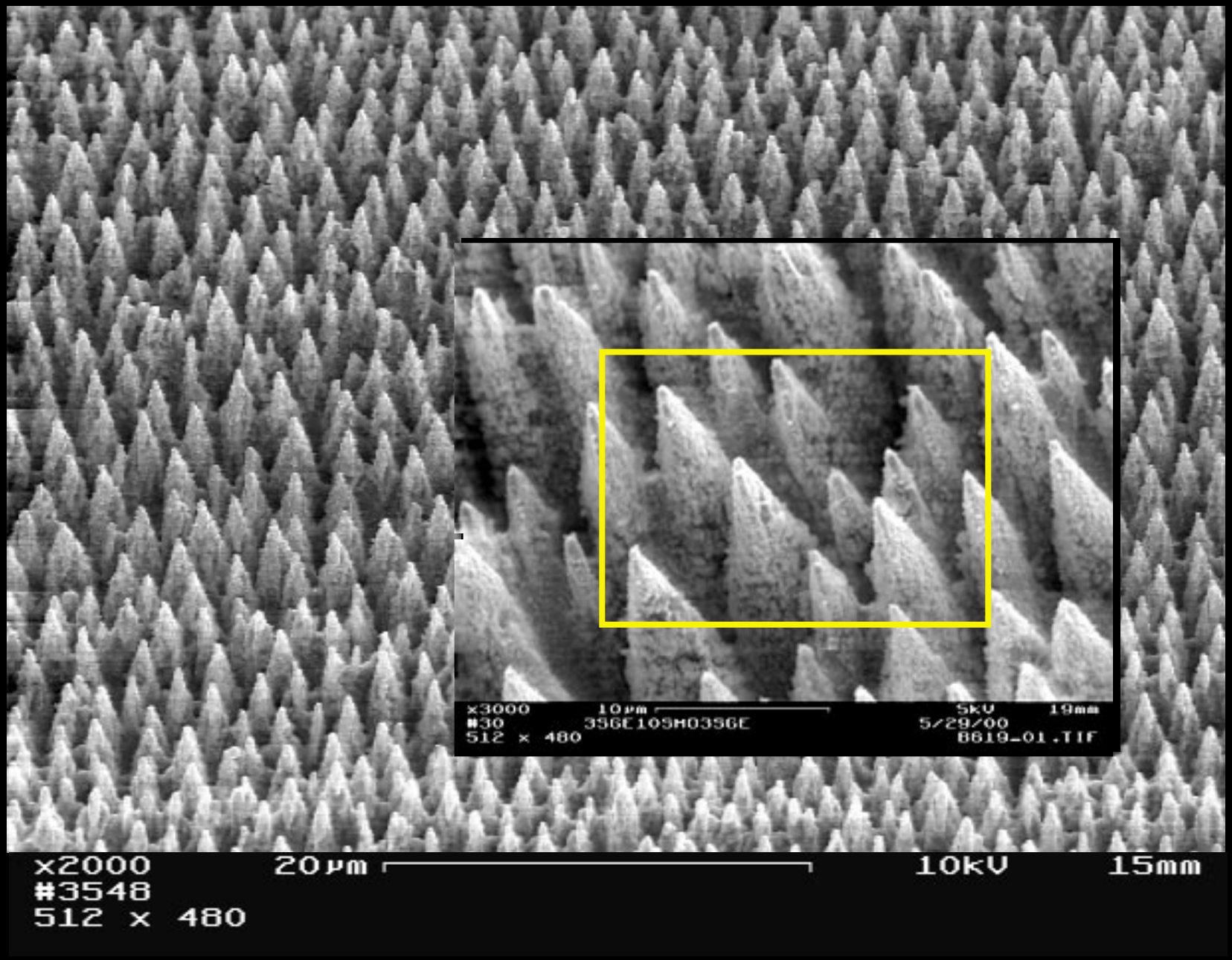

x3000 10µm 5kV 19mm
#30 356E105M0356E 5/29/00
512 x 480 8819-01.TIF
x2000 20µm 10kV 15mm
#3548
512 x 480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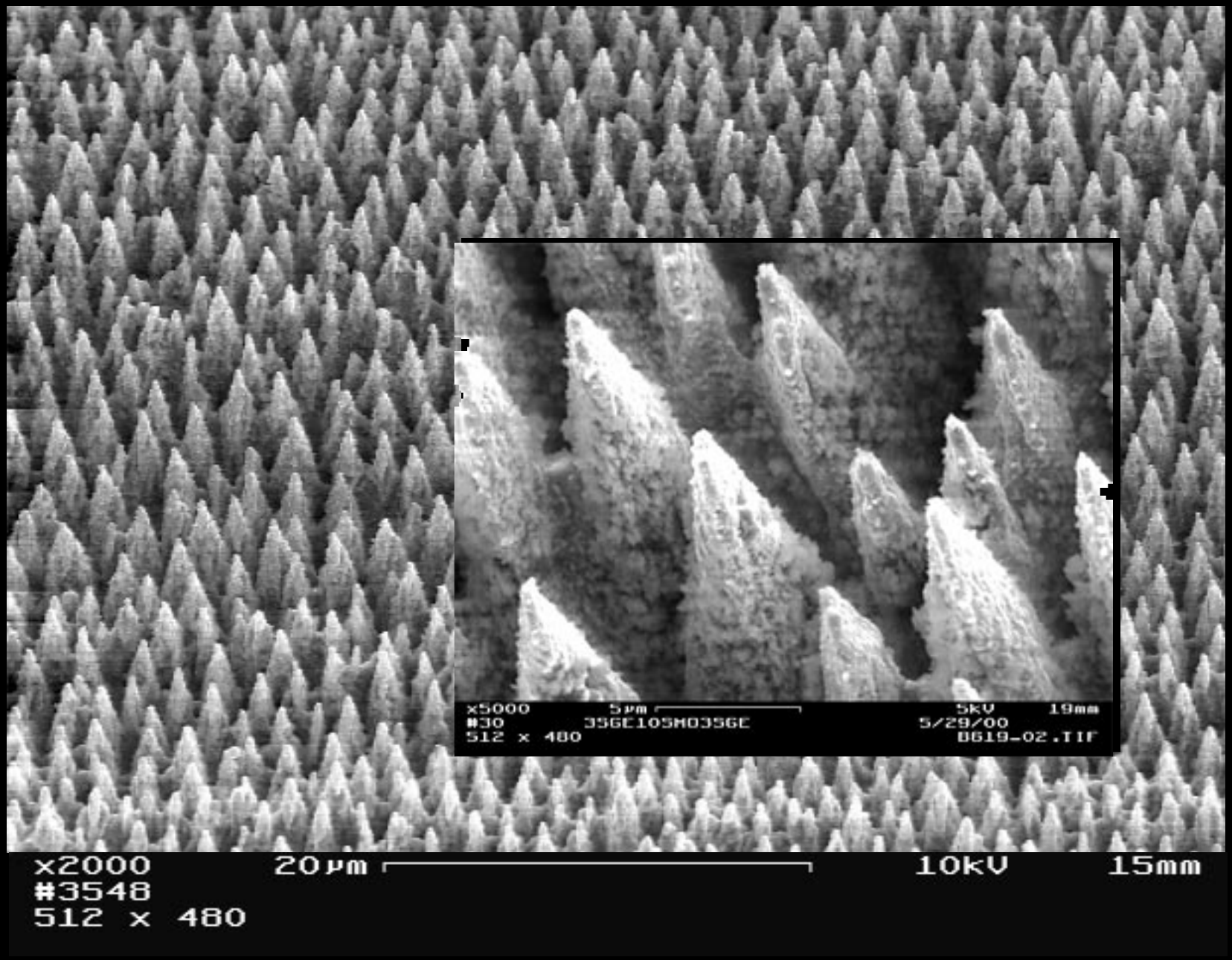
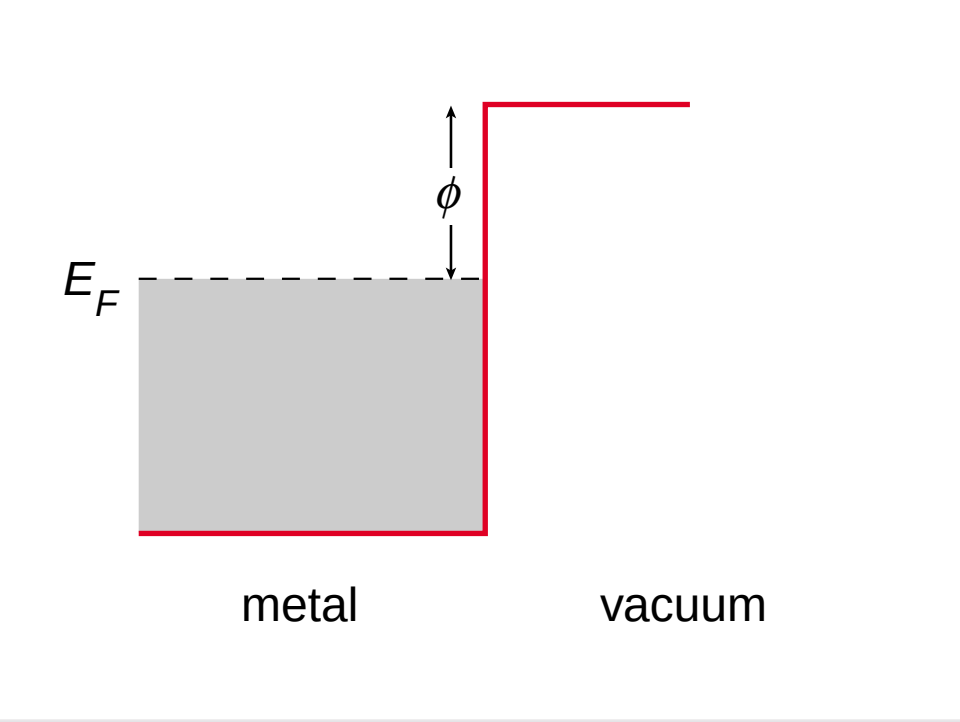
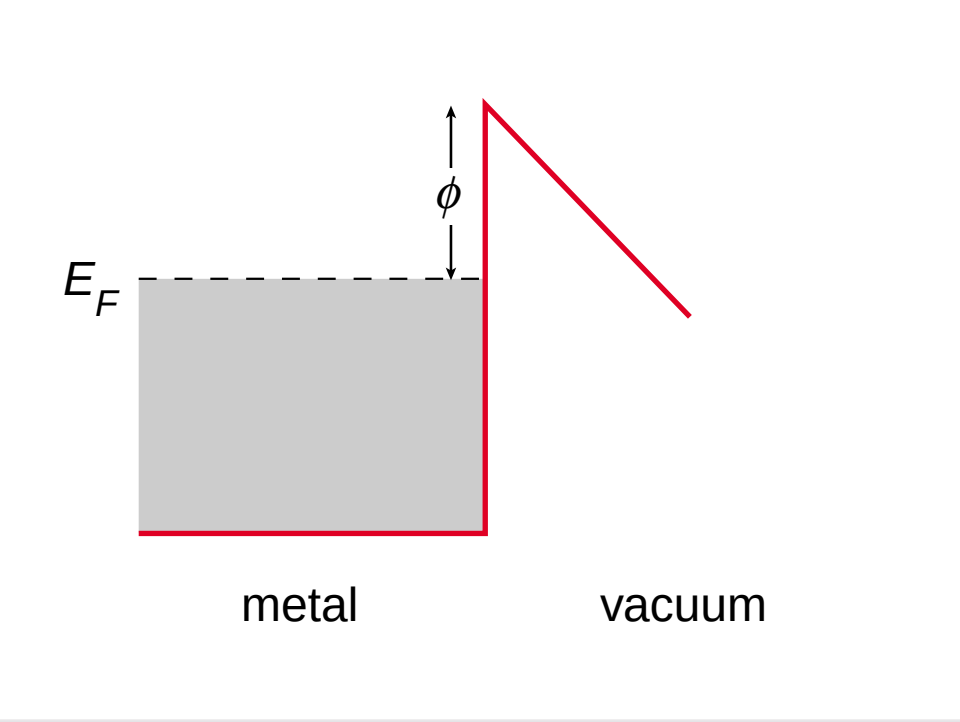
#30 356E105M0356E 5/29/00
512 x 480 8819-01.TIF
x2000 20µm 10kV 15mm
#3548
512 x 480


