Contact Potential Difference Measurements of Self Assembled Monolayers

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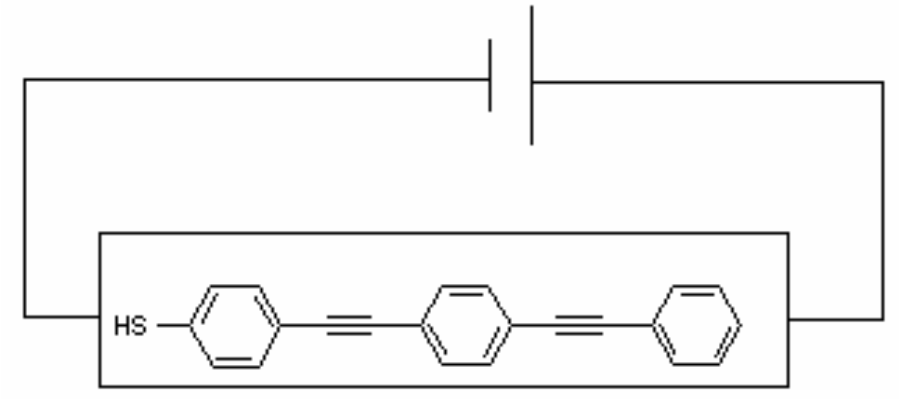
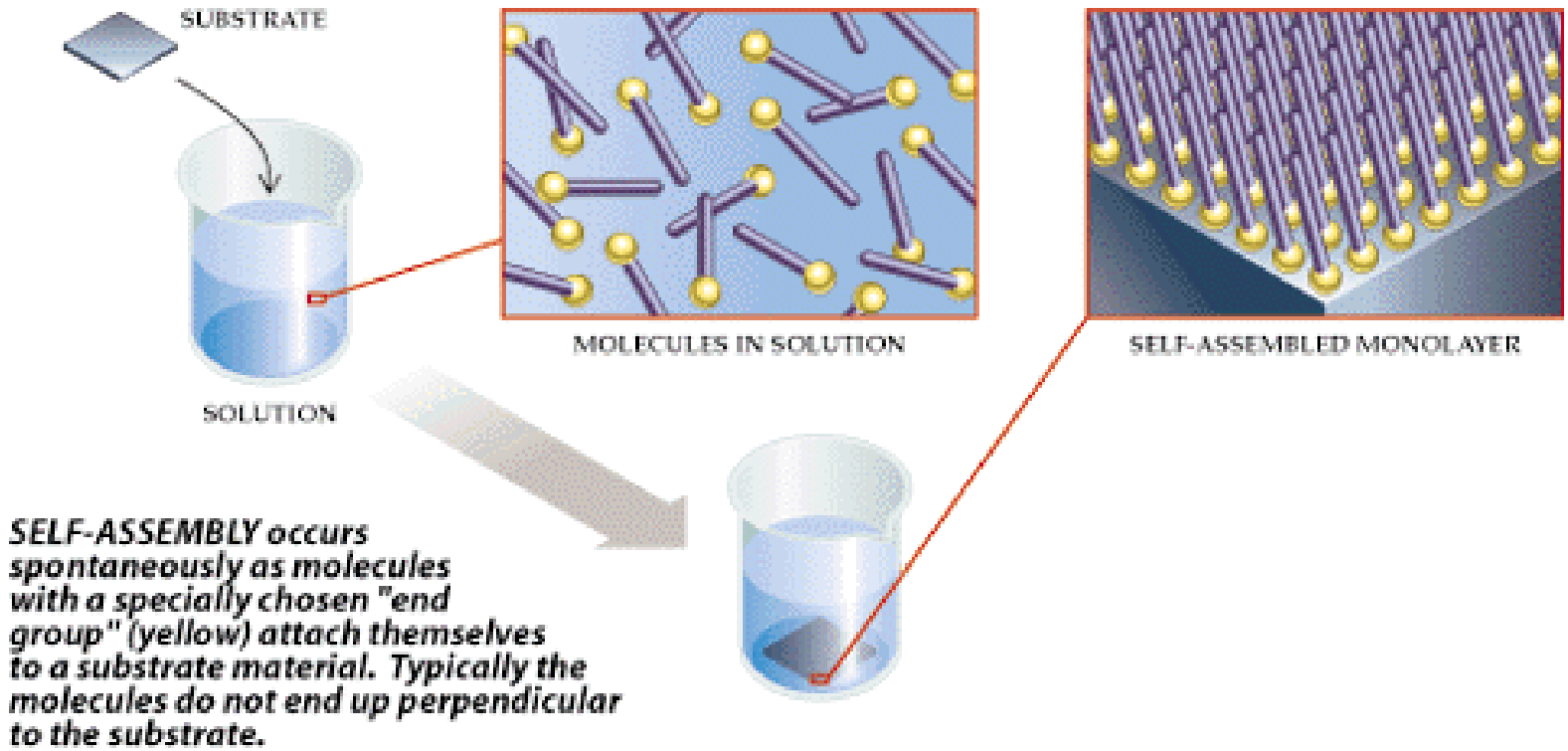
Molecular Electronics are Good

- Theoretically an individual molecule can act like a small electronic device.
- These devices would allow electronic devices to be much smaller.



