The Development of MEMS-Based Time-Of-Flight SFM

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Outline

1. Introduction.

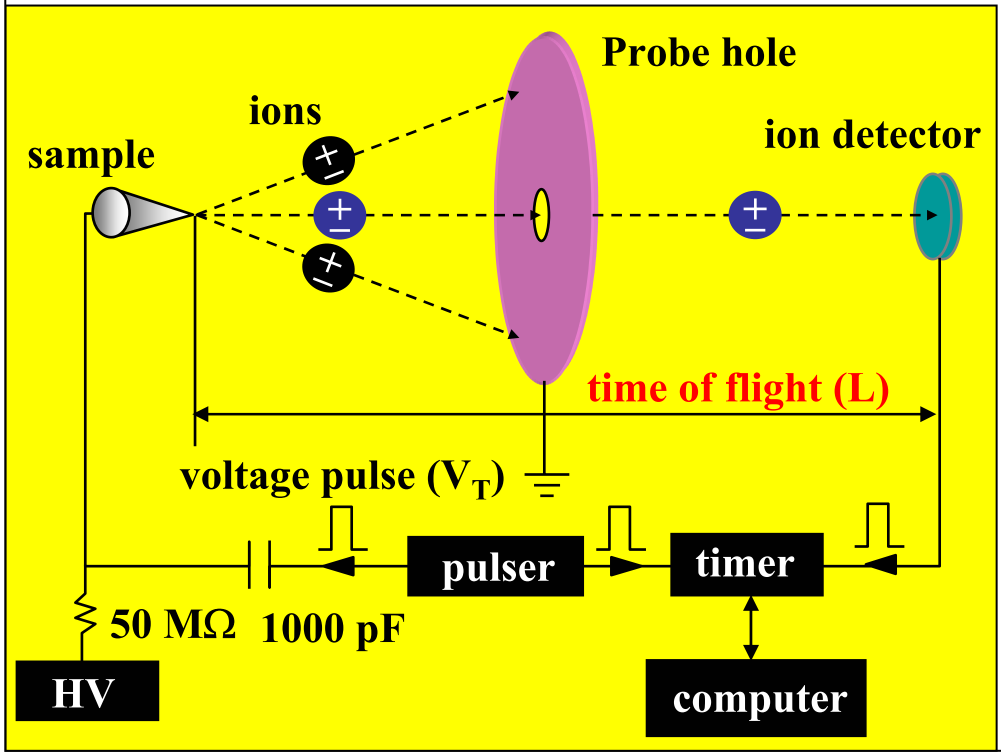
2. Concept of MEMS-based TOF-SFM.

3. Experimental results.

Conventional methods for chemical analysis

Atom probe: Erwin Müller in 1968 (FIM+MS)

Basic configuration of the AP with TOF-MS



Mass analysis (m)

$$m = 2neV_T t^2/L^2$$

Where t is the flight time,

e is electric charge of electron,

L is the flight length,

V_T is applied voltage pulse,

n # *of* electrons

Min. field for ion evaporation: 10^8 to 10^9 V/m

Drawback: Sample needs to be a very sharp tip

Recent approaches →

- Scanning atom probe (SAP): O. Nishikawa in 1994
- Scanning tunneling atom probe (STAP): J. Spence in 1995

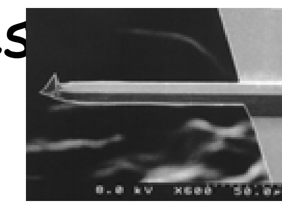
TOF-SFM based on MEMS technology

Scanning force microscopy (SFM)

SFM is an important tool to make a 3D surface image of solid surfaces at atomic scale resolution.

