Lithography by SFM

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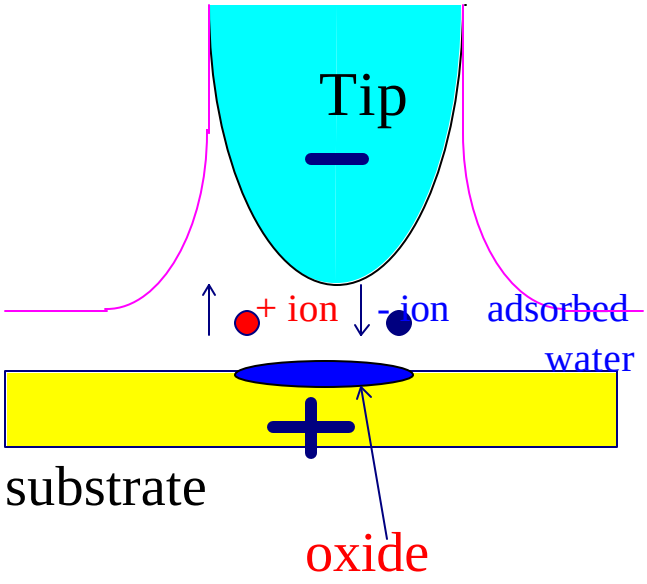
Principle of Local Oxidation of Si or metal surfaces by SFM

- Field Induced Oxidation



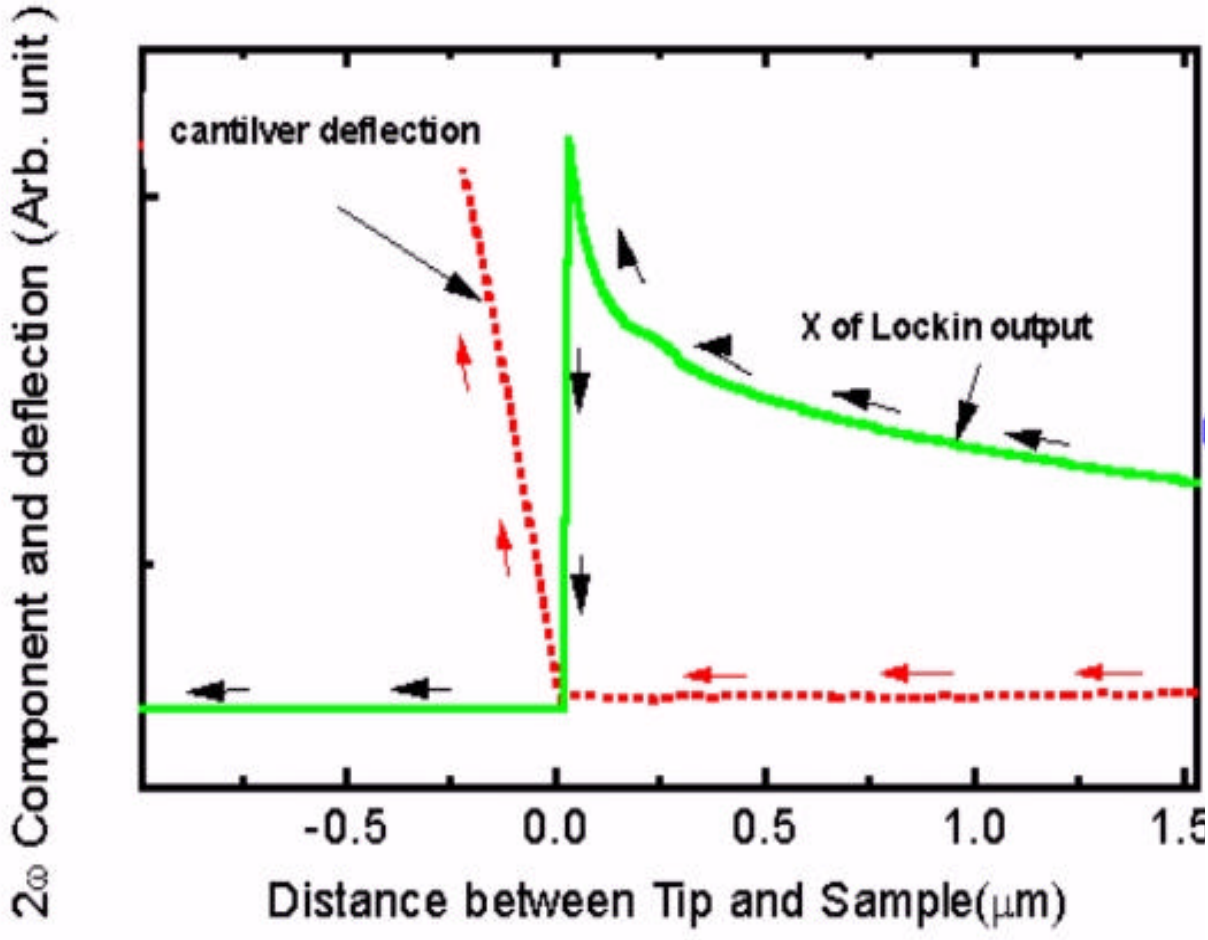
✧E field between tip & sample ~ a few V/nm
- ✓AFM tip radius ~ 30 nm
- ✓tip-sample distance ~nm
- ✓voltage between (3*V* - 10*V*)