Molecular Electronics is Founded Upon SAMS

The molecules that we are working with Self Assemble on gold.

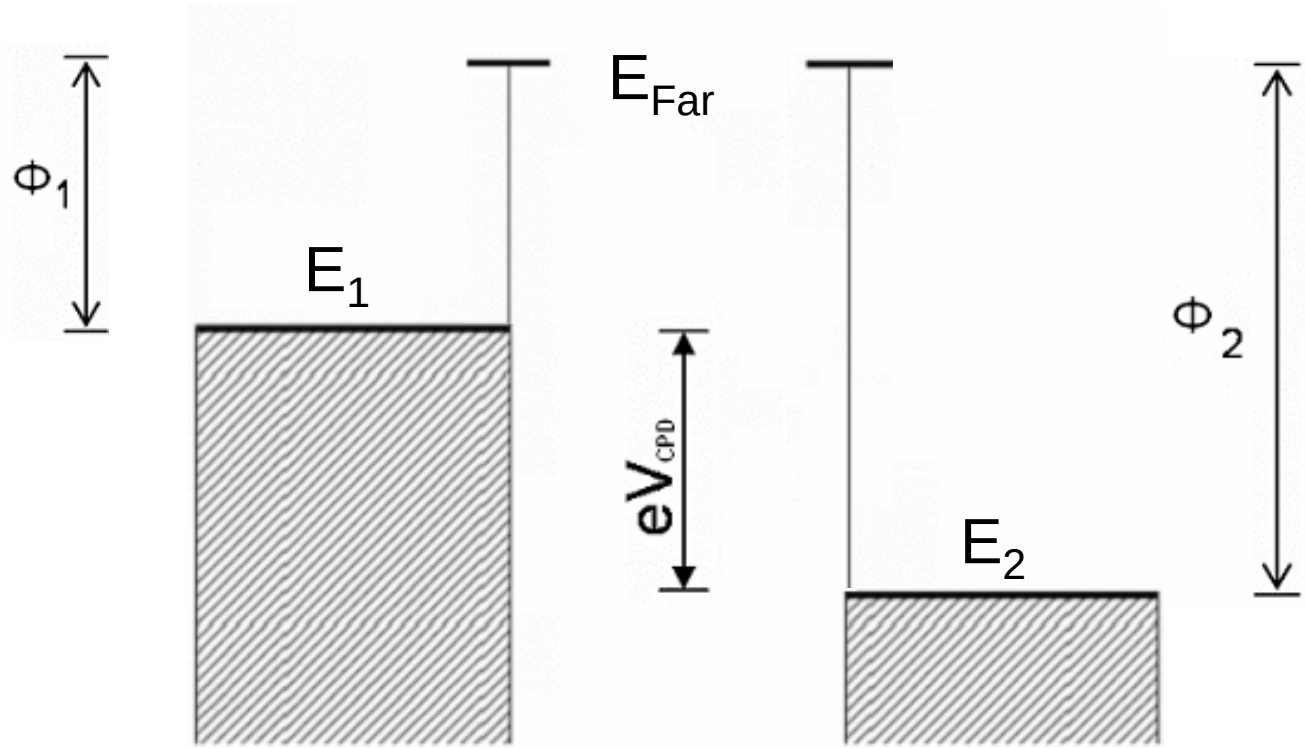


M. A. Reed and J. M. Tour, "Computing with Molecules", Scientific American 282, 86, 2000.

Today

- Contact Potential Difference
- The Work Function
- SKPM

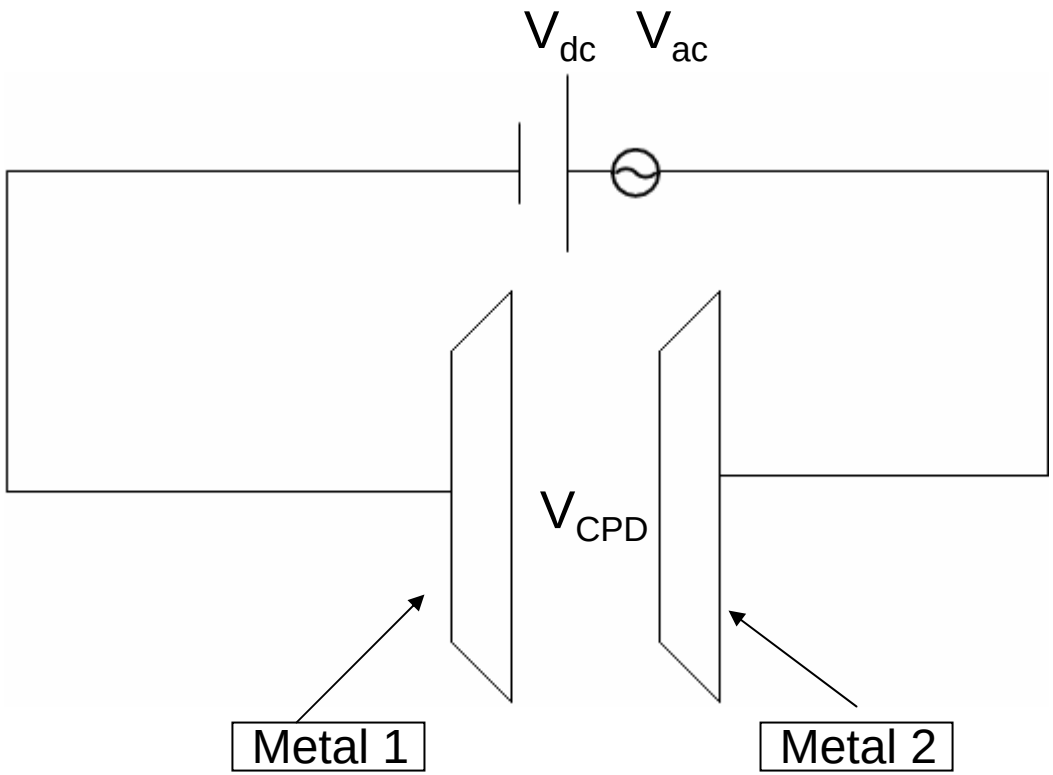