Time of flight (TOF) mass spectrometer

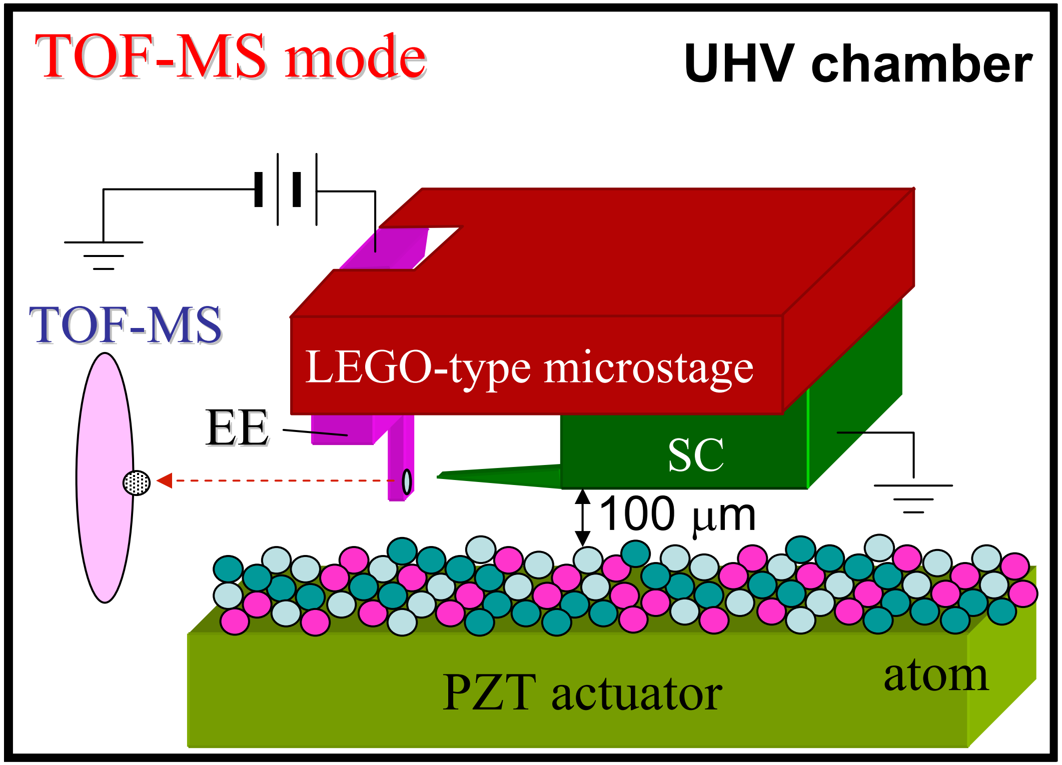
Time-of-flight mass spectrometer is a powerful tool to identify the chemical property of solid surfaces.

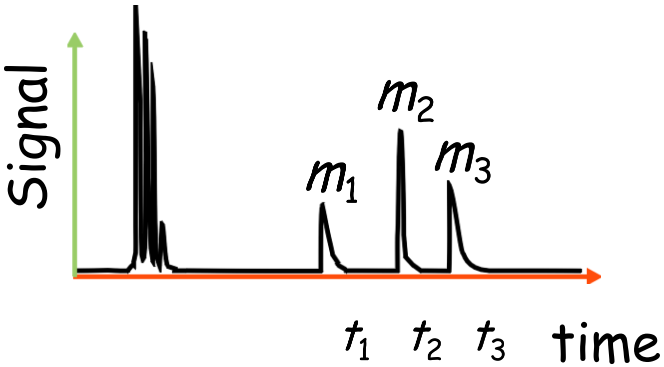


MEMS-based cantilever device

Combination of advantages in both techniques allows chemical and topographical analyses on a nm scale.