✧ionization of adsorbed water on Si or Ti
- ✓O^- ions + holes in Si or metal
- ✓humidity dependence

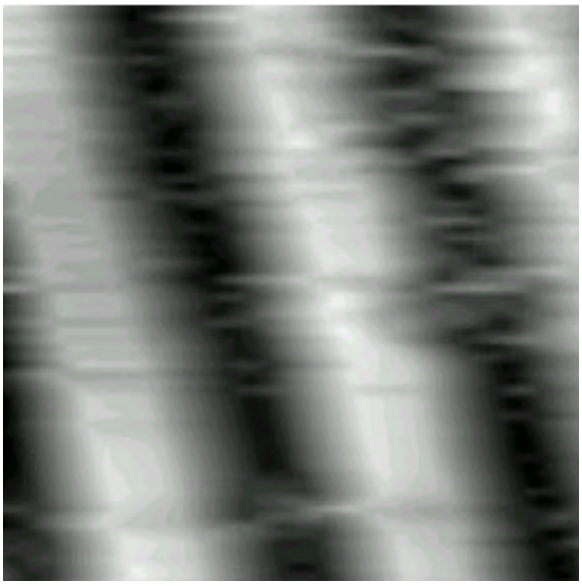
✧reaction of ionized water with positively biased Si or metal surfaces
- ✓growth of oxidation on Si or metal surfaces
- ✓tip velocity : 0.1μm/s ~ 10μm/s

Electrostatic Tapping Mode SFM

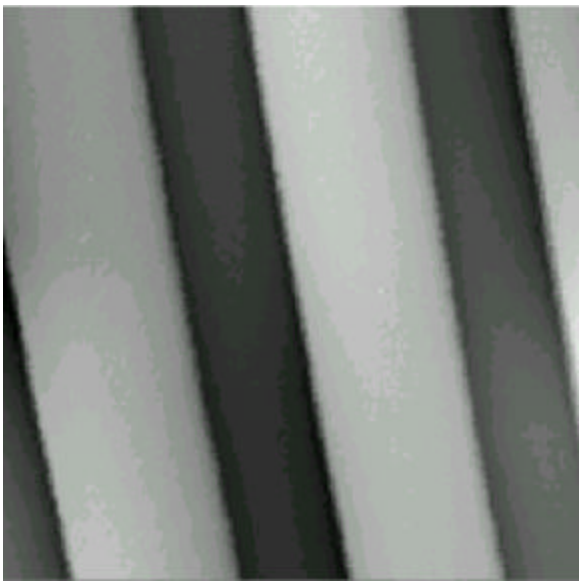
- approaching curve
  - ✧simultaneous measurement
    - ✓2ω component of driving signal versus tip-sample spacing
    - ✓deflection versus tip-sample spacing
  - ✧tapping slope> contact slope
    - ✓higher z-sensitivity of tapping mode