Contact Potential Difference



E = Energy Level

Φ = Work Function

Parallel Plate Capacitor

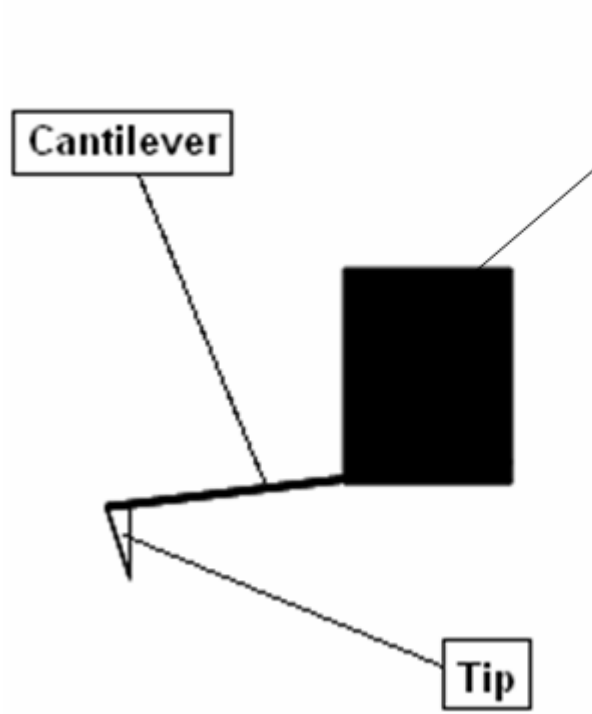


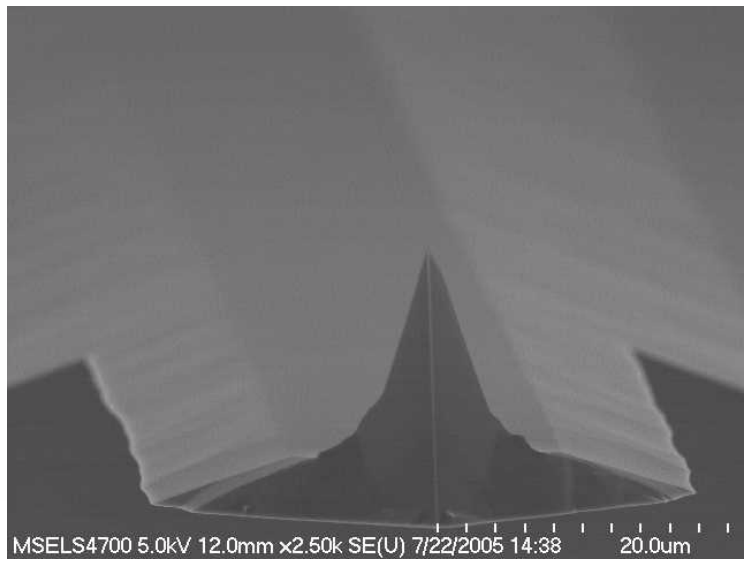
Energy is given by

$$U = \tfrac{1}{2}\, C \cdot V^2$$

$$V = V_{cpd} + V_{dc} + V_{ac}\sin(\omega t)$$

What is an Atomic Force Microscope?