Basic of the TOF-SFM concept

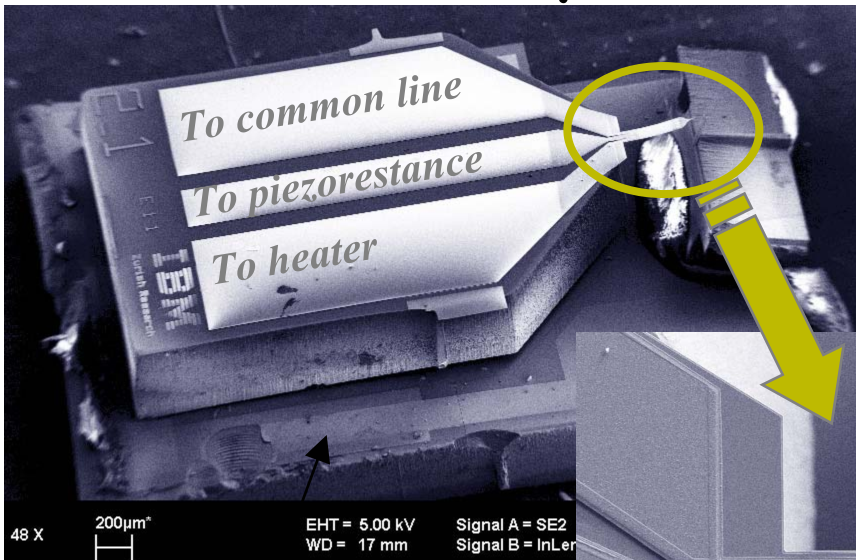


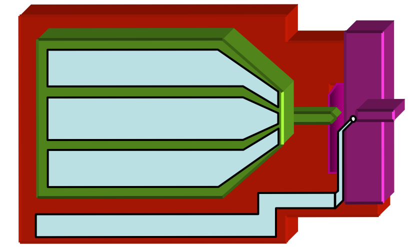


Advantages of this approach for TOF-SFM

1. There is no sample limitation.
2. A short tip-electrode distance to minimize the ion extraction voltage.
3. Fast switching between the SFM and TOF mode (msec's)

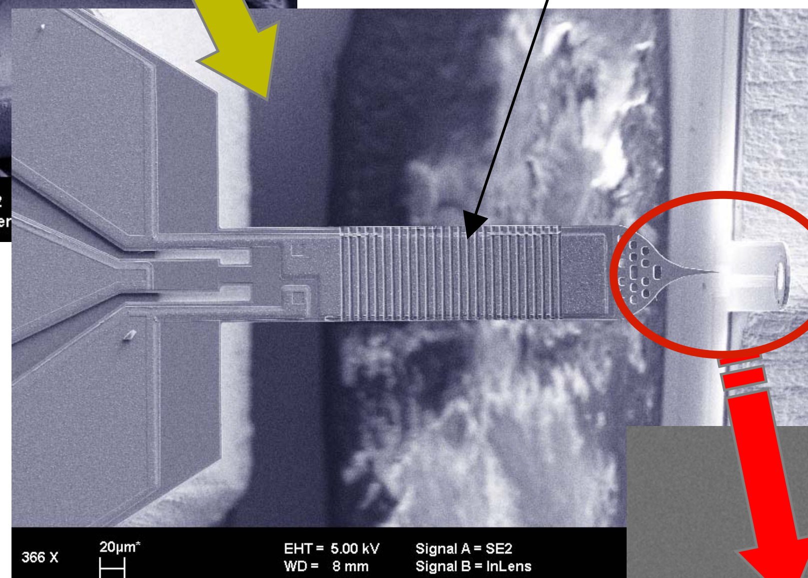
SEM of fully assembled cantilever device