x5000 5µm 5kV 19mm
#30 35GE105M035GE 5/29/00
512 x 480 B619-02.TIF
x2000 20µm 10kV 15mm
#3548
512 x 480

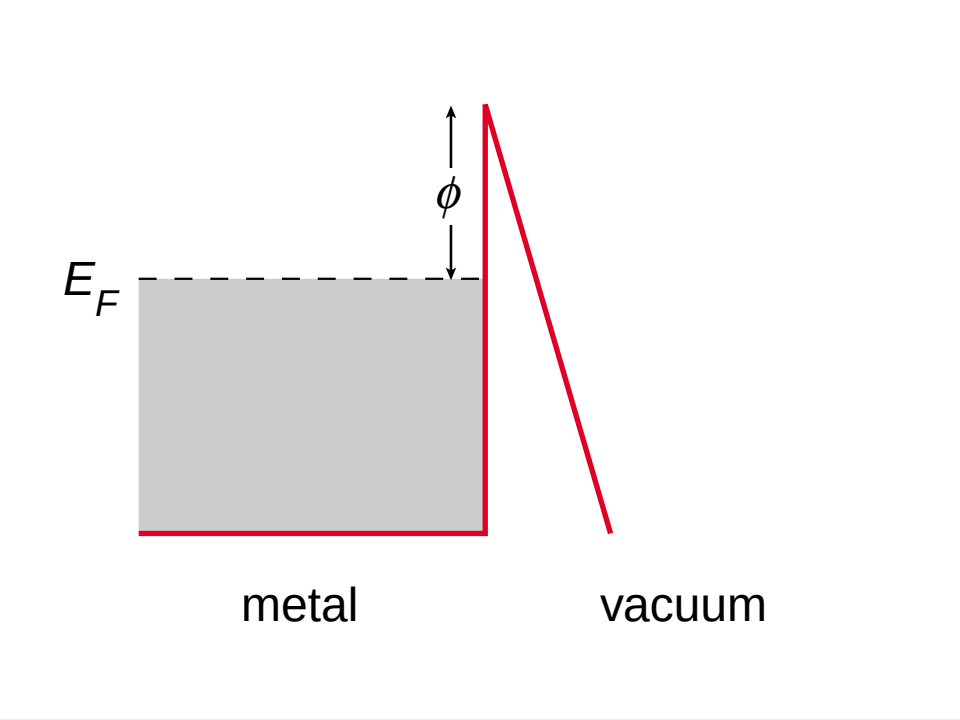
Field emission



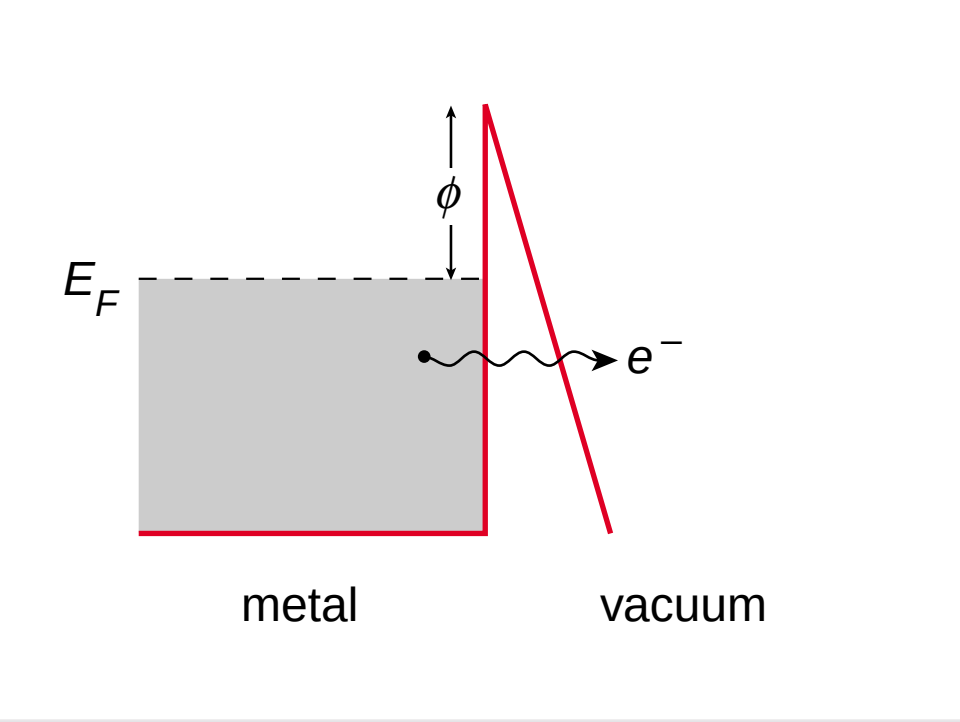
Field emission



Field emission



Field emission



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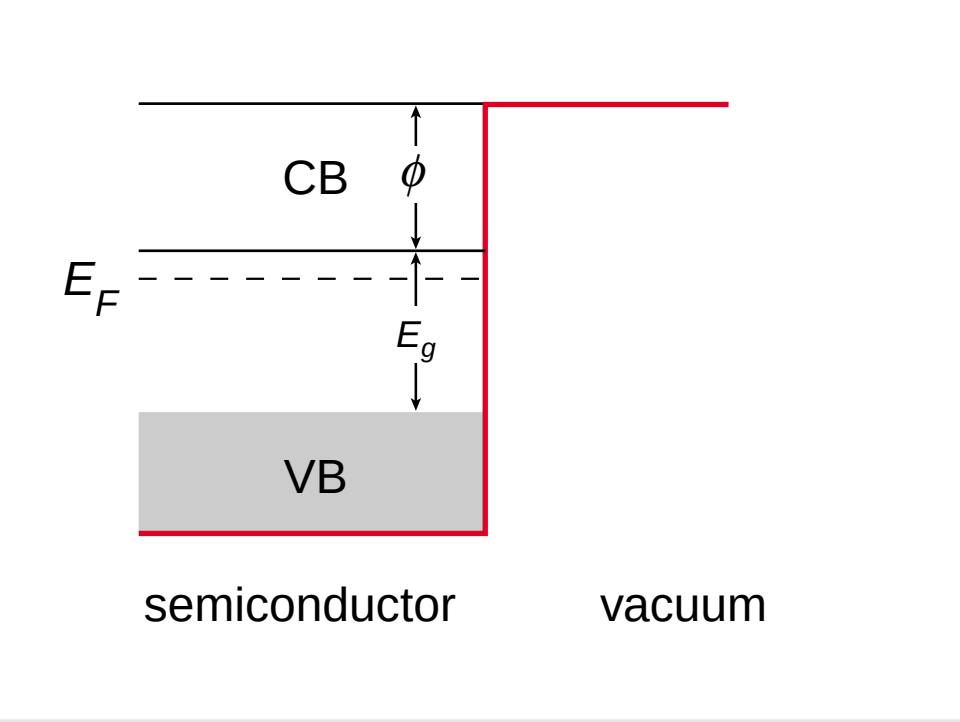
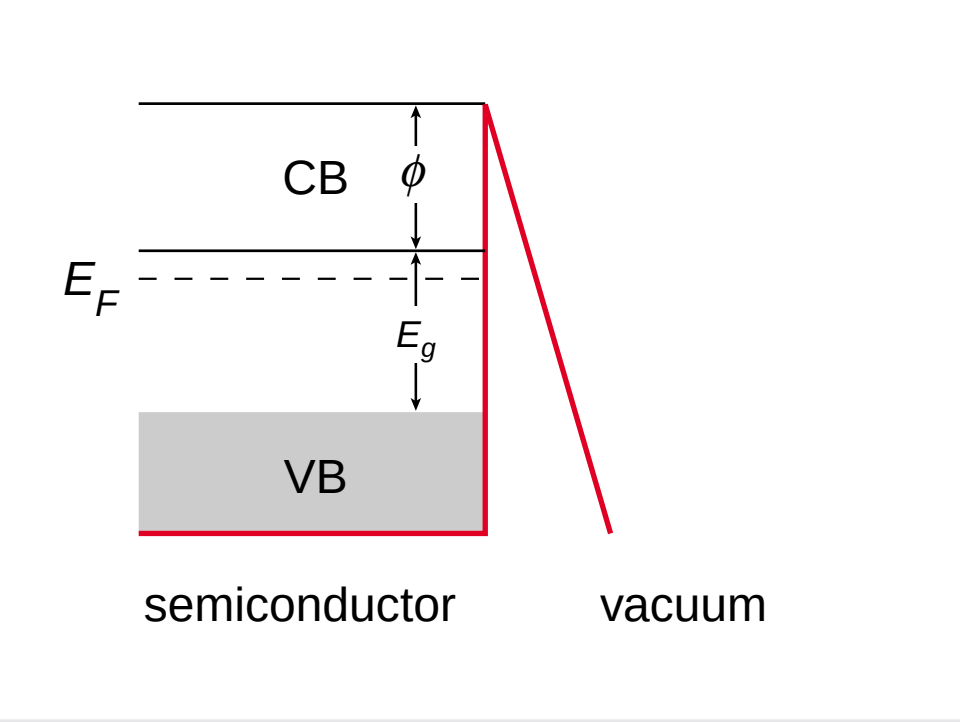
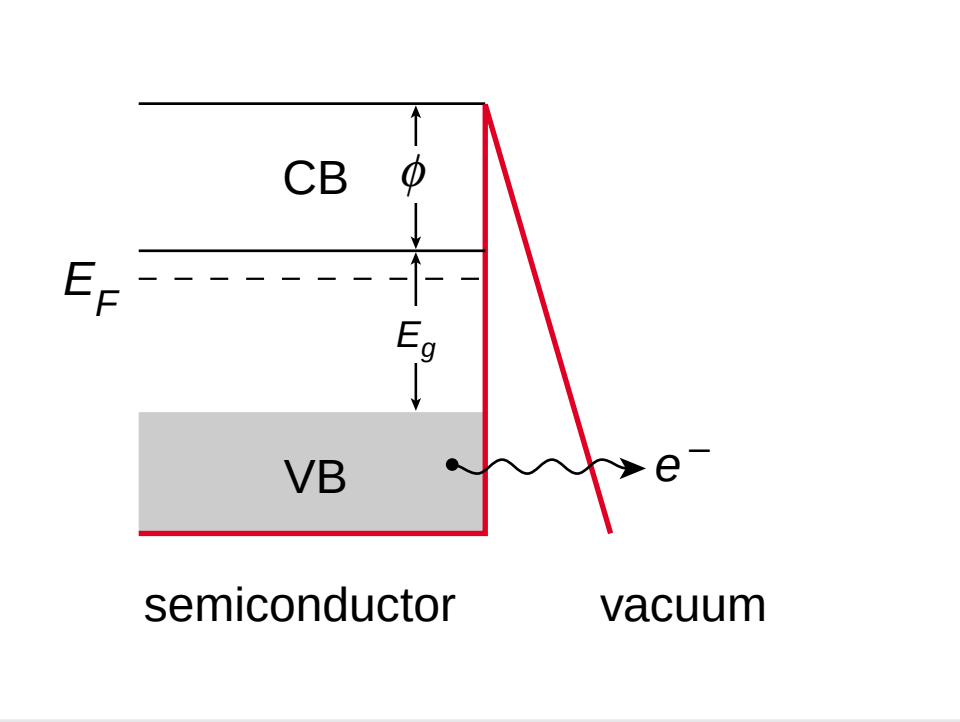


