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

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Outline

- Background
- Results
- Discussion
irradiate with 100-fs 10 kJ/m² pulses
Field emission

\[ E_F \]

metal \hspace{2cm} vacuum

\[ \phi \]
Field emission

$E_F$  $\phi$

metal  vacuum
Field emission

Diagram showing the presence of a potential barrier $\phi$ between a metal and vacuum environment, with the Fermi level $E_F$ at the metal-vacuum interface.
Field emission

$E_F$  

metal vacuum

$\phi$  

$e^-$
Field emission

![Diagram showing semiconductor vacuum with energy levels and field emission](image-url)
Field emission

- Semiconductor vacuum
- $E_F$, $E_g$
- $\phi$
- VB
- $e^-$
Field emission

- CB
- VB
- $E_F$
- $e^-$

semiconductor

vacuum
Field emission

- Semiconductor vacuum
- CB
- VB
- $E_F$
- $e^-$
- $e^-$
- Semiconductor
- Vacuum
Field emission

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

Setup
gold coating
Setup

20 µm mica spacers

gold coating
Setup

anode

gold coating
Setup

Diagram:
- Anode
- Gold coating
- 1 MΩ resistance
- Voltage (V)
- Ammeter (A)
Results
Results

turn-on field (1 µA/cm²): 1.3 V/µm
threshold field (10 μA/cm²): 2.15 V/μm
Results
Results
Results

![Graph showing the relationship between potential difference (V) and current (mA). The x-axis represents potential difference (V) ranging from 0 to 1200, and the y-axis represents current (mA) ranging from 0 to 1.6.]
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
sulfur introduces states in the gap
Discussion

sulfur introduces states in the gap

Discussion

states broaden into a band
Discussion
sulfur band provides additional electrons
Microstructured silicon

- fabricated by simple, maskless process
Microstructured silicon

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

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

- fabricated by simple, maskless process
- can be integrated with microelectronics
- provides stable, high field-emission current
- is durable
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For a copy of this talk and additional information, see
http://mazur-www.harvard.edu
Space charge effect

Space charge effect

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

Space charge effect

Space charge effect