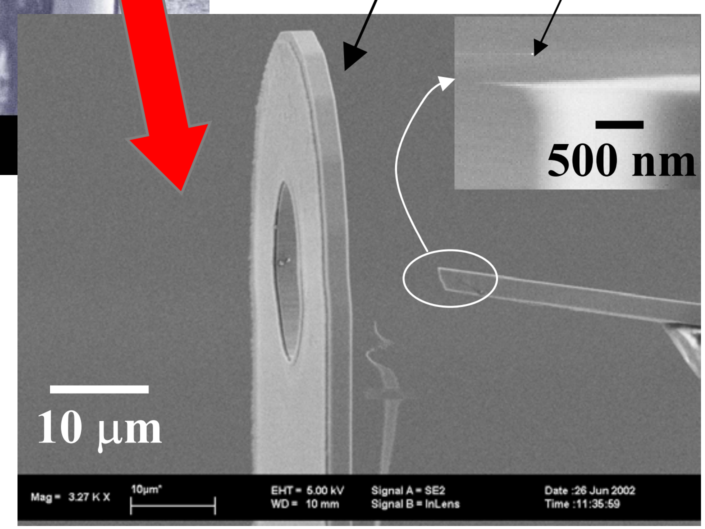
LEGO-type stage

Switchable cantilever



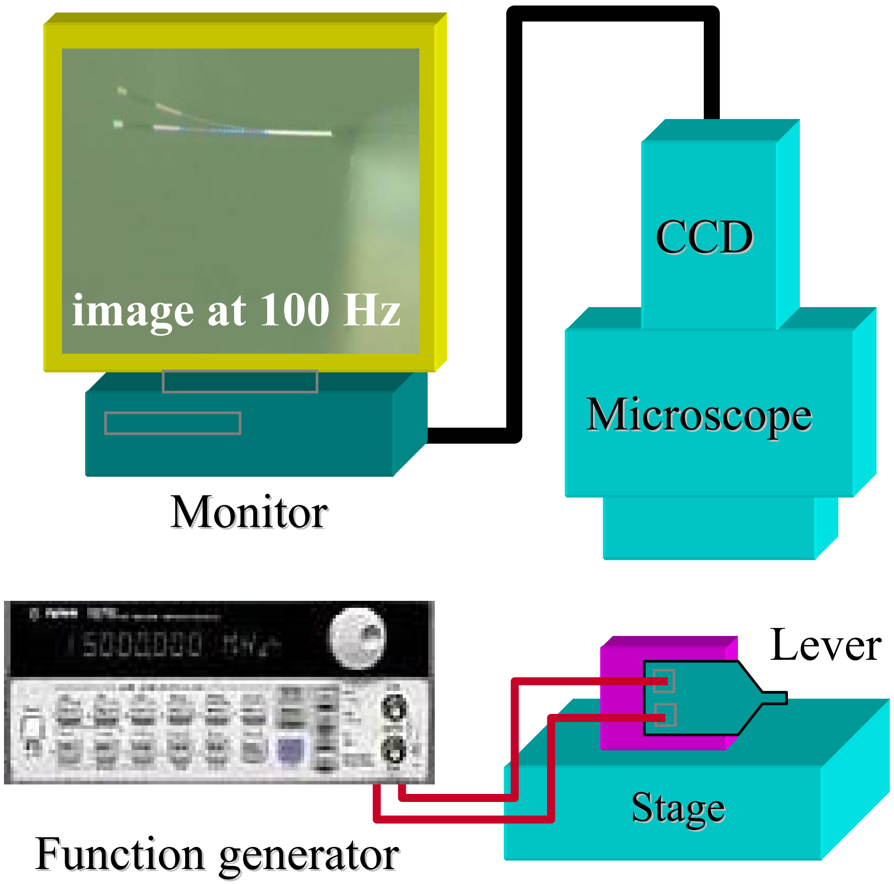
Extraction electrode

In-plane tip

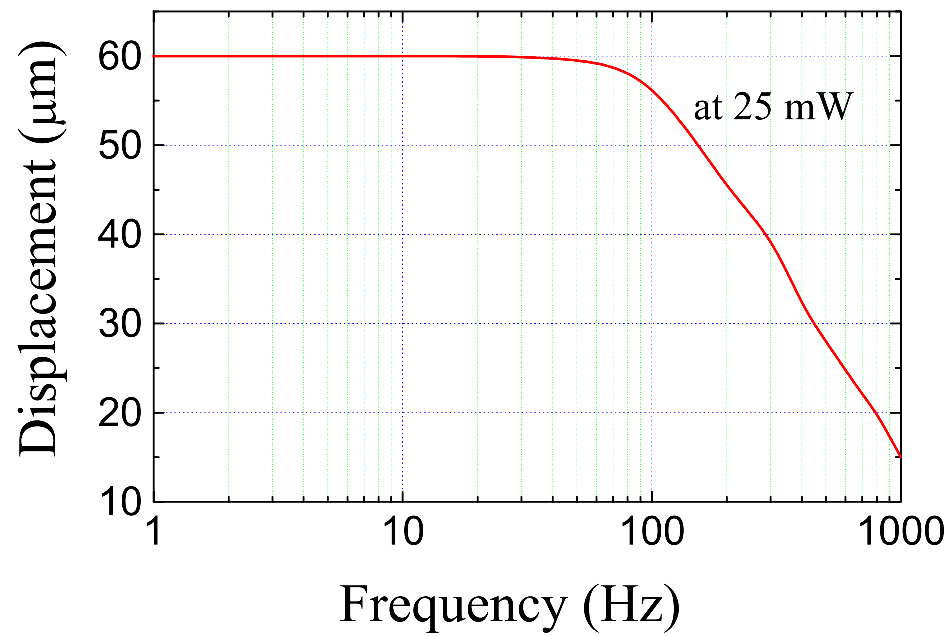


A tip-extraction electrode distance of 10 µm achieved by LEGO microstage