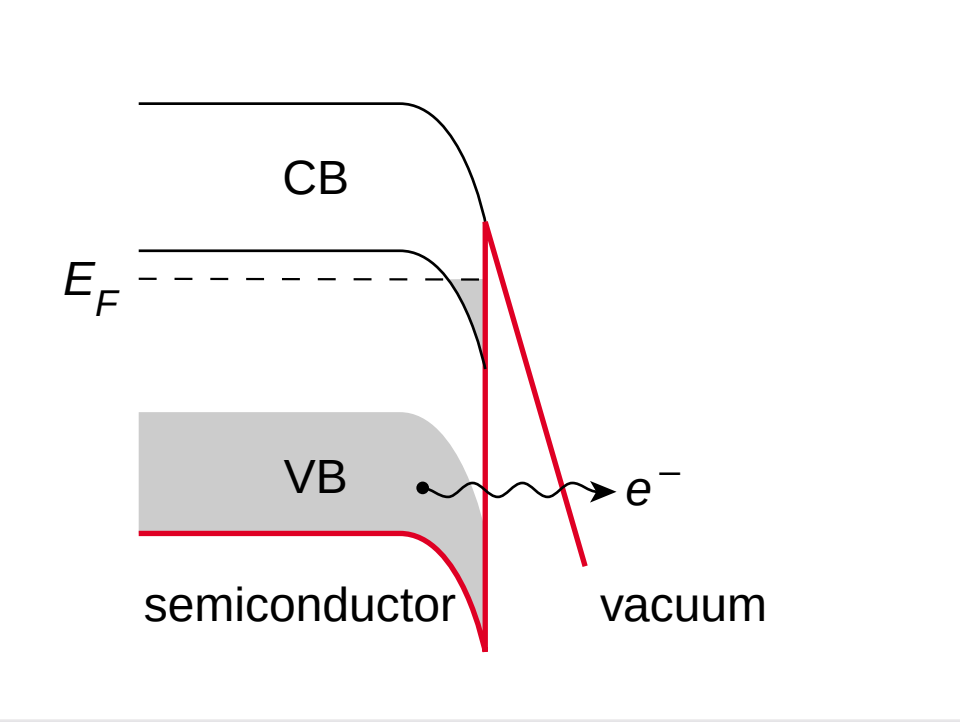
Field emission



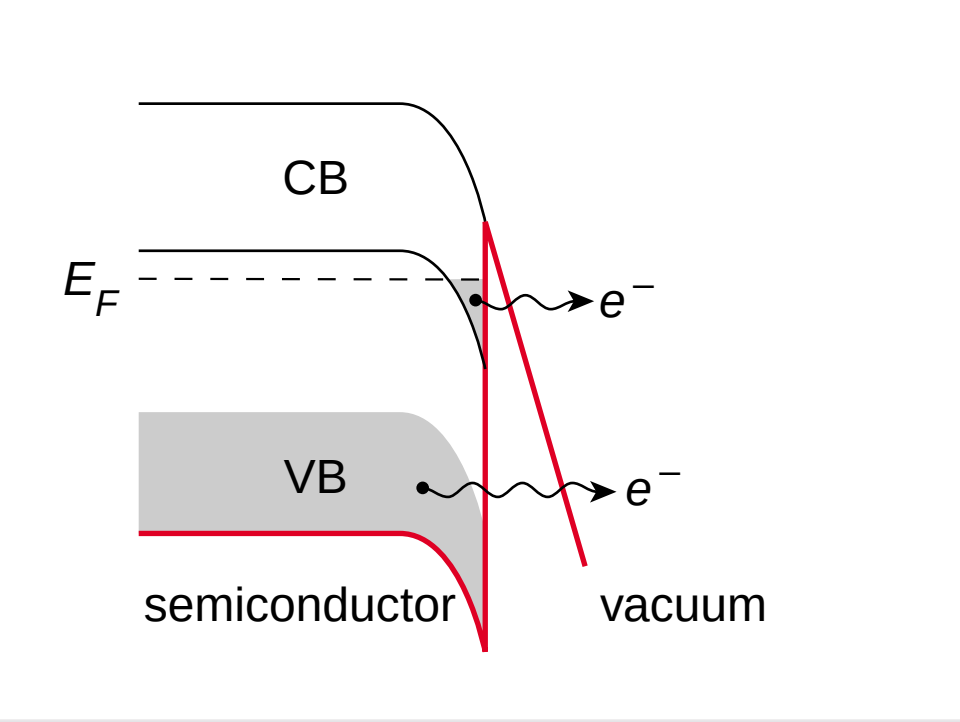
Field emission



Field emission

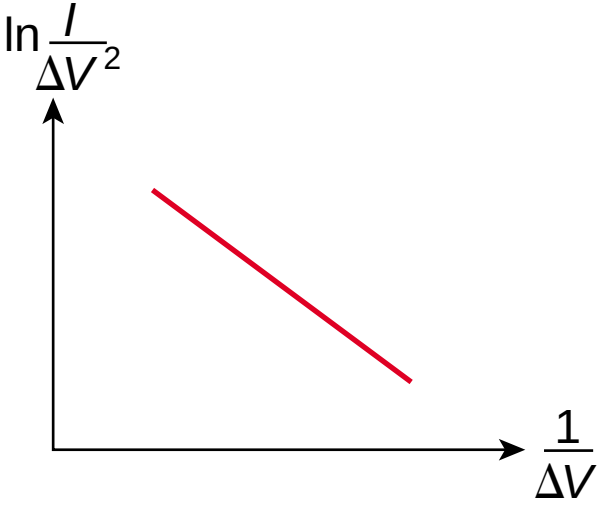


Field emission



Field emission

$$\ln \frac{I}{\Delta V^2} = \ln a - b\frac{1}{\Delta V}$$



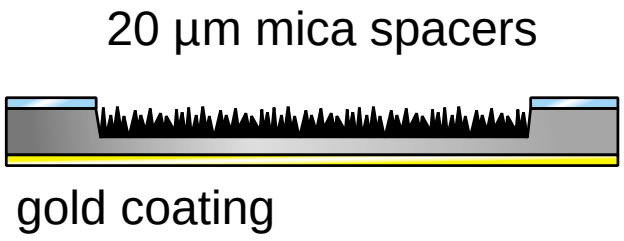
R.H. Fowler and L. Nordheim, *Proc. R. Soc. Lond. A* (1928)