- tapping mode imaging of soft material
  - ✧sample: photo-resistor



contact mode



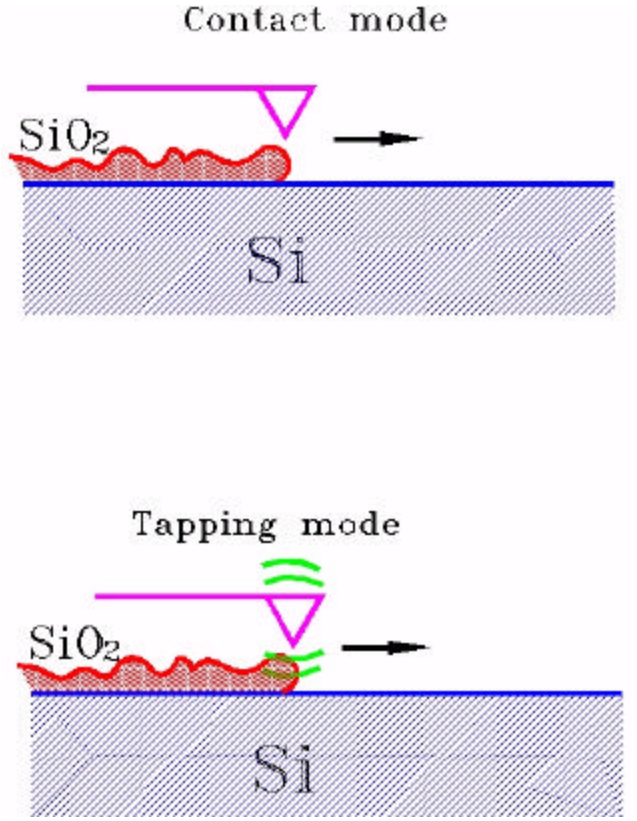
tapping mode
(10μm×10μm)

- ✧low loading force
- ✧low lateral force

✧high resolution imaging without damage

Lithogaphy by Electrostatic Tapping Mode SFM

● improvement of the resolution



● sample preparation

✧H passivated n-type(5 - 12Ωcm) Si(100)