Deflection vs. frequency characteristics



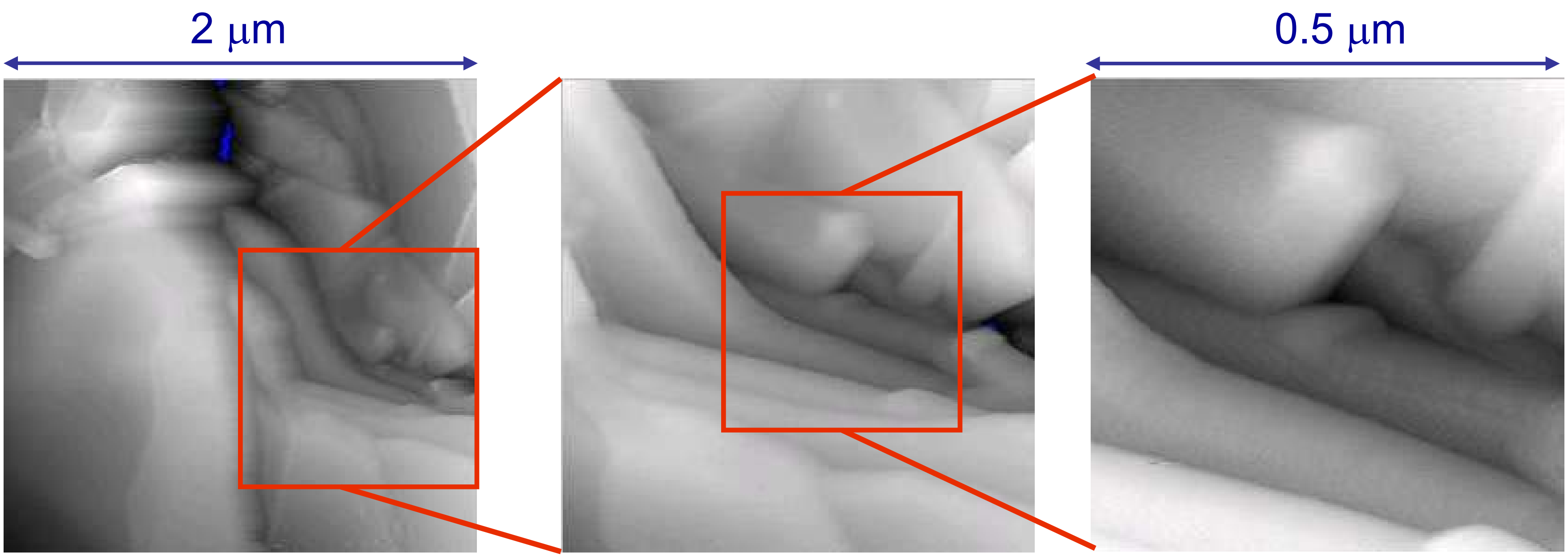
Maximum switching speed : ~ 10 msec



TOF-SFM measurements can be done orders of magnitude faster than with currently available systems