Setup

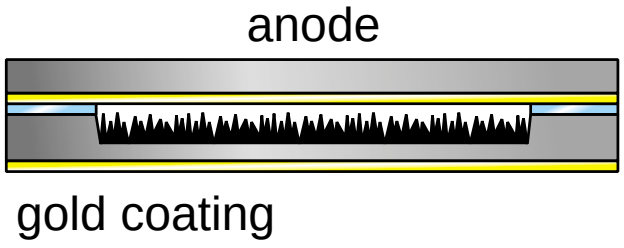
Setup

gold coating

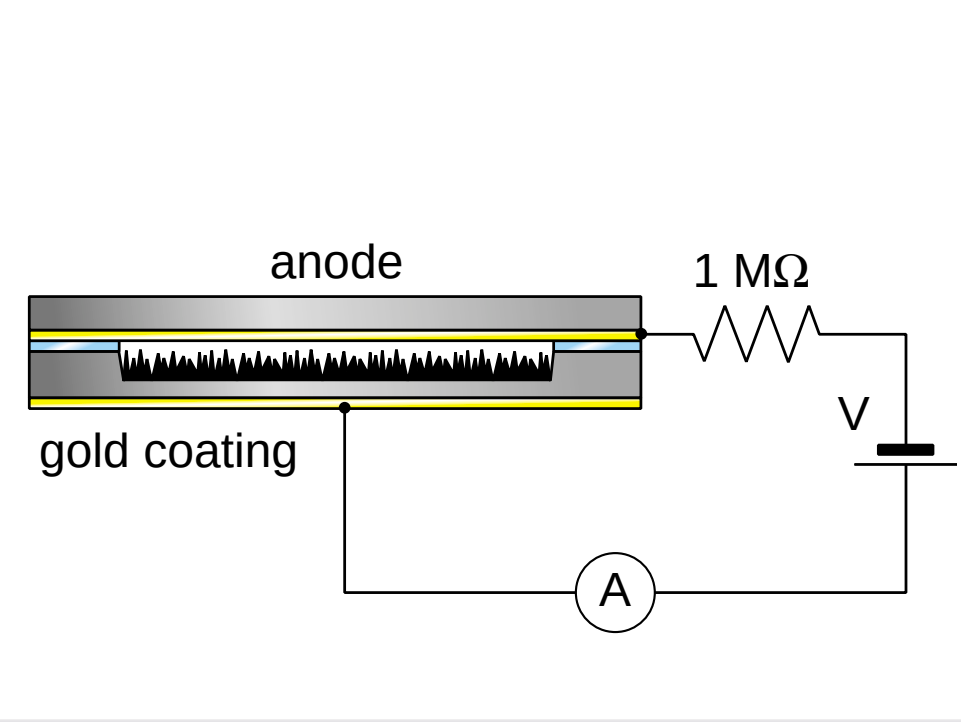
Setup



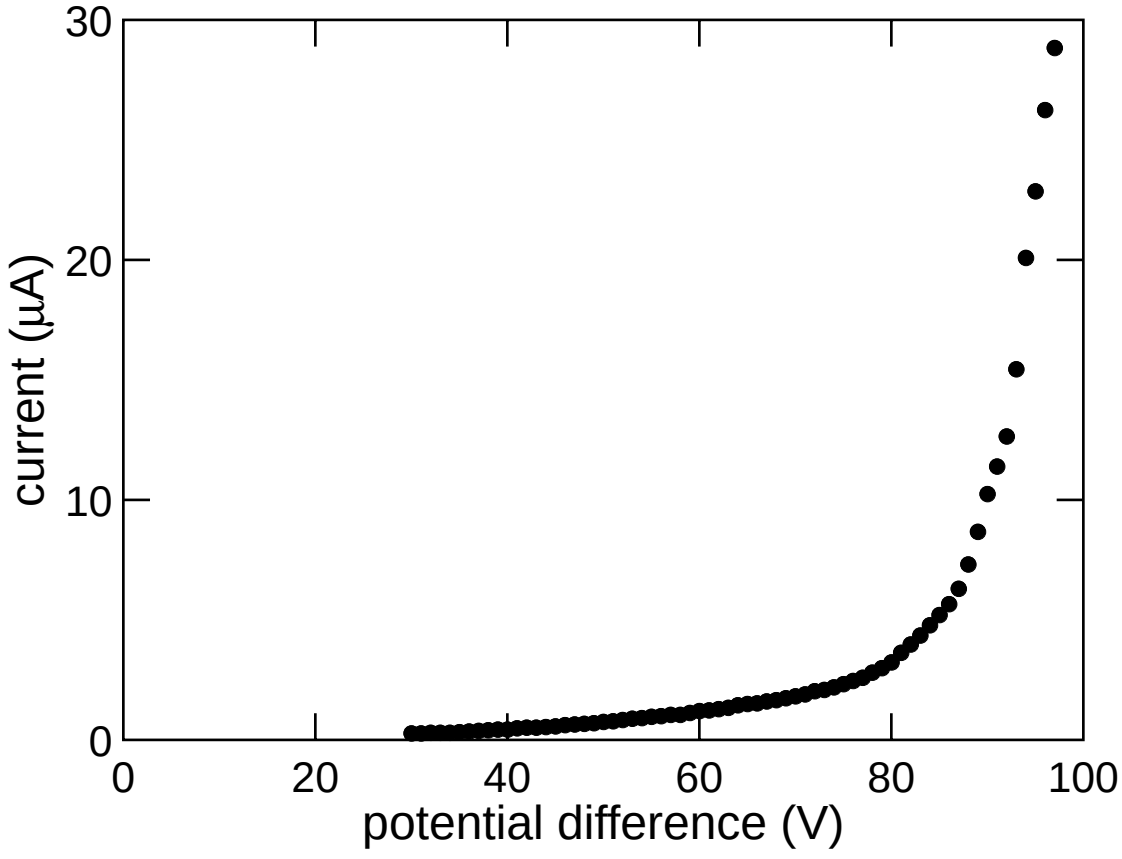
Setup



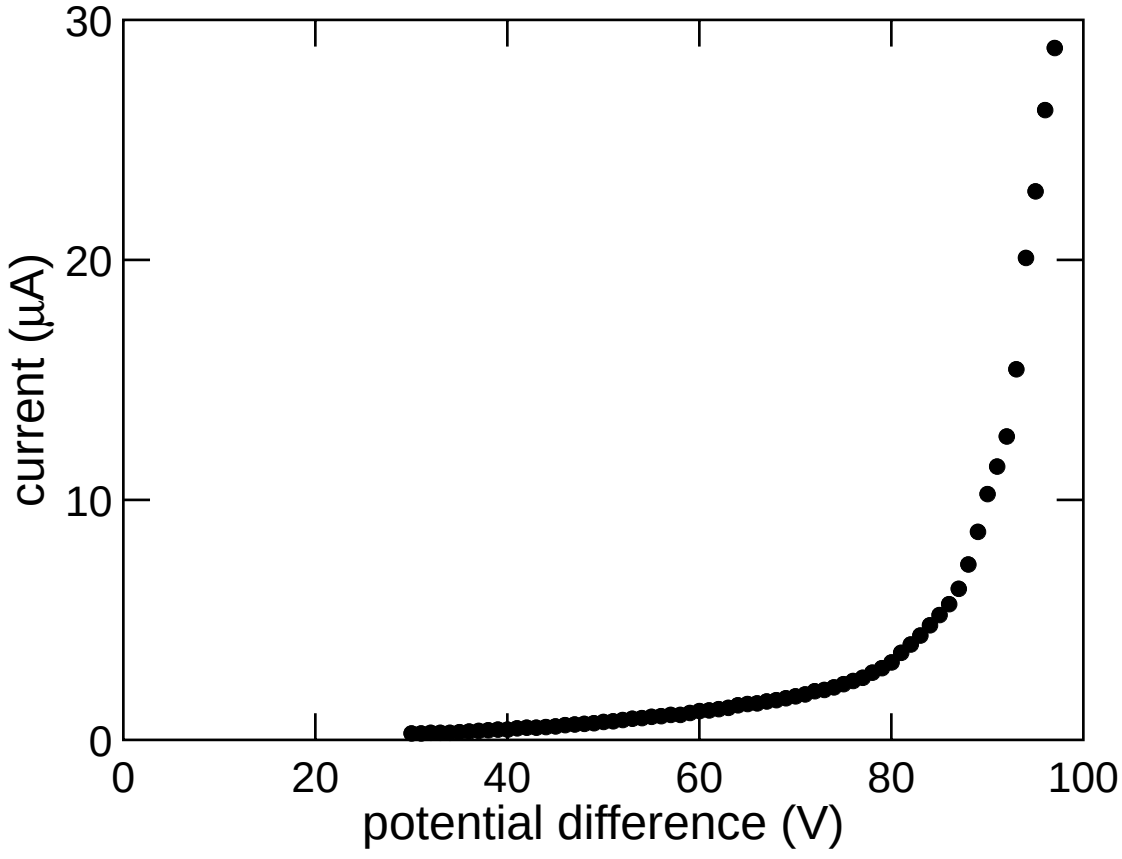
Setup



Results

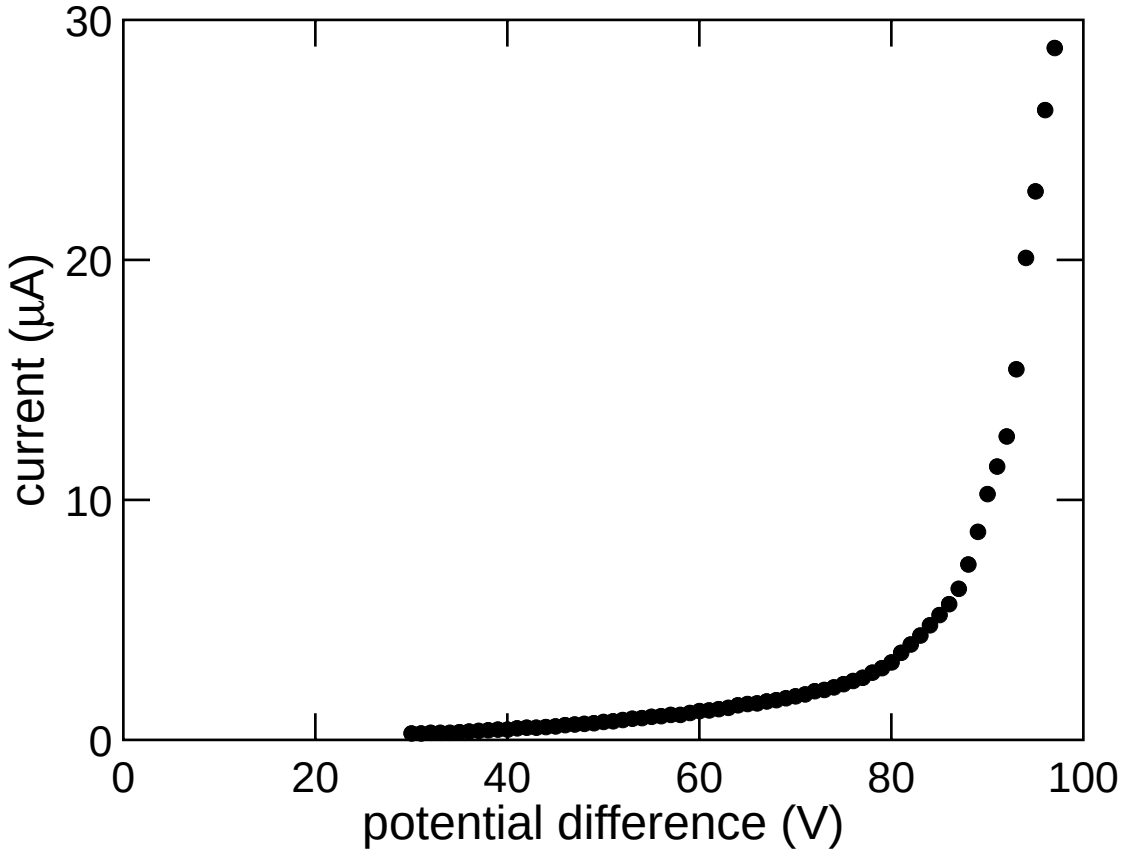


