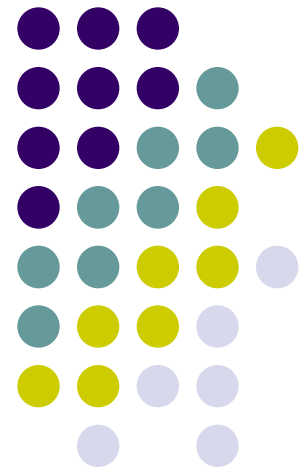


# Introduction to Molecular Conductor

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Solid State Physics II  
Instructor: Eblilio Dagotto  
Spring 2008



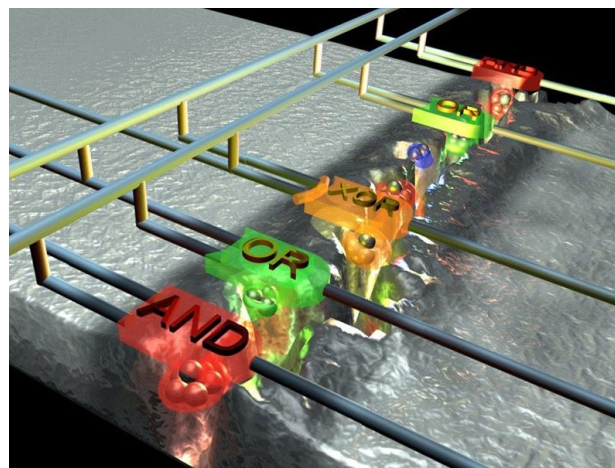
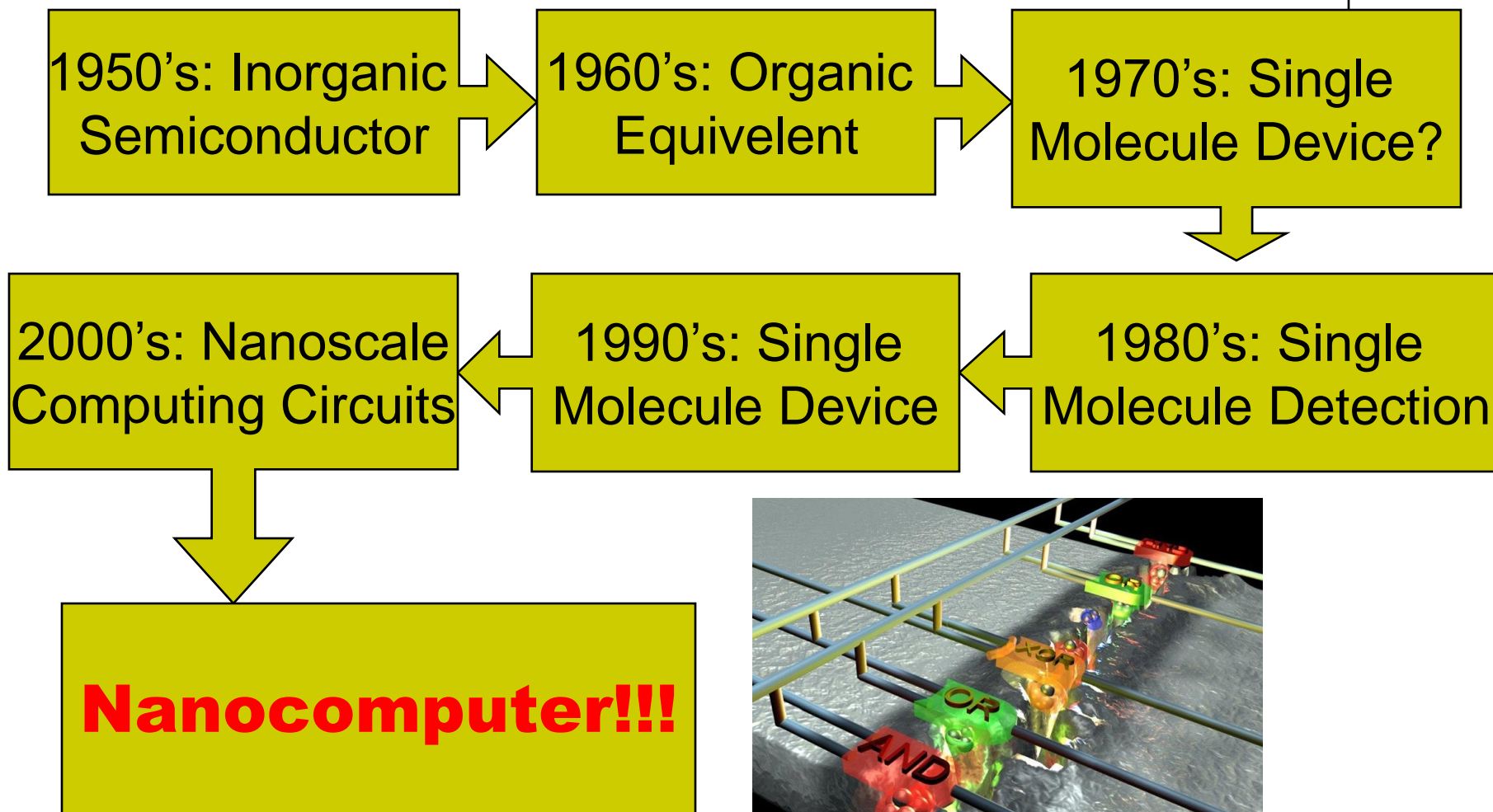
# Outline