✧treatment in H_2SO_4 and H_2O_2

✓ $H_2SO_4 : H_2O_2 = 4 : 1$

✓ 120°C for 10min

✧dip in buffered HF

✓ $NH_4F:HF=7:1$

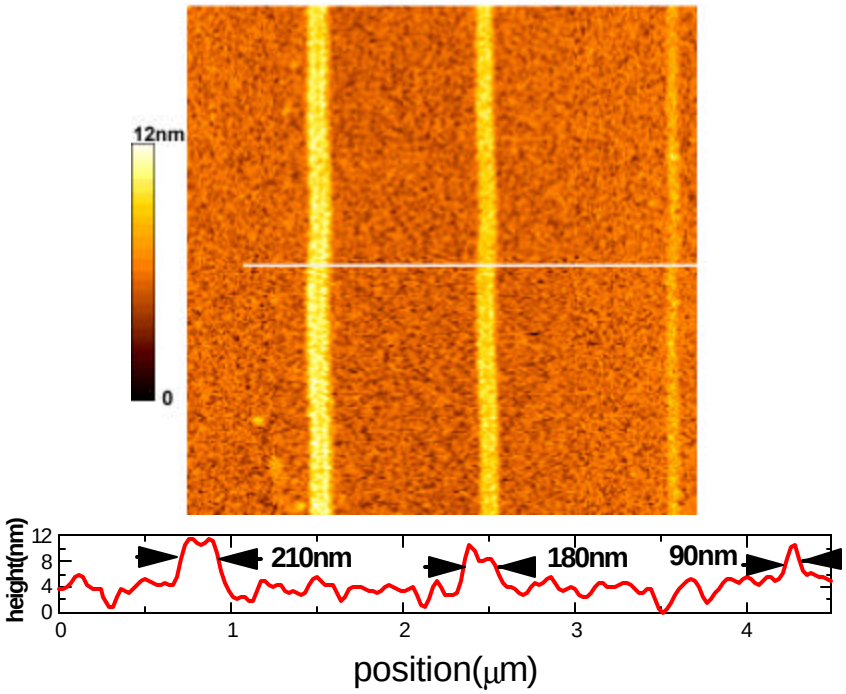
✧deionized water for a 10s

- oxidation pattern

✧bias voltage 15 V, 12.5 V and 10V

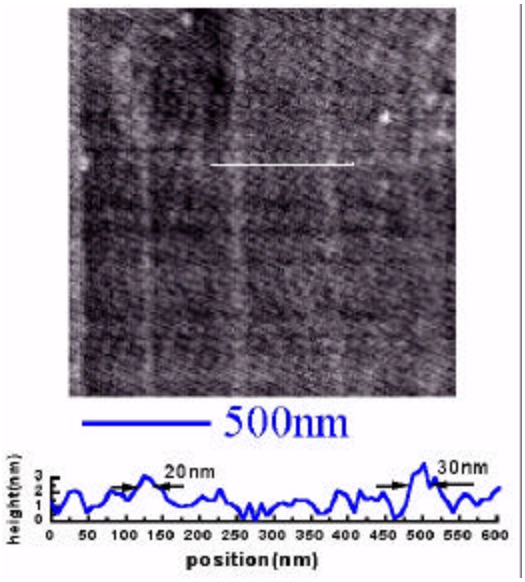
✧feedback with V_{ac} =12V by tapping mode

✧patterning speed ~ 0.5 μm/s (6μm × 6μm)



✧line width :20-30 nm, v_t=0.05μm/s

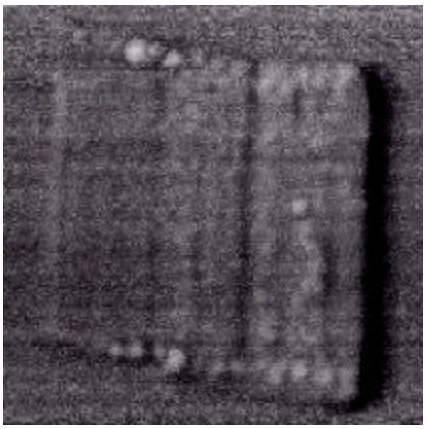
✧bias:10 V, 8.75V, 7.5V, 6.25V, 5V @d=5nm



✧wire with width 50nm on Si substrate

✧patterning speed ~ 0.6 μm/s (V_t=10V)

✧humidity~60%



(1.8μm×1.8μm)

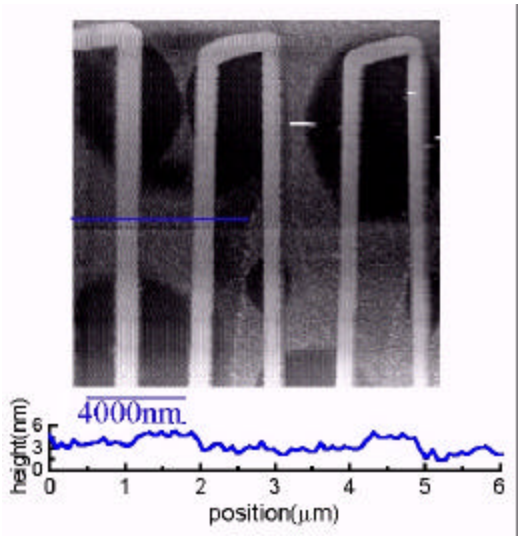
●etching process

✧pattern transfer

✧1 M aqueous KOH solution in 60°C for 3 s

✧V_{ac} : 12 V, d = 2 nm

✧bias : 26 V, 22V, 18V, 14V, 10V (from left to right)