Results



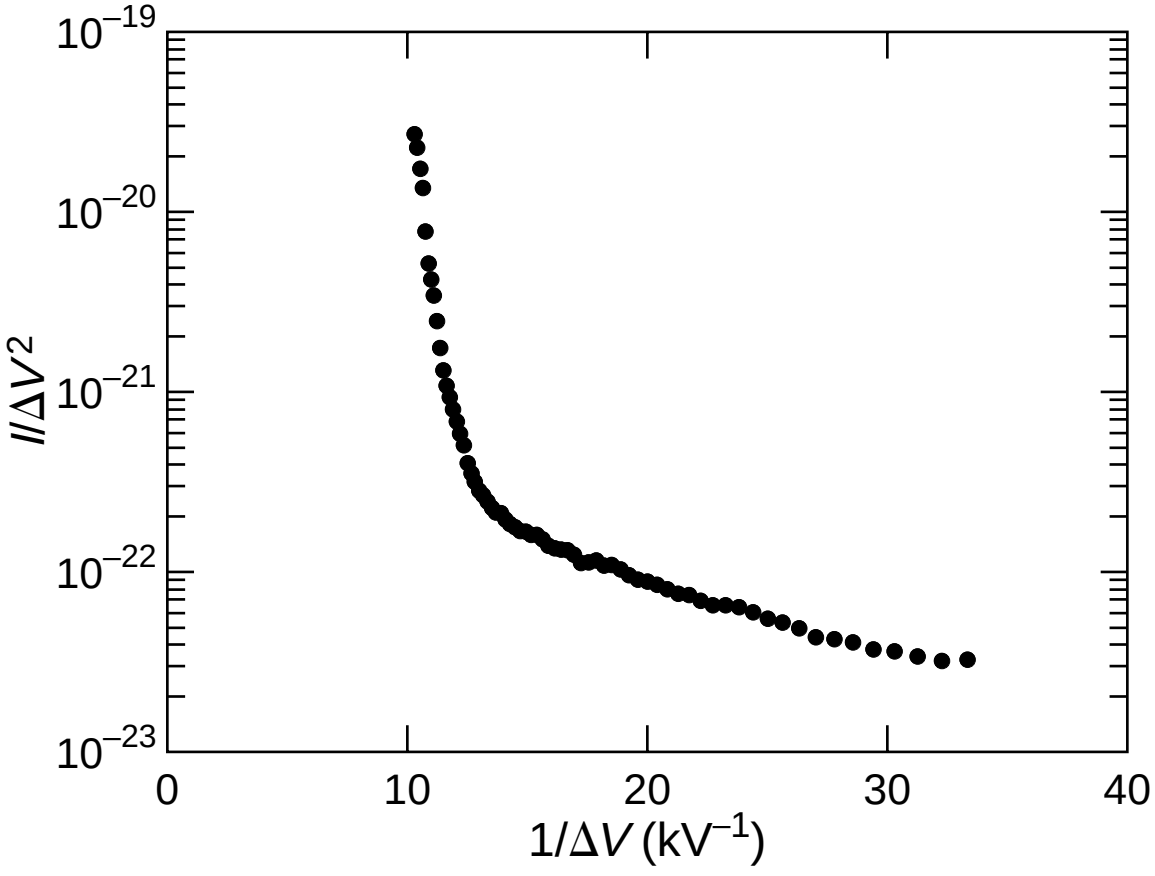
turn-on field (1 μA/cm^2): 1.3 V/μm

Results

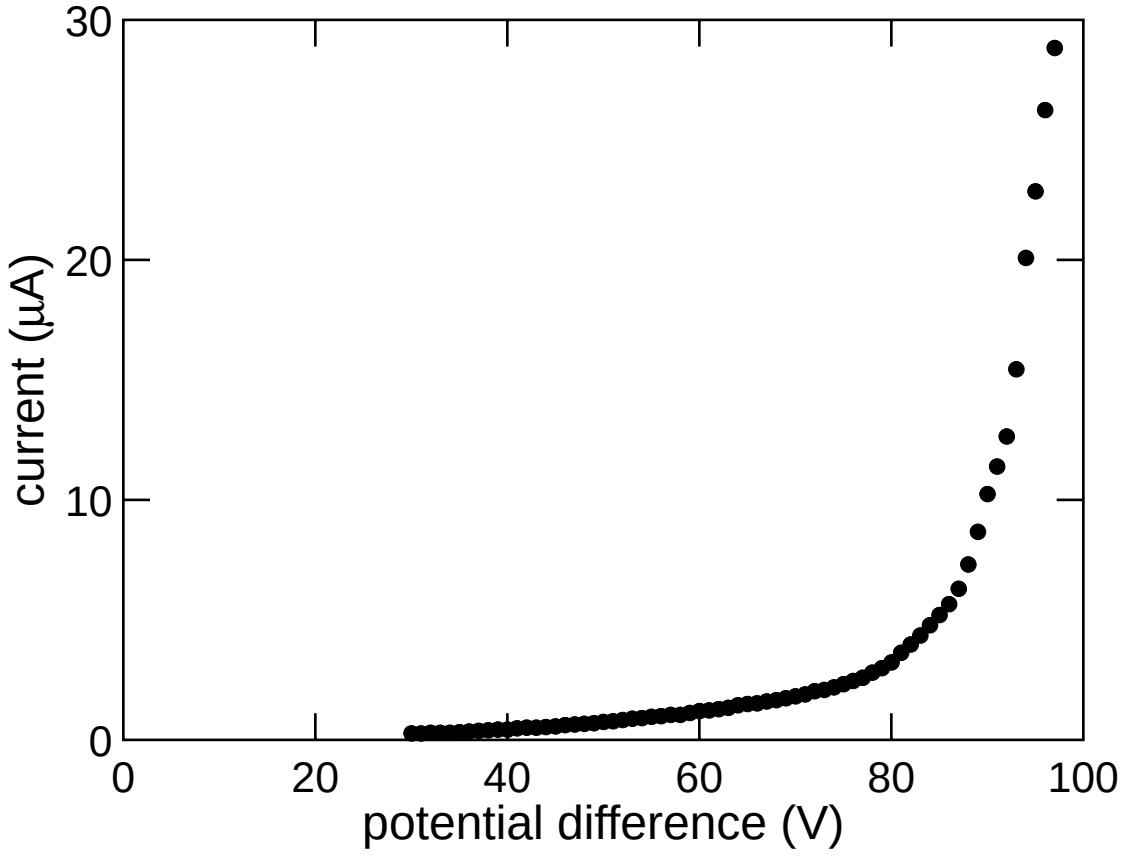


threshold field (10 μA/cm^2): 2.15 V/μm

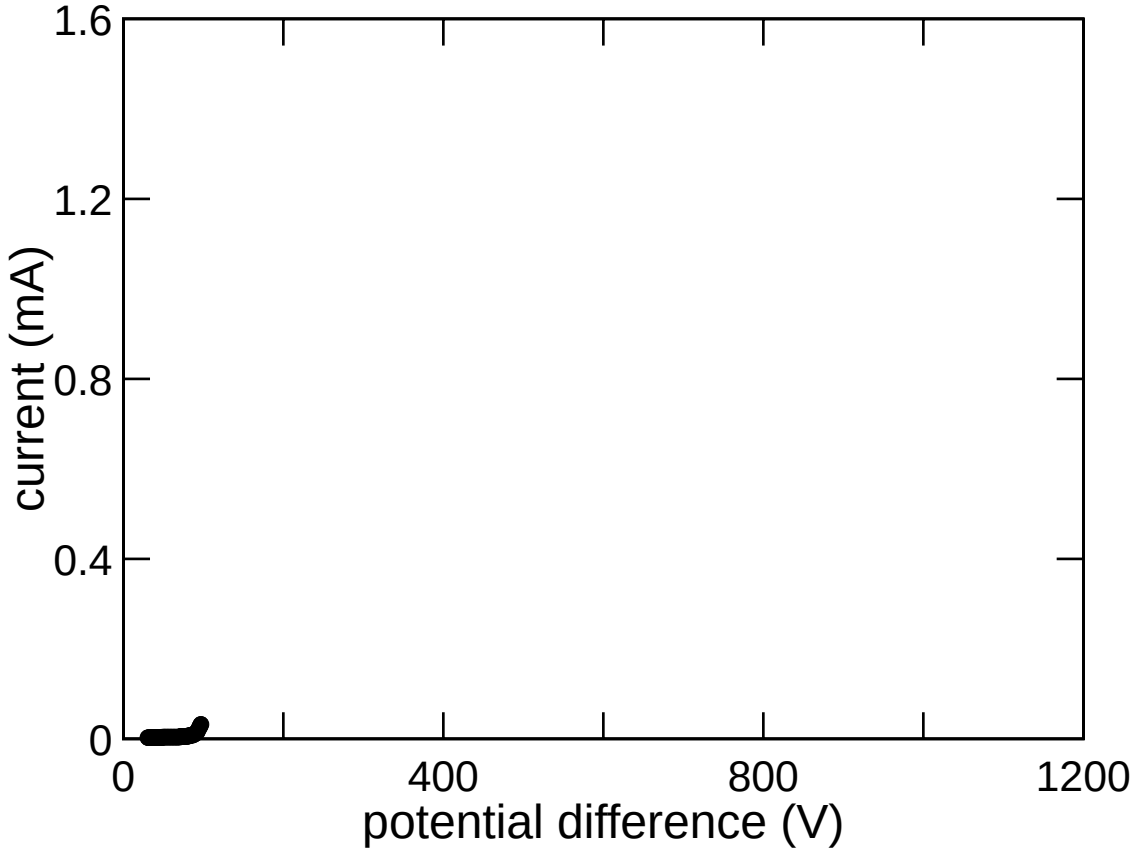
Results