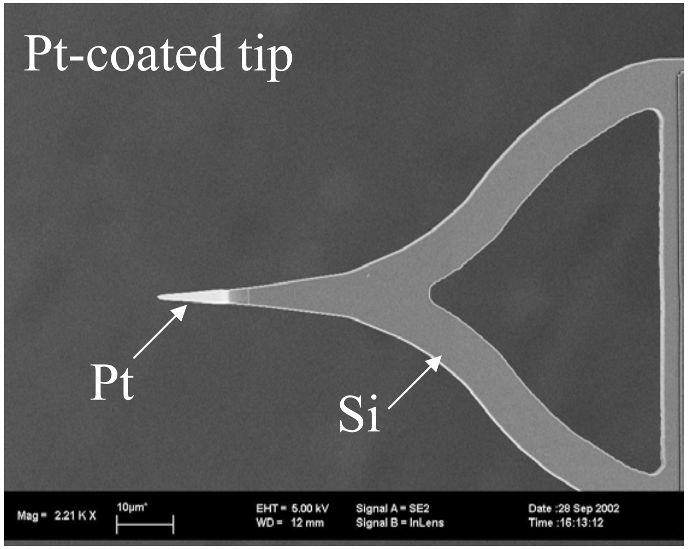
Topographic image at dynamic AFM mode

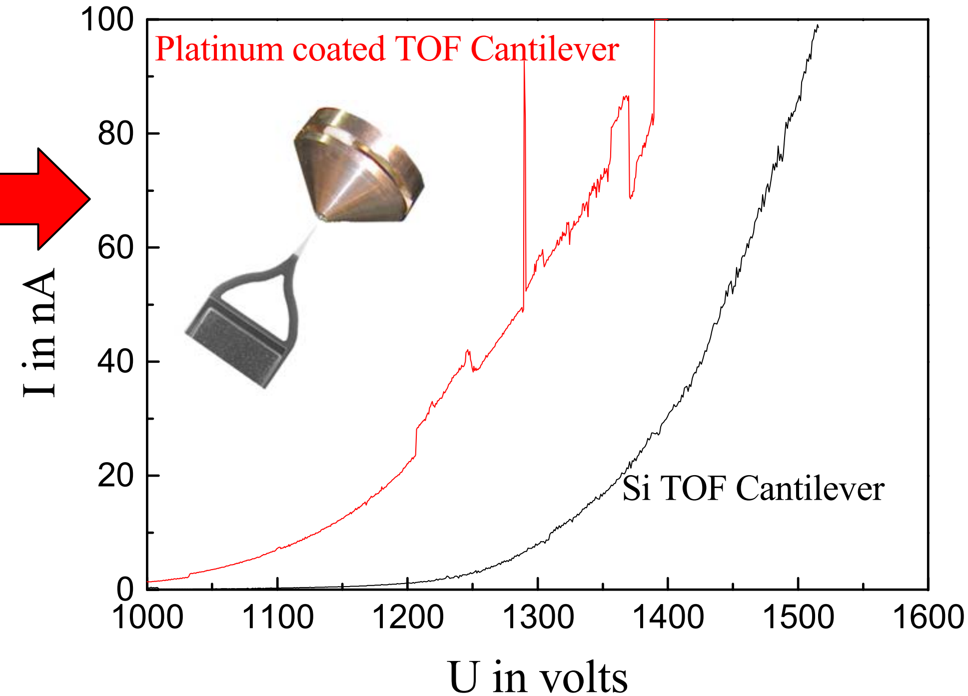
- Regulated on constant amplitude with integrated piezoresistive detection.
- pressure $p < 10^{-9}$ mbar.
- preamplifier in vacuum ($G = 100_{UHV} \times 100_{air}$)

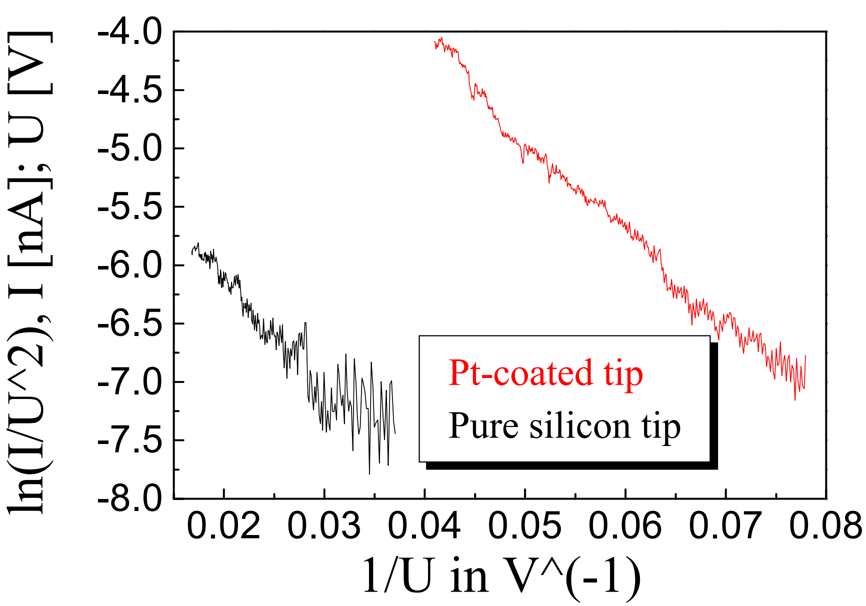


2000nm^2; $z \in [0,250nm]$ 1000nm^2; $z \in [0,180nm]$ 500nm^2; $z \in [0,113nm]$

Field emission behaviors





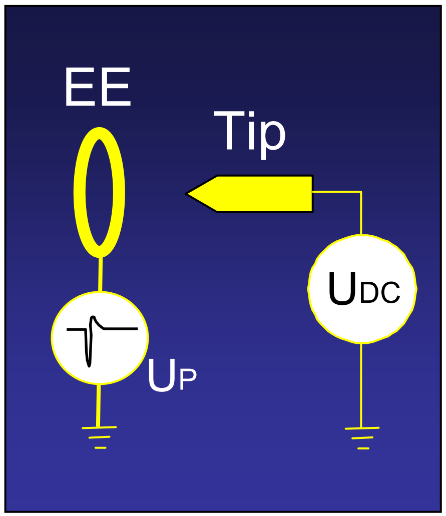


Turn-on field emission for the Pt-coated tip has demonstrated with an extraction voltage as low as 15 V