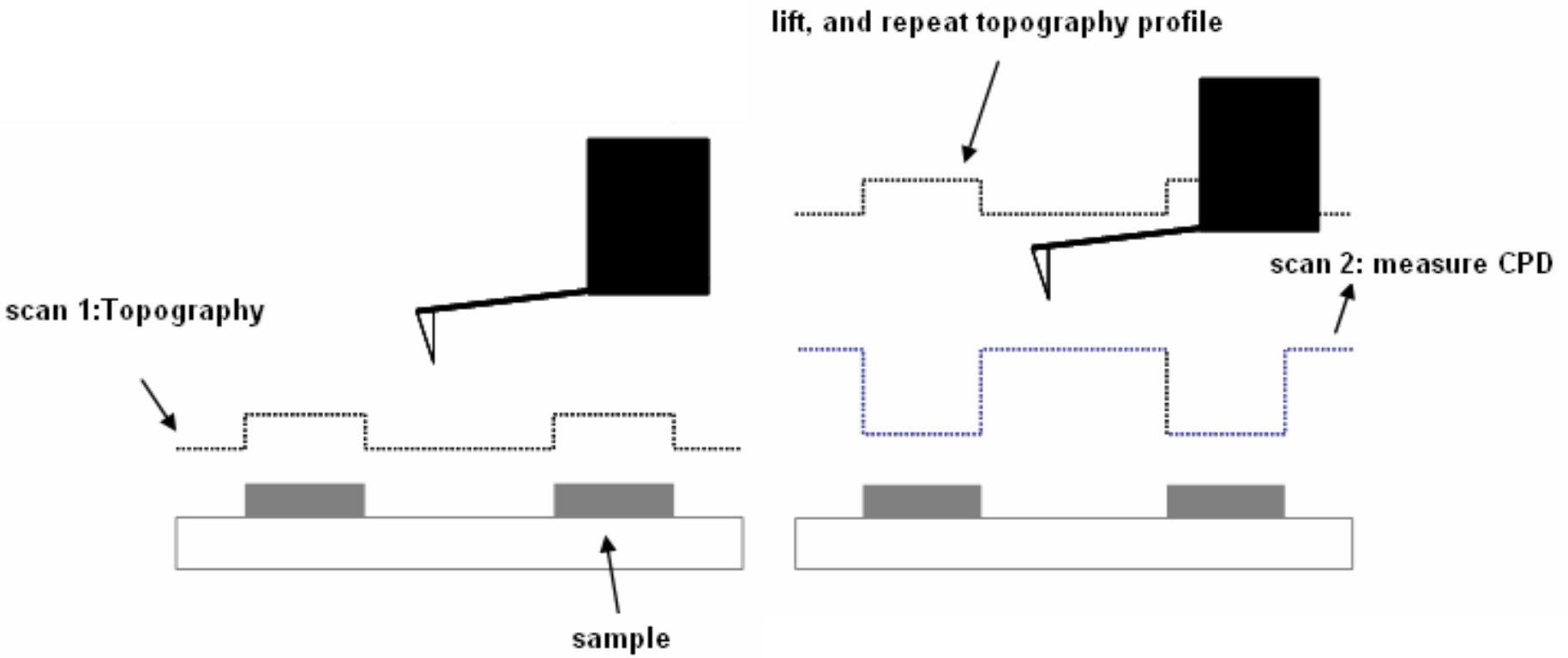




An AFM measures atomic forces.

Commonly used to take high resolution pictures of surfaces.

Scanning Kelvin Probe Microscopy



$$U = \tfrac{1}{2}\, C \cdot V^2$$

$$F(\omega) = -dU/dZ \propto [V_{cpd} - V_{dc}] \cdot V_{ac} \sin(\omega t)$$

Self Assembled Monolayers

1. measure bare surface ϕ_1.

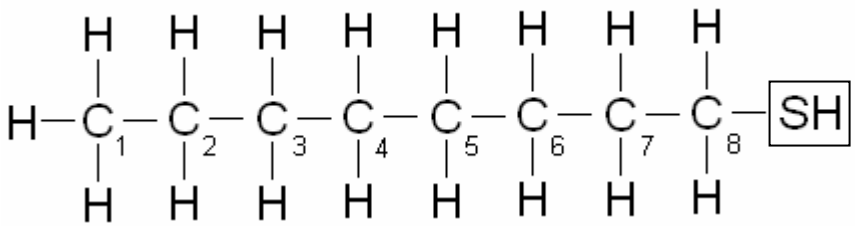
2. Measure modified surface ϕ_2.

Determine V_{CPD}.

MOLECULES:

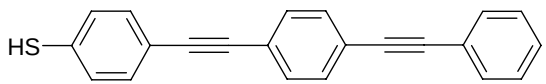
Alkanethiols (C8, C12, C18)

C8

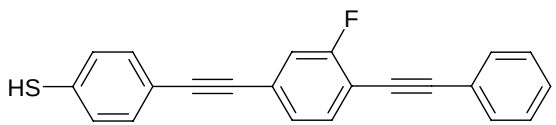


OPE (Oligo phenylene ethynylene) , NO2-OPE, and F-OPE

OPE



F-OPE



Sample Preparation

(1)

450 nm Au

Si(001)