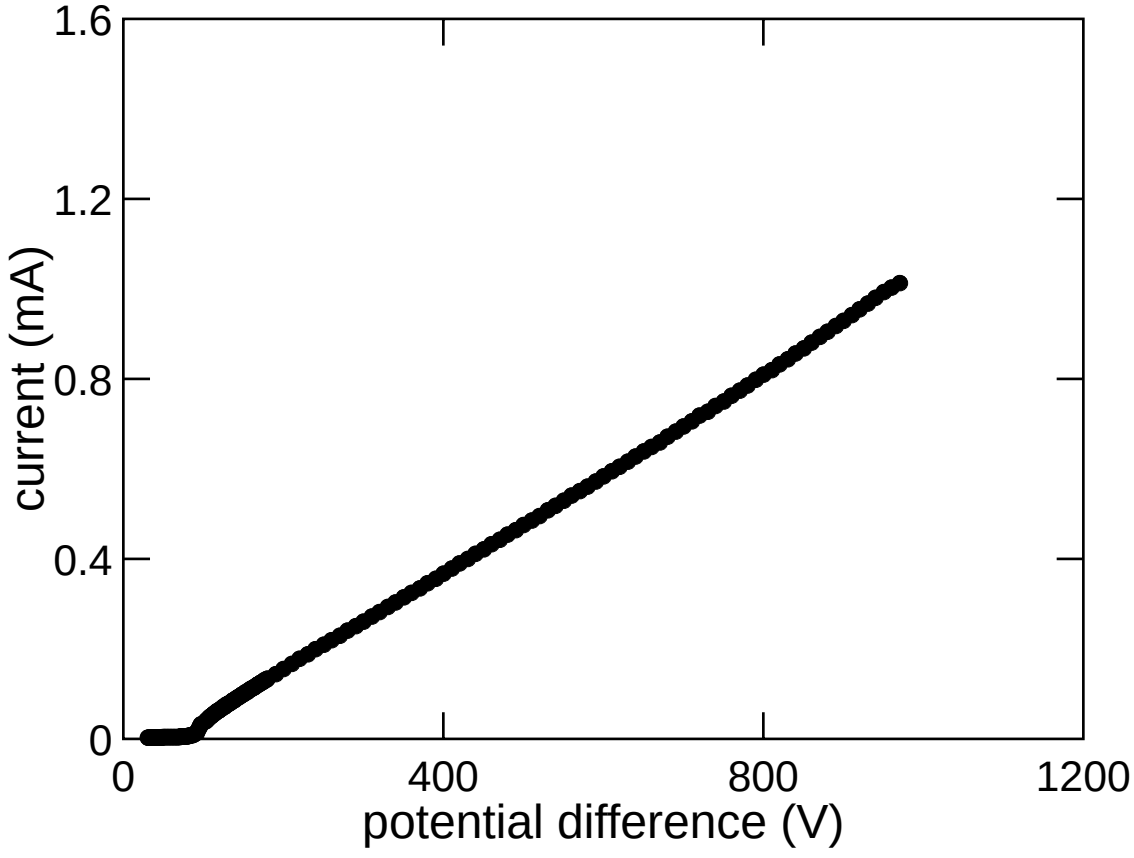
Results



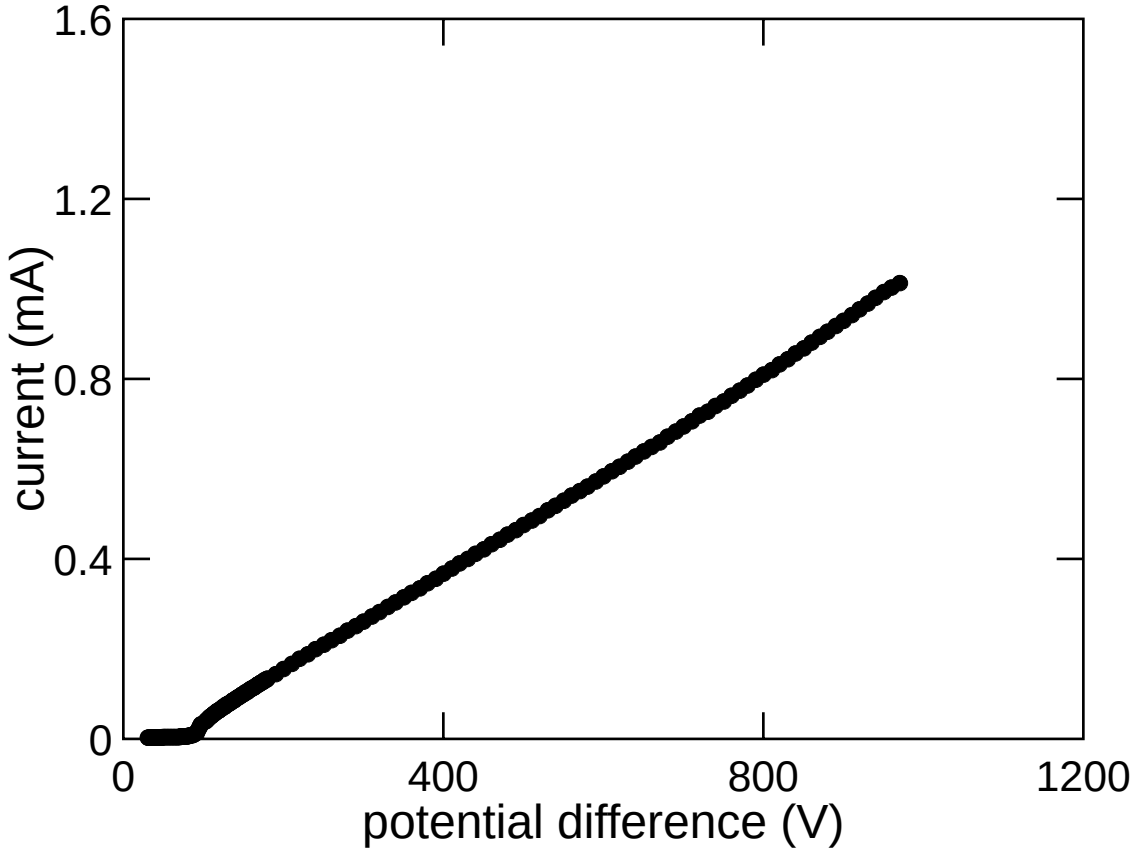
Results



Results

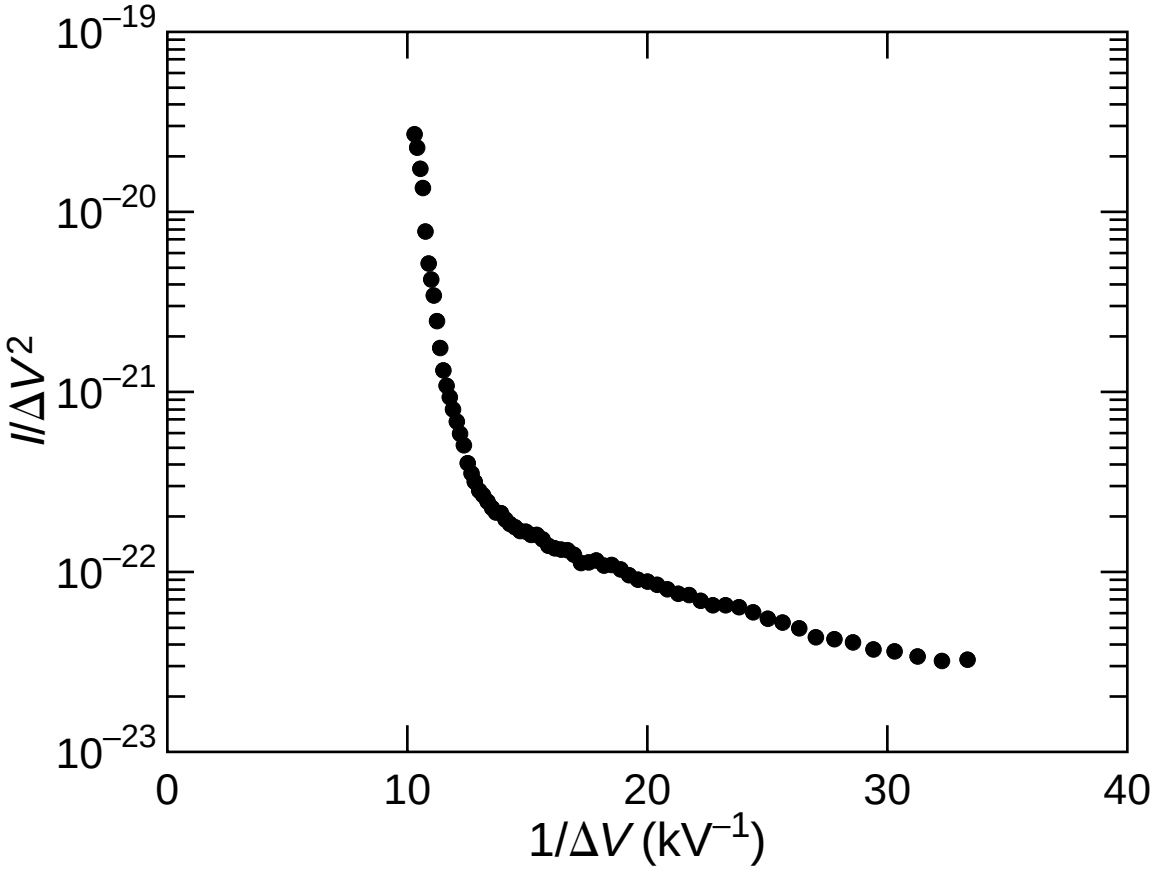


Results

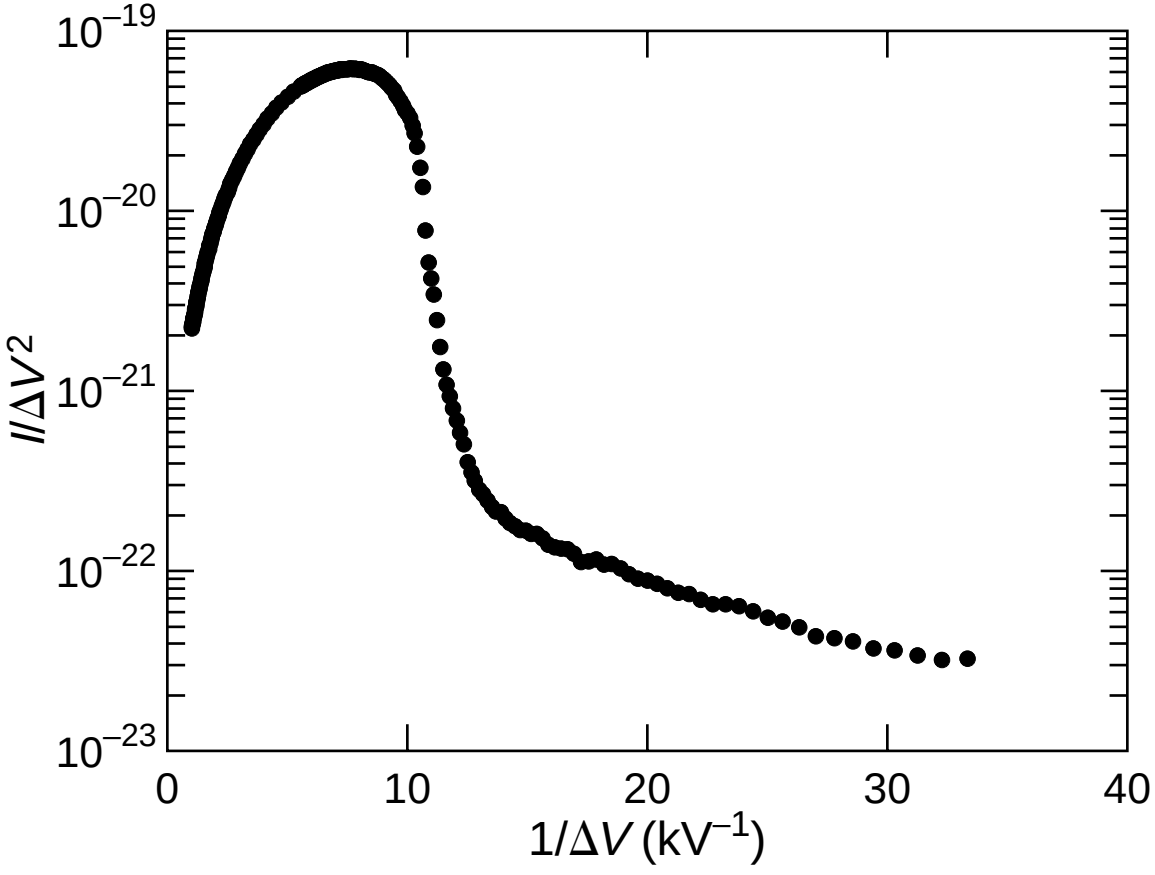


maximum current: 2 mA (4 mm^2 sample)