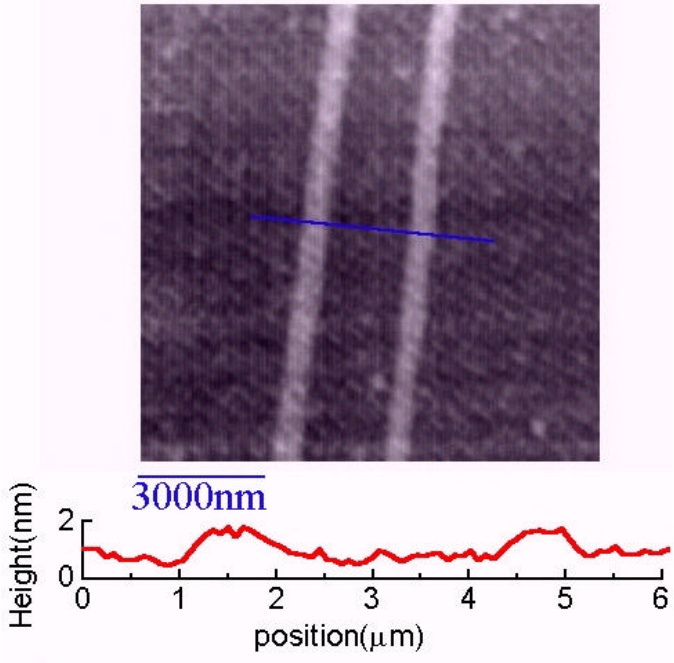


(15μm×15μm)

✧bias voltage 12 V and 10 V

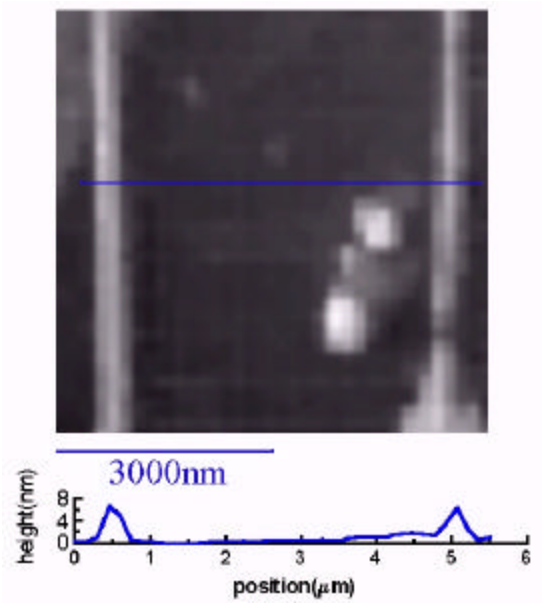
✧feedback with V_{ac} =12V

✧image with V_{dc}=0V and V_{ac}= 12V, d=2nm



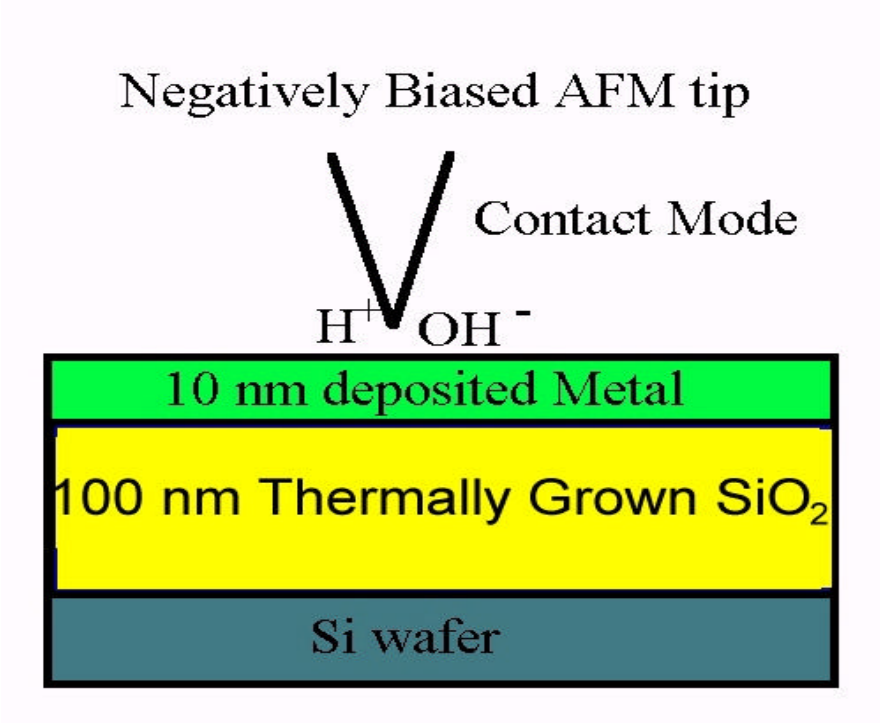
(11μm×11μm)

✧1 mol. aq. KOH solution in 60°C for 15s



(7μm×7μm)