- Background
- Metal-Molecule-Metal Junction
- Experiment Techniques
- Summary and Prospect

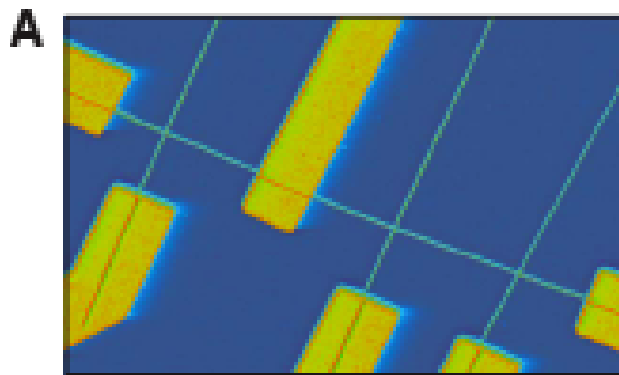




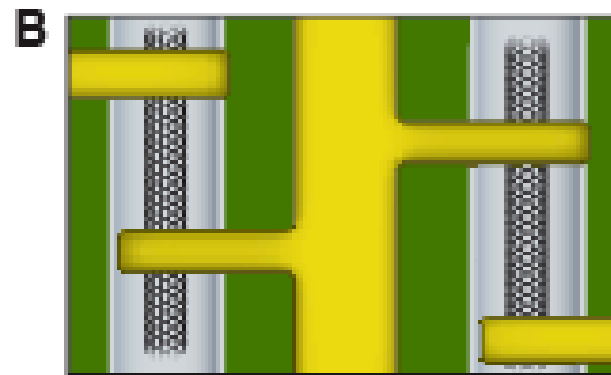
# Historical Perspective



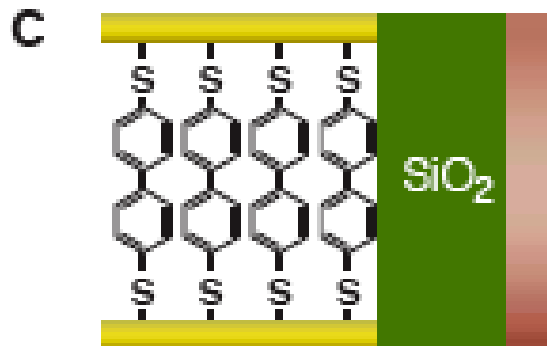
# Molecular Electronics



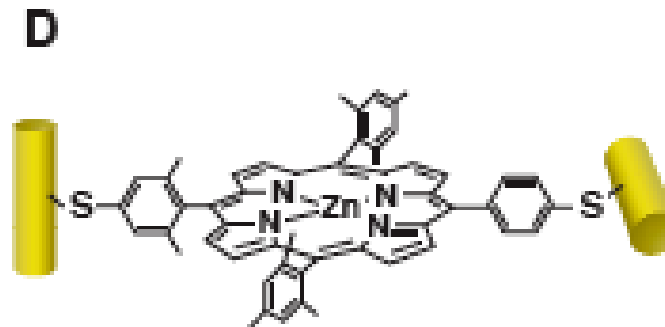
Nanowires



Carbon nanotubes



Small organic molecules



Biomolecules

# Why molecules?



## **Molecules are small.**

With transistor size at 180 nm on a side, molecules are some 30,000 times smaller.