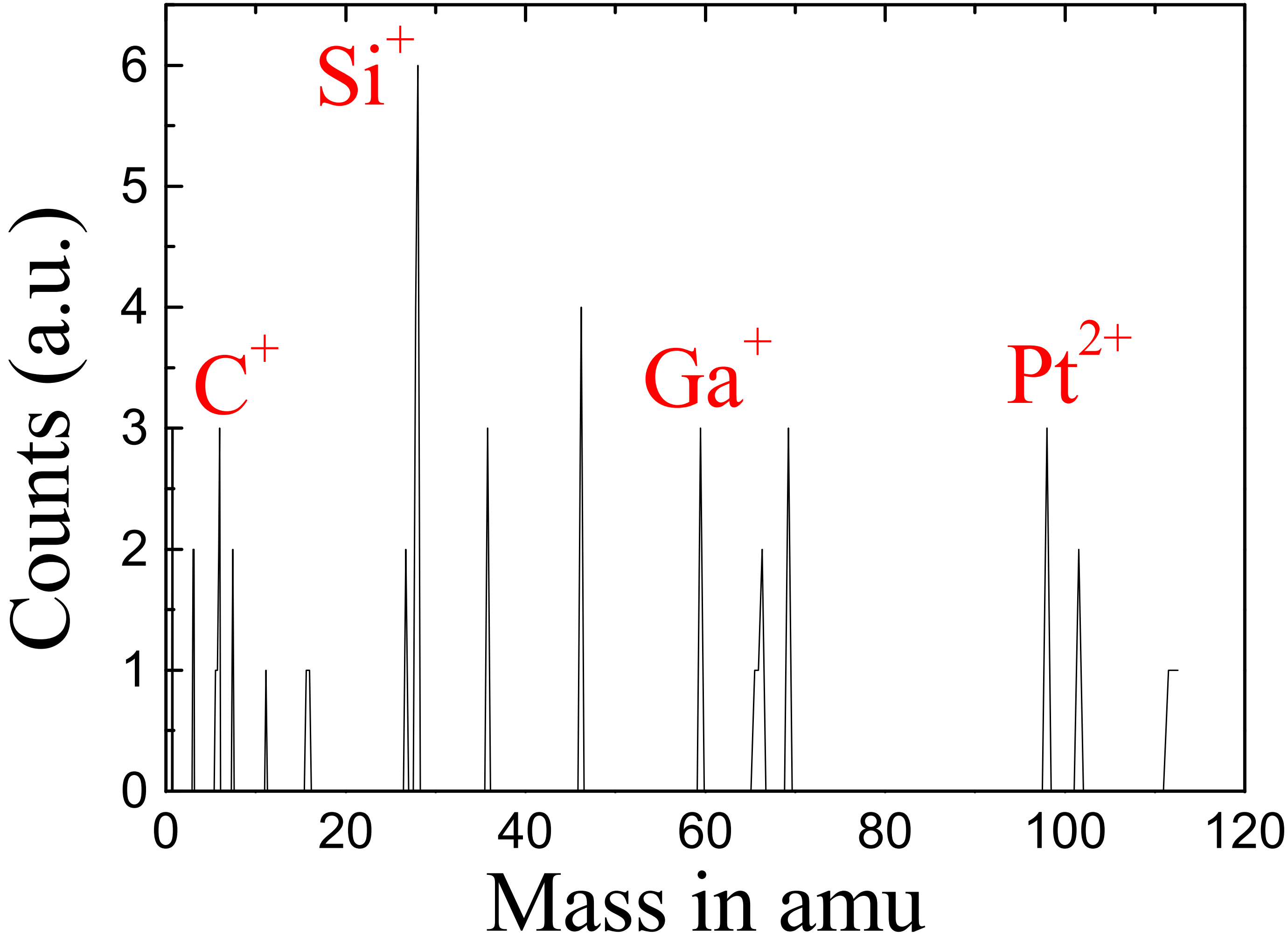
Fowler Nordheim plot

TOF analysis using the SC with the Pt tip

Setup



30 pulses
at U_{DC}=800 V
and U_P=-240 V



Si^+ and Pt^{2+} peaks of Pt-coated tip at mass to charge ratio of 28 and 97.5