Local collection with a STM tip of photoelectrons emitted by a surface irradiated by visible or UV laser beam

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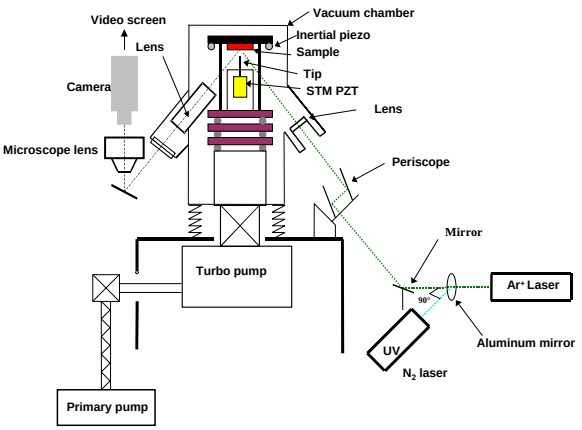
Abstract : The purpose of the present work is to investigate the possibility of local collection with a STM probe of photoelectrons emitted from a surface irradiated with a tightly focused laser beam. The sensitivity of the I-V converter of our STM is about 20 pA, which corresponds to an electron flow of 10^8 s^{-1}. Two laser sources have been used : a cw Ar^+ laser (λ = 514 nm, $E_{h\nu}$ = 2.41 eV) and a pulsed N_2 laser (λ = 337 nm, $E_{h\nu}$ = 3.68 eV). The photon energy of the visible laser is lower than the work function of the standard materials investigated (gold and silicon in our case) and the tip-sample current increase observed during sample irradiation is due to the tip-sample gap decrease induced by thermal expansion of both sample and tip. However, using UV photons of higher energy, electron photoemission was clearly observed from hafnium surface, material of work function of the same order of magnitude than the energy of the incident photons.

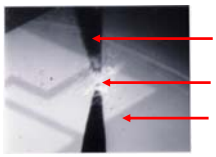
1. Experimental set-up



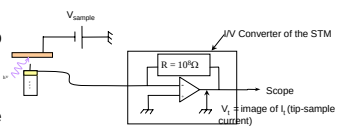
Cw Ar^+ laser : cw
wavelength 514 nm (2.41 eV)
$\Phi_{spot} \approx 40$ µm
maximum power 3 W

N_2 laser : pulsed (duration 10 ns, frequency tunable in the range1 to 40 Hz),
wavelength 337 nm (3.68 eV)
$\Phi_{spot} \approx 40$ µm
pulse power 6 mW

Optical view of the tip-sample system



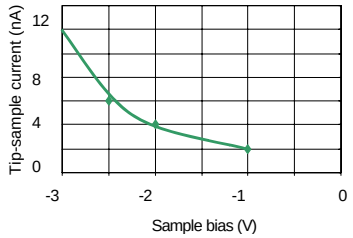
Electrical scheme

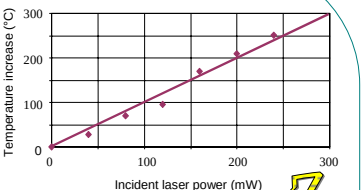


2. Results on silicon sample irradiated by the visible laser

Tip-sample regulation parameters : Sample bias = -2 V
I_T = 300 pA

Incident laser power : 100 mW





PZT calibration : 5nmV ⇔ **Si thermal expansion : 4.68 10^{-6} K^{-1}**

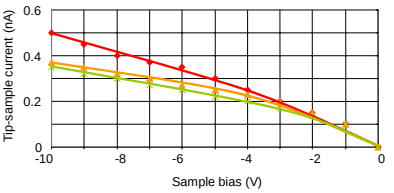
Tip-sample current increase due to sample thermal dilatation [1, 2] and thus to tip-sample distance decrease [3-5]

3. Results with the UV laser

3.1. Gold sample

No signal on pure gold
Gold work function : 5.1 eV

Gold sample coated with fluorescent ink

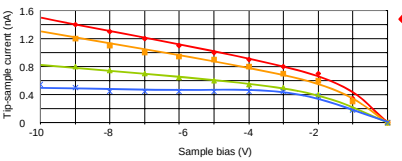


Tip-sample distance
◆ 14 µm ▲ 75 µm ◤ 104 µm

Tip-sample distance (µm)	14	75	104
Magnitude of the tip-sample current peak (pA)	500	370	350
Number of electrons collected per pulse (x 10^4)	7,80	5,77	5,46

3.2. Hafnium sample

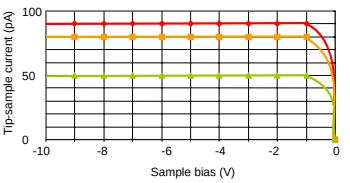
Results on fluorescent ink



Tip-sample distance
◆ 14 µm ■ 43 µm ▲ 130 µm ⌄ > 303 µm

Tip-sample distance (µm)	14	43	130	> 303
Magnitude of the tip-sample current peak (pA)	1500	1300	850	550
Number of electrons collected (x 10^5)	2,34	2,03	1,33	0,858

Results on hafnium



Tip-sample distance
◆ 29 µm ■ 87 µm ▲ 188 µm

Tip-sample distance (µm)	14	43	130	> 303
Magnitude of the tip-sample current peak (pA)	1500	1300	850	550
Number of electrons collected (x 10^5)	2,34	2,03	1,33	0,858

Electron photoemission on hafnium (Hf work function of 3.9eV ≈photon energy)

7. References

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