Results



Results



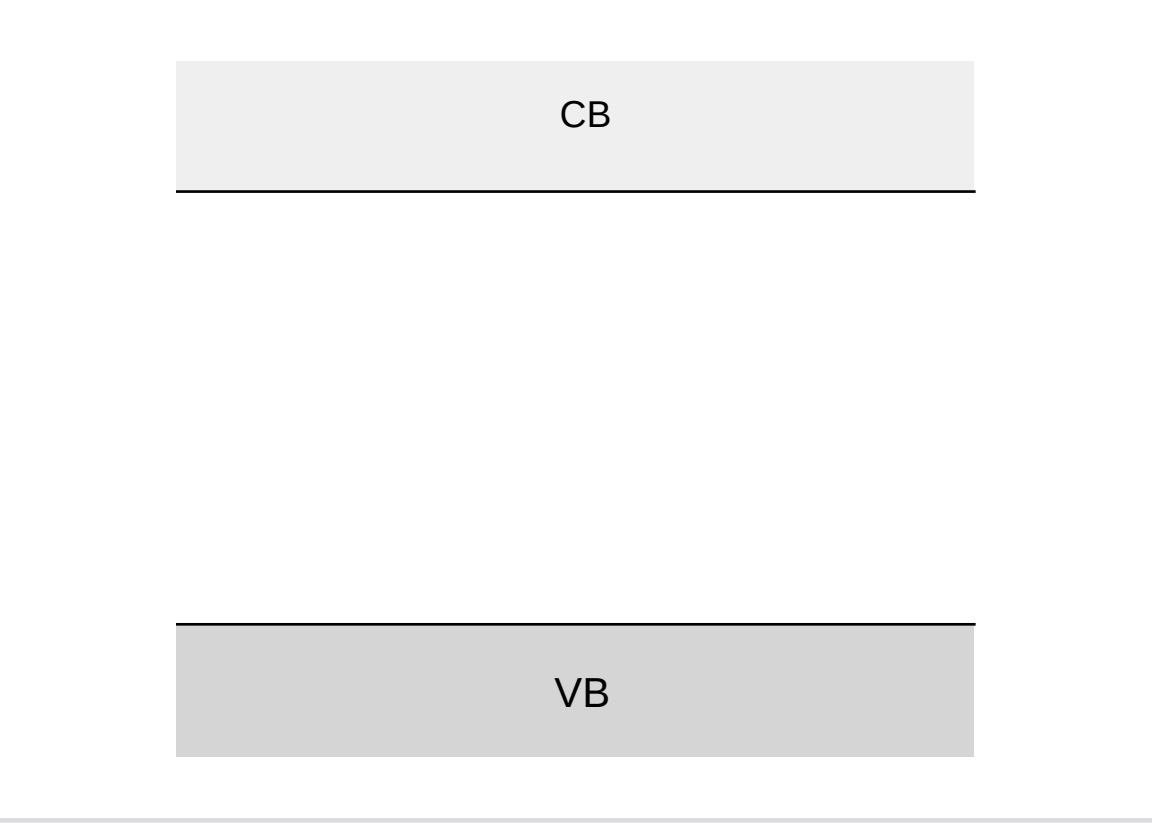
Discussion

Secondary ion mass spectrometry:

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

Discussion

sulfur introduces states in the gap



Discussion

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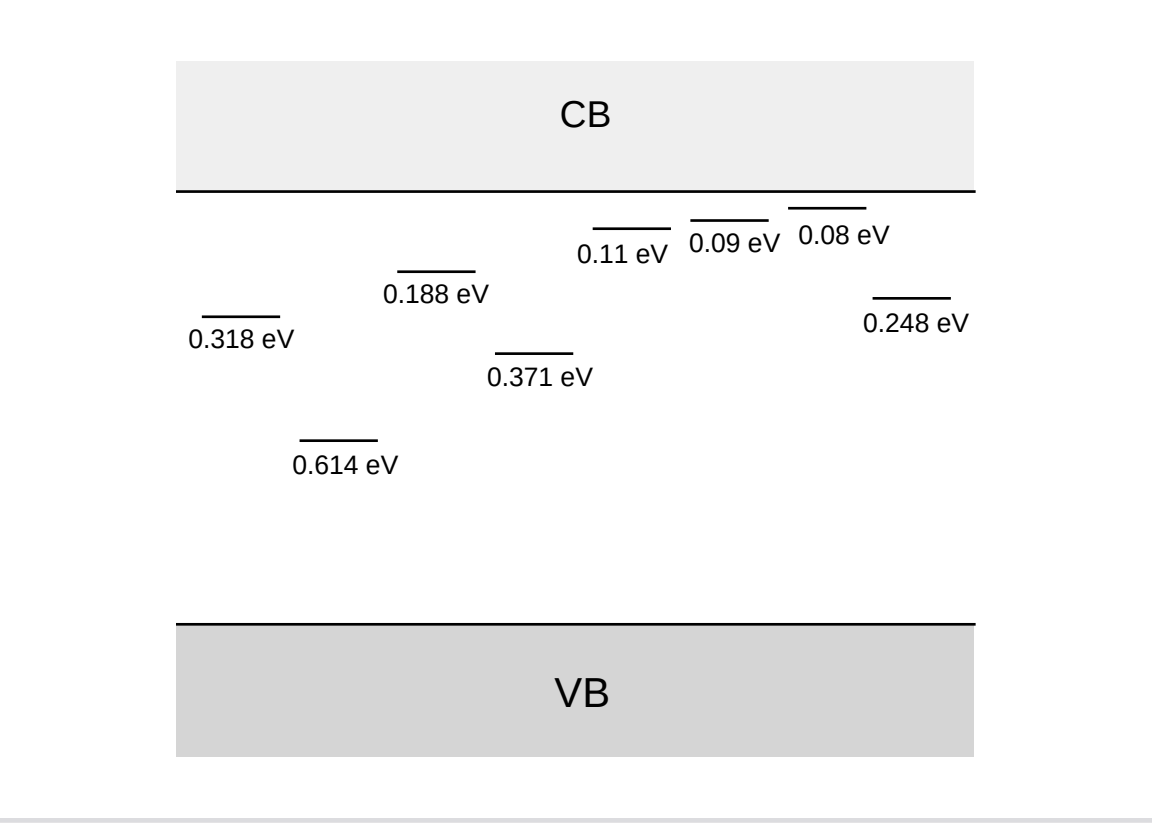
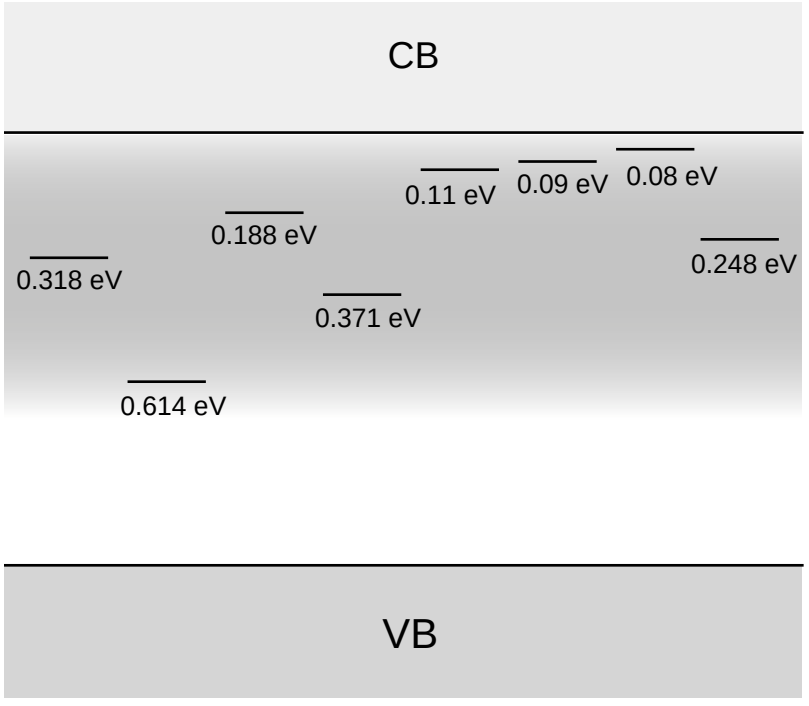


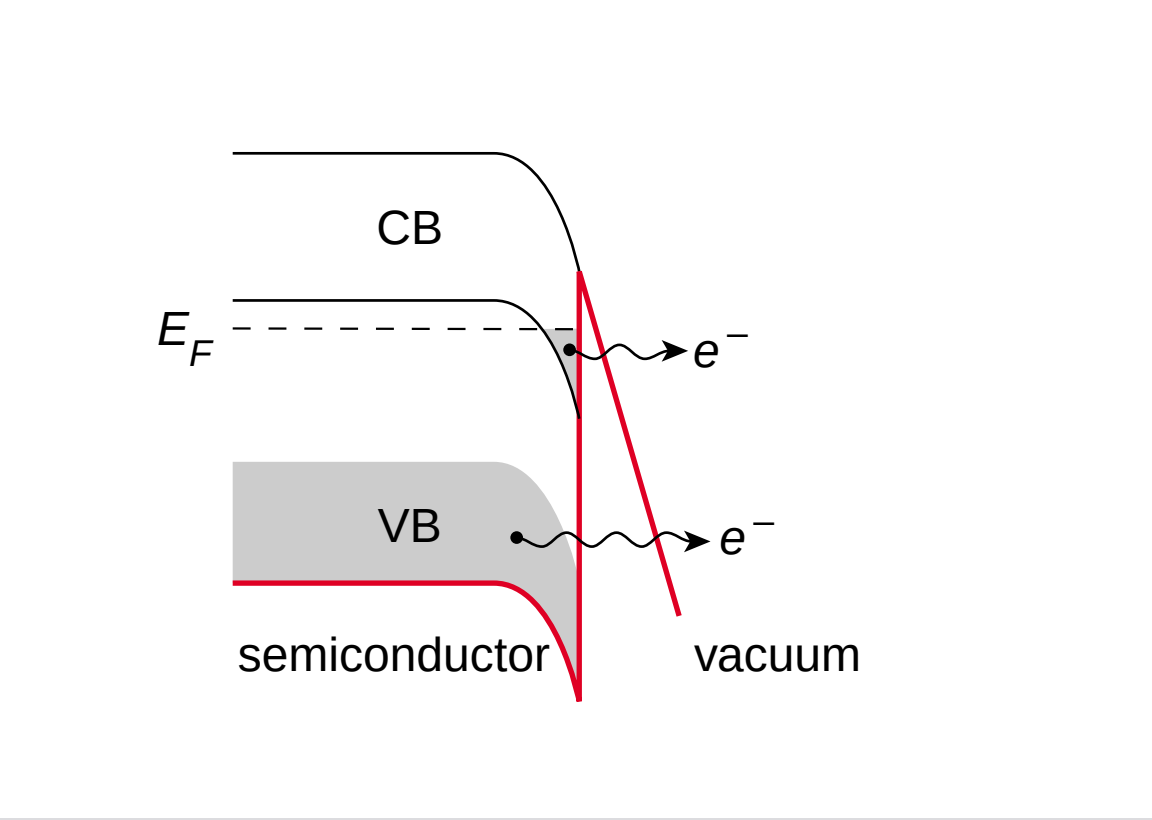
Janzén, *et al.*, *Phys. Rev. B* **29**,1907 (1984)