5 nm Cr

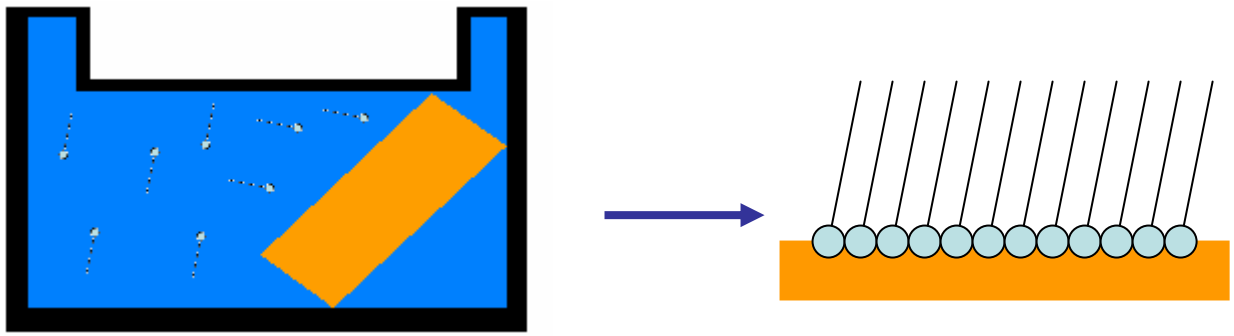
Oz Cleaned

(2)

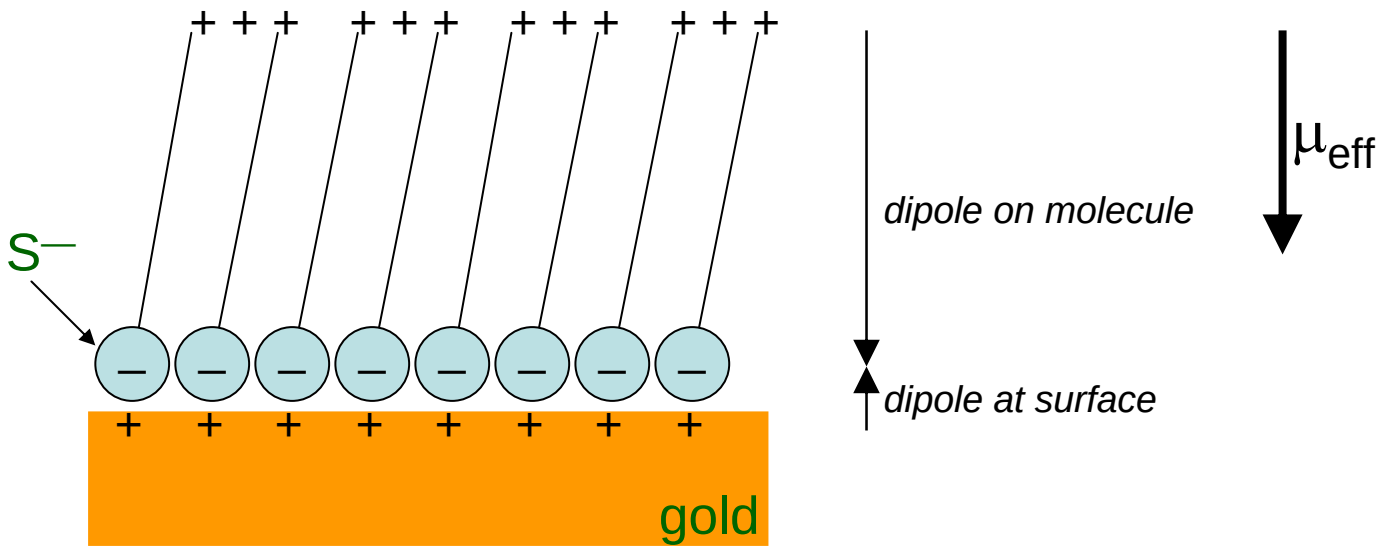
(3)

Prepared in Solution

(4)