- narrow Ti wire fabrication

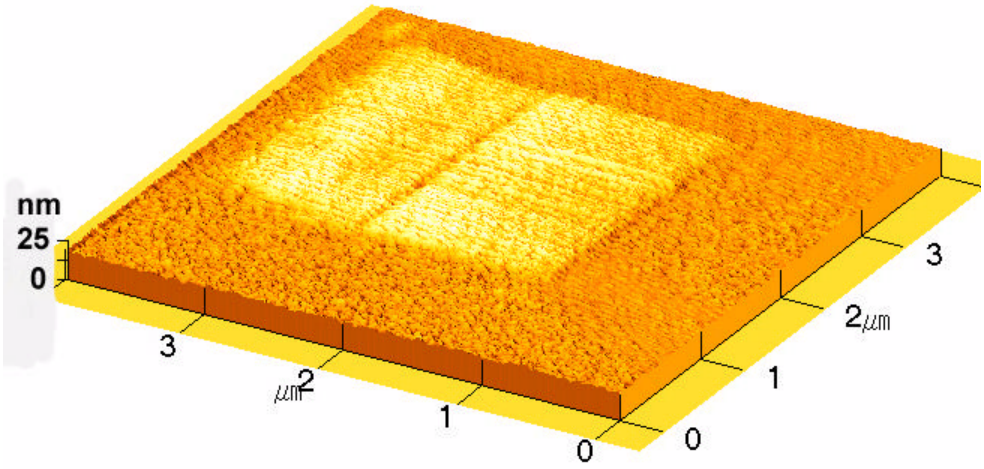


✧Votage between tip & sample(V_t = 10V)

✧Tip velocity = 100nm/sec

✧Humidity ~ 60 %

✧Wire Width ~ 60nm



Local Surface Potential Measurement

● Principle

Surface Potential $V_{surface}$

Tip Bias V_{tip}

$$V_{tip} = V_{\mathrm{mod}} \cos wt$$

$$F = \frac{1}{2}\frac{dC}{dz}(V_{tip} - V_{surface})^2$$

Decompose the Mixing terms :

$$F = \frac{dC}{dz}\left[-V_{surface}V_{\mathrm{mod}}\cos wt + \frac{1}{4}V_{\mathrm{mod}}{}^2\cos 2wt + \cdots\right]$$