Discussion

states broaden into a band

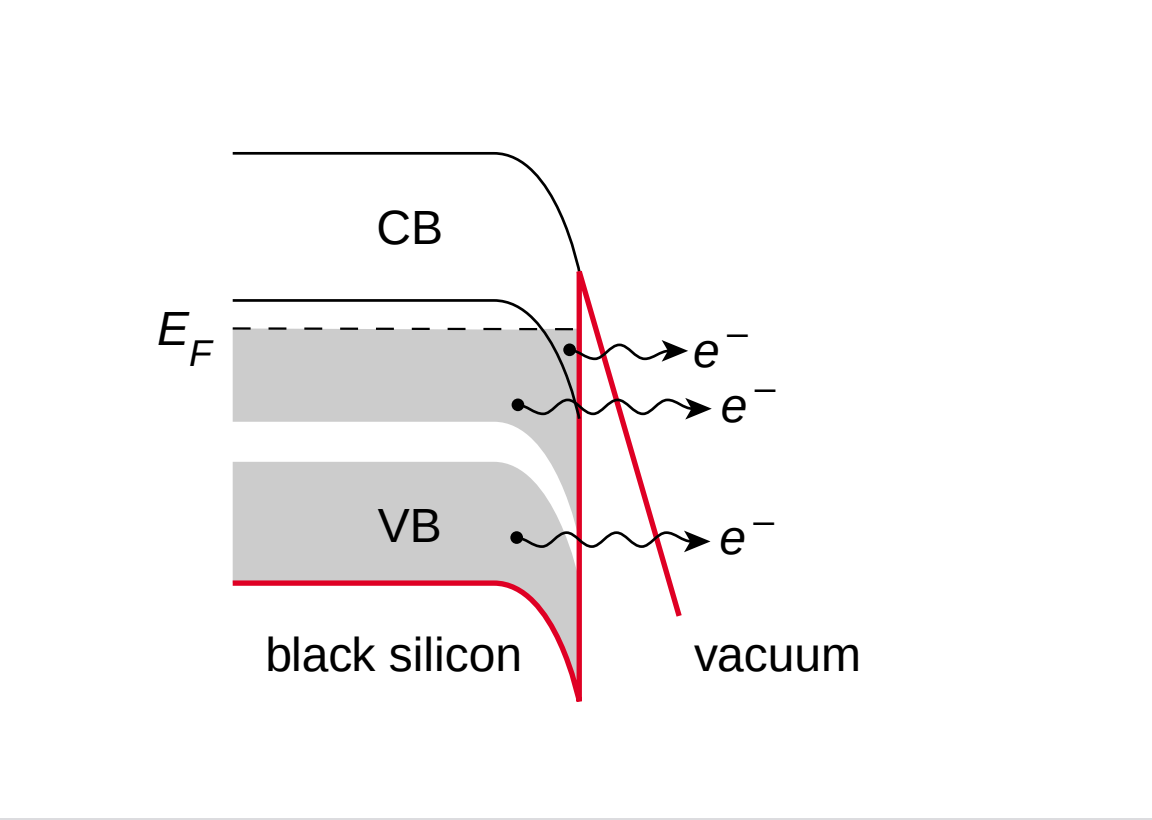


Discussion



Discussion

sulfur band provides additional electrons



Summary

Microstructured silicon

- **fabricated by simple, maskless process**

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Summary

Microstructured silicon

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

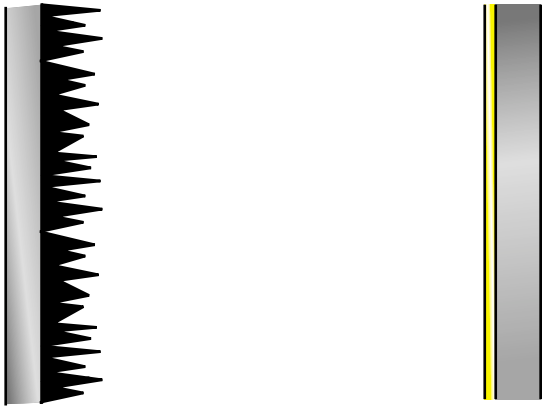
Funding: Army Research Office
Department of Energy
NDSEG

Acknowledgments:
Prof. Mike Aziz (Harvard University)

For a copy of this talk and additional information, see

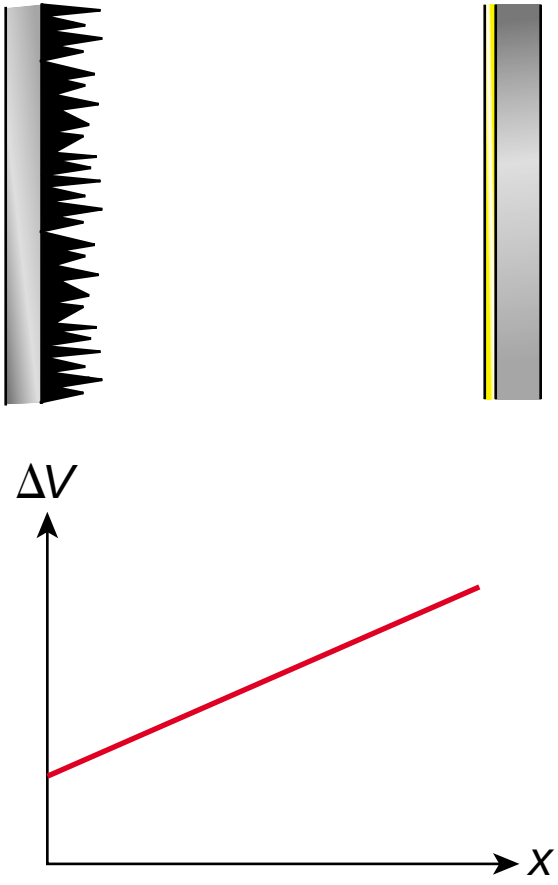
http://mazur-www.harvard.edu

Space charge effect



Y.Y. Lau *et al*., *Phys. Plasmas* 1, 2082 (1994)

Space charge effect



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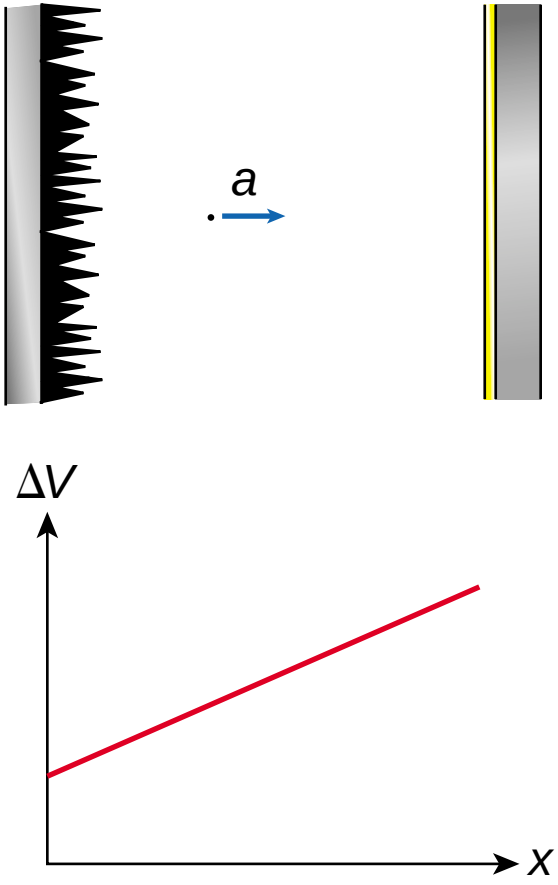
Space charge effect



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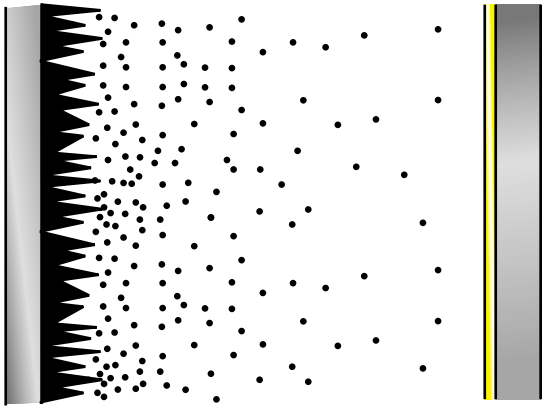

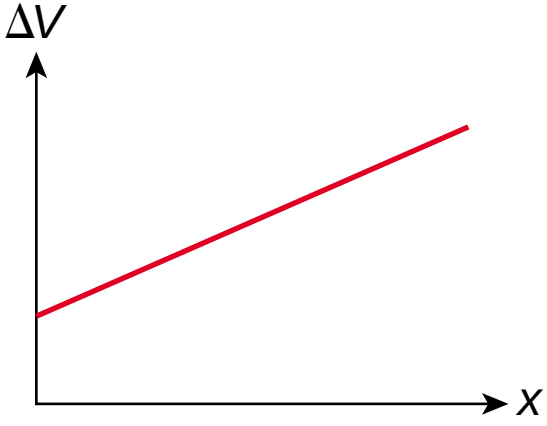

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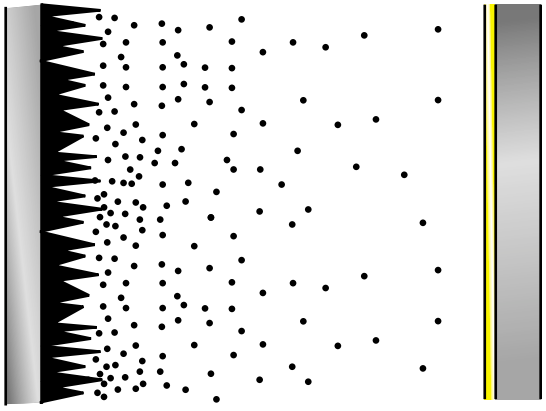

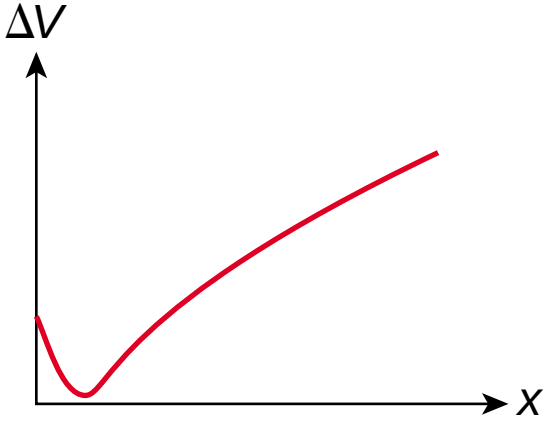

Y.Y. Lau *et al.*, *Phys. Plasmas* 1, 2082 (1994)