Helmholtz Double Layer

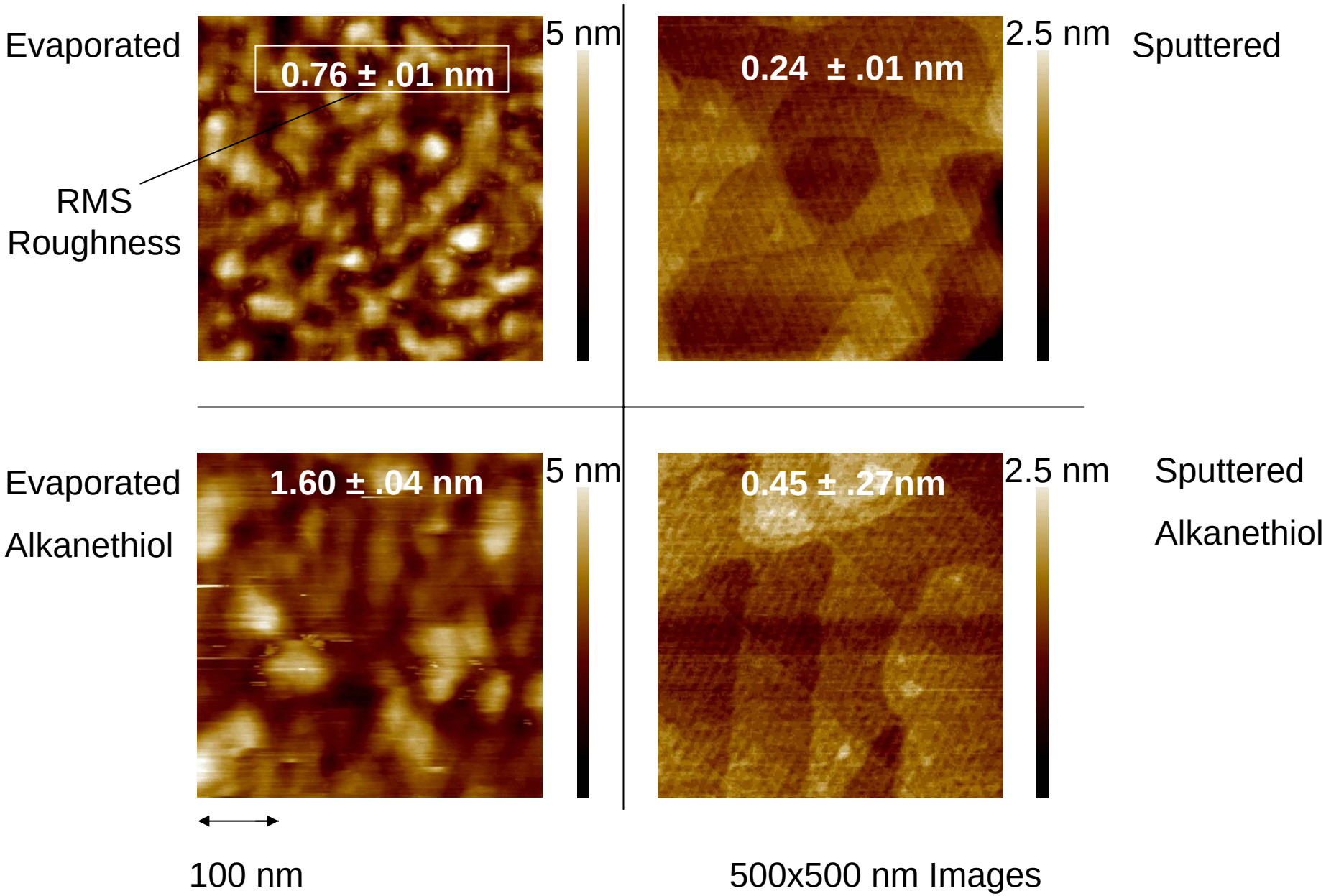


> So there is an effective dipole, μ_{eff}, pointing from the molecule to the gold.

This dipole corresponds to a potential drop at the interface and can be modeled as a Helmholtz double layer, to:

$$eV_{CPD} = n \cdot \mu_{eff} / \varepsilon_0 \varepsilon$$

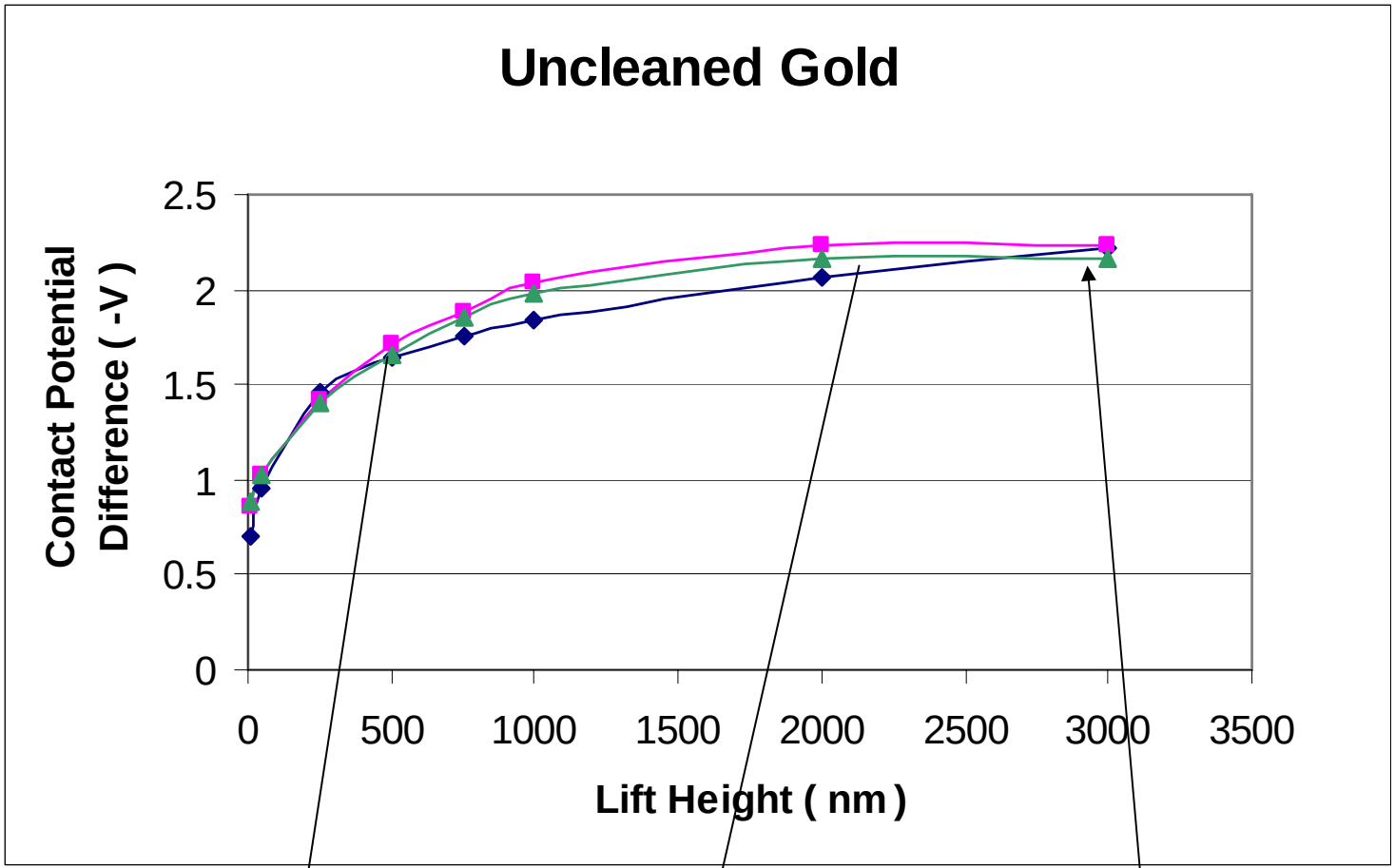
Surfaces


Evaporated
0.76 ± .01 nm
5 nm
RMS
Roughness
0.24 ± .01 nm
2.5 nm
Sputtered
Evaporated
Alkanethiol
1.60 ± .04 nm
5 nm
0.45 ± .27nm
2.5 nm
Sputtered
Alkanethiol
100 nm
500x500 nm Images

How is the Data Collection done?

- First, take V_{CPD} data of gold sample.
- Then, V_{CPD} of modified surface.
- Finally, take the difference of these measurements to get Work Function.
- Repeat this procedure to get an average value and a standard deviation.
- Repeat this process for each molecule.

Collected Data

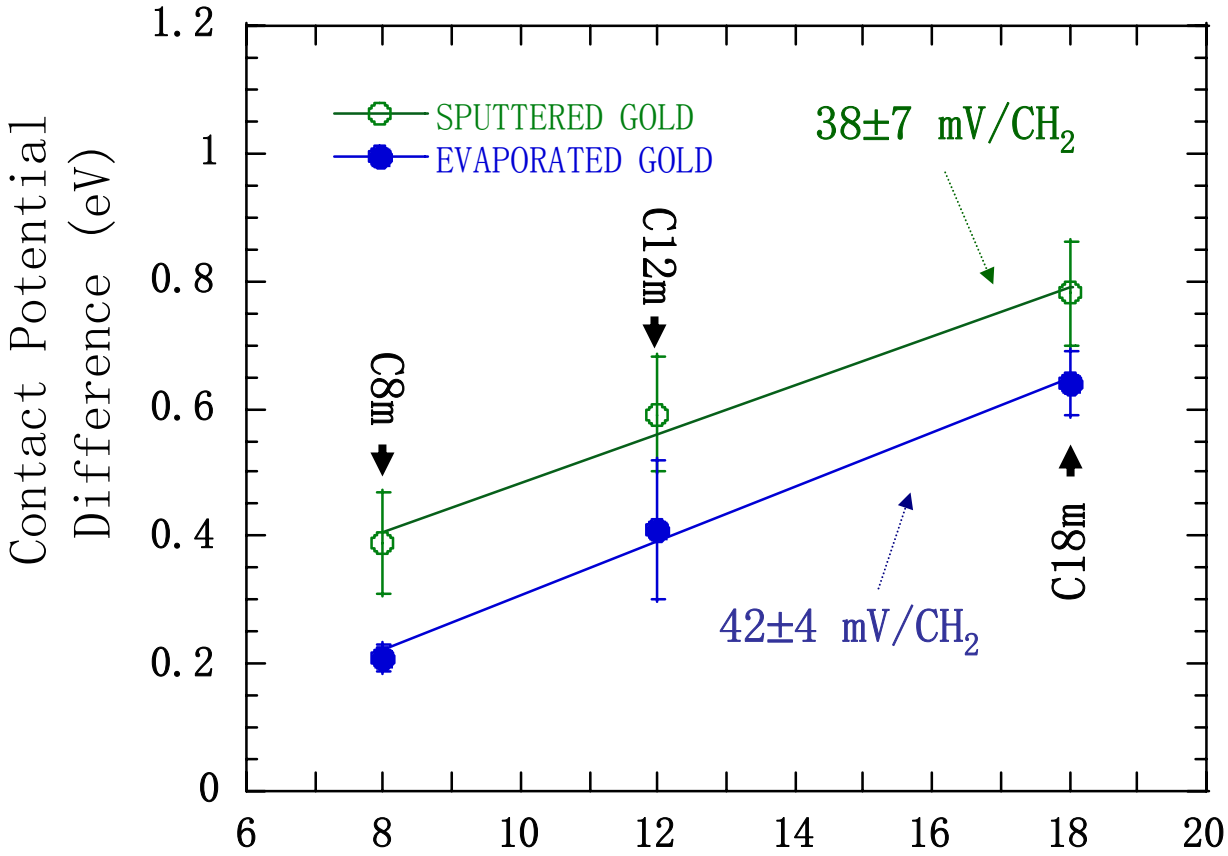


Coulombic Forces are Dominant

Capacitive Forces are Dominant

Here is where I took my data.