$$F_{2w} = \frac{1}{4}\frac{dC}{dz}V_{\text{mod}}^{2}\cos 2wt :$$

✧feedback of tapping amplitude of 2ω component

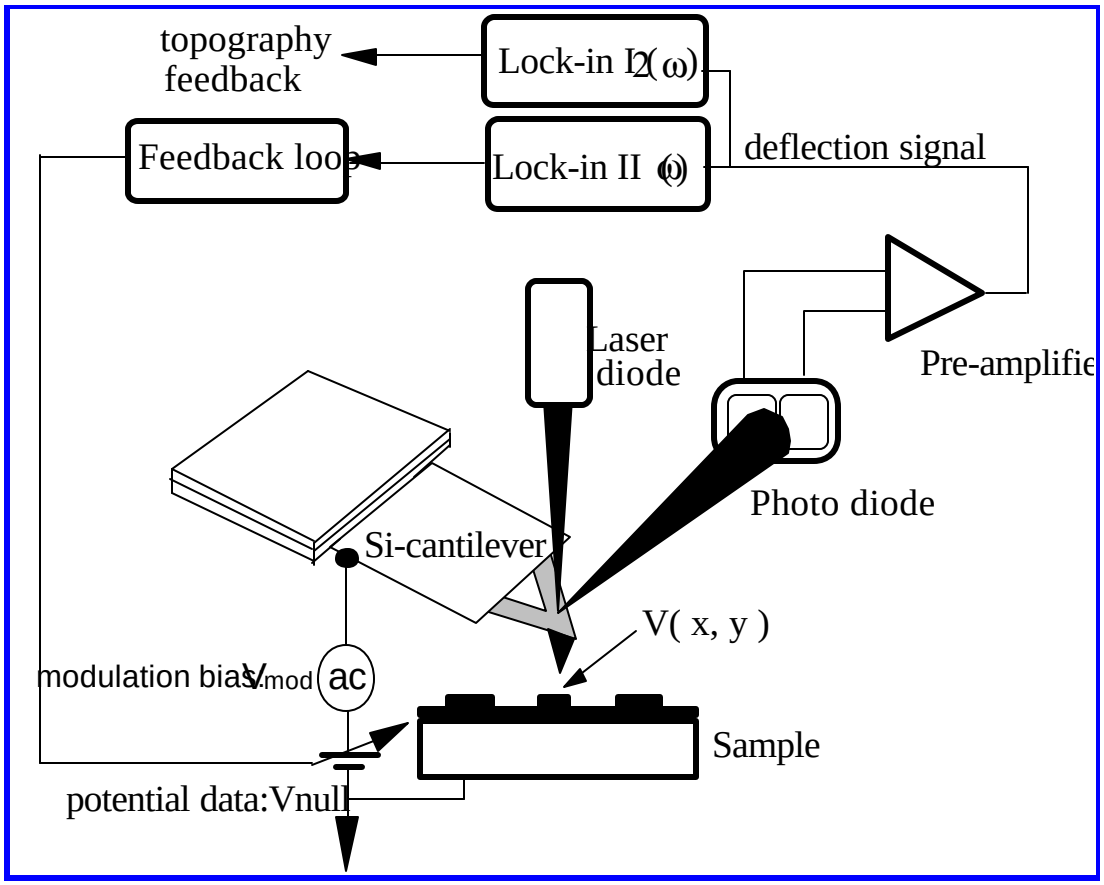
⇒Topography

$$F_{w} = -\frac{dC}{dz}V_{surface}V_{\text{mod}}\cos wt$$

✧measurement of ω component

⇒Surface Potential

● experimental setup

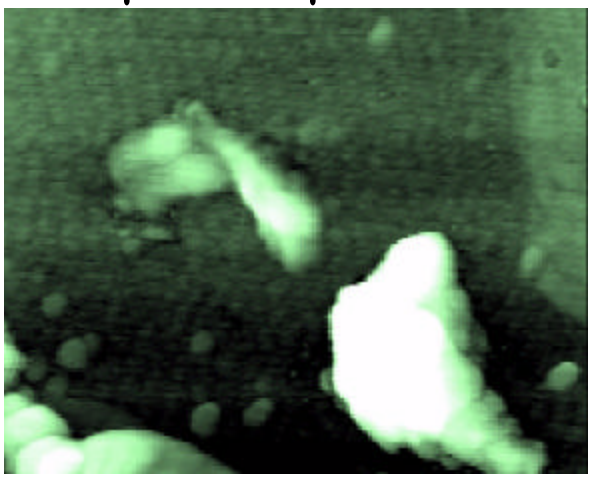


- ✧simultaneous measurement
  - ✓topography
  - ✓surface potential
- ✧*in situ* diagnostic technique
- ✧local electrical properties of the nano-system
  - ✓contact potential difference
  - ✓voltage probe

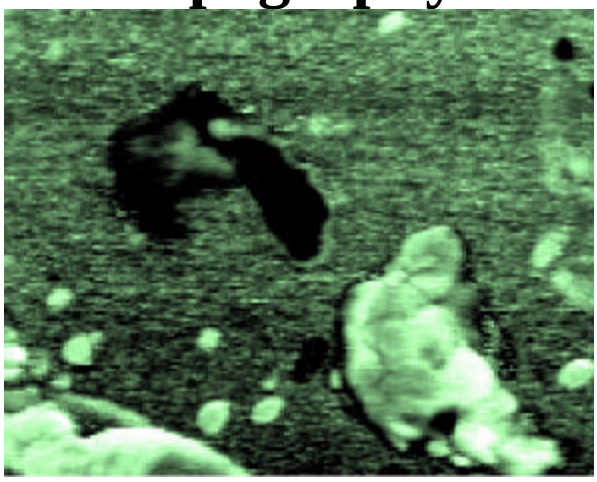
● surface potential

- ✧topography of TiO_x hillocks

- ✓ field induced oxidation on Ti film
- ✓ tapping mode of 2ω component
- ✧ surface potential(ω component)
- ✓ charge accumulation during oxidation
- ✓ ε=170 at 300K
- ✧ scan area : 4.5μm×3.5μm



topography



surface potential