Alkanethiol Results

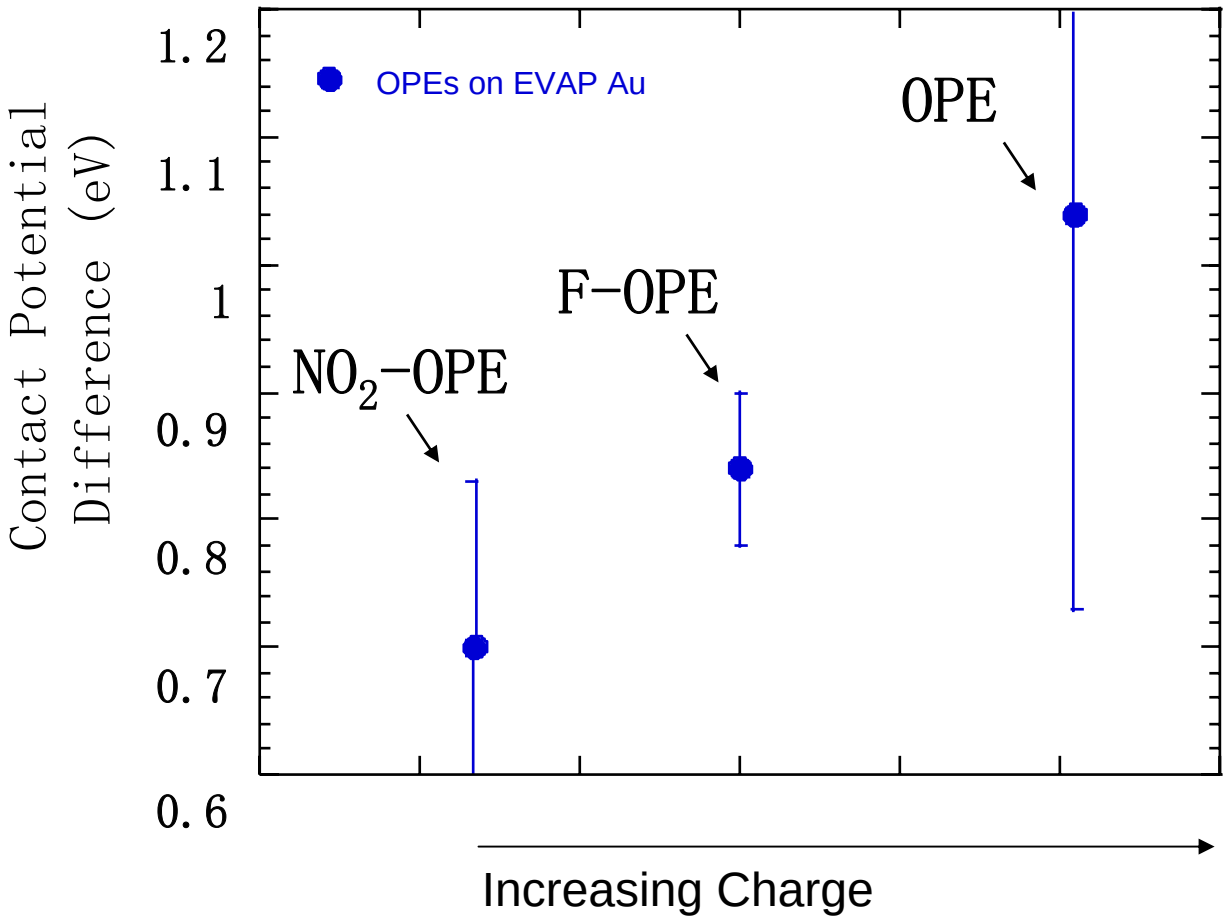


○ Evaporated

● Sputtered

$\mu = q * d$

OPE Results



$$\mu = q * d$$

Experimental vs Theoretical Results V_{CPD} for C_{12}

$$e\,V_{CPD} = n \cdot \mu_{eff} / \varepsilon_0 \varepsilon$$

Theoretical

$\mu = .6 \times 3.33 \times 10^{-30}$ C*m

$n = 4.5 \times 10^{18}$ molecules/m^2

$\varepsilon_0 = 8.9 \times 10^{-12}$ C^2/N

$\varepsilon = 2$

$$e\,V_{CPD} = .51 \text{ eV}$$

Experimental

$$e\,V_{CPD} = .47 \pm .03 \text{ eV}$$

Conclusions

- Work Function
- Scanning Kelvin Probe Microscopy
- Molecular Electronics

We have a manuscript in preparation to be **Published!**

Acknowledgements

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Questions ?