## **Electrons are confined in molecules.**

Whereas electrons moving in silicon have many possible energies that will facilitate jumping from device to device, electron energies in molecules and atoms are quantized there is a discrete number of allowable energies.

## **Molecules have extended pi systems.**

Provides thermodynamically favorable electron conduit - molecules act as wires.

## **Molecules are flexible.**

Pi conjugation and therefore conduction can be switched on and off by changing molecular conformation providing potential control over electron flow.

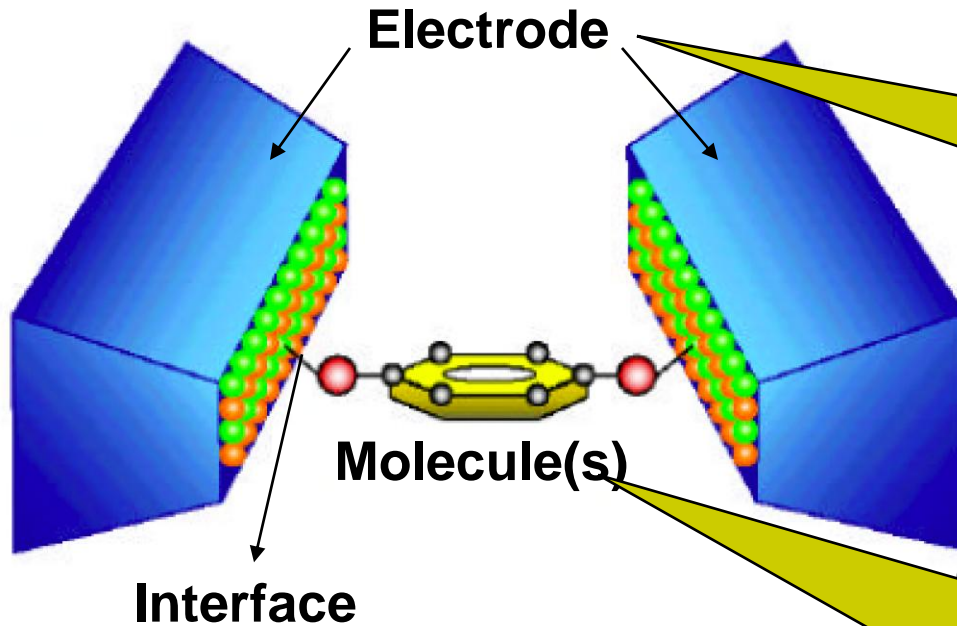
## **Molecules are identical.**

Can be fabricated defect-free in enormous numbers.

## **Some molecules can self-assemble.**

Can create large arrays of identical devices.

# Metal-Molecule-Metal Junction



Composition, shape, surface cleanliness and topography

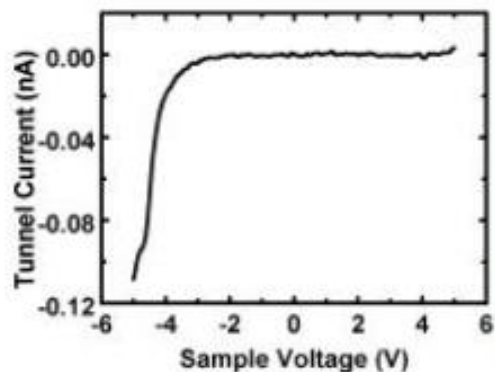
1. composition, configuration (flat phase, standing, loop phase)
2. Backbone, length,
3. Head group and end group

Binding site, coupling, contact type  
Conductance:  $G = R_0 \times T_l \times T_{mol} \times T_r$



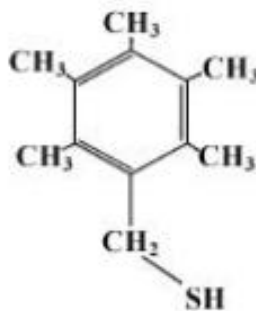
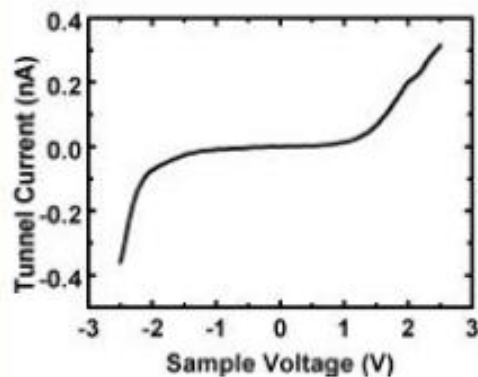
# I-V Characteristic

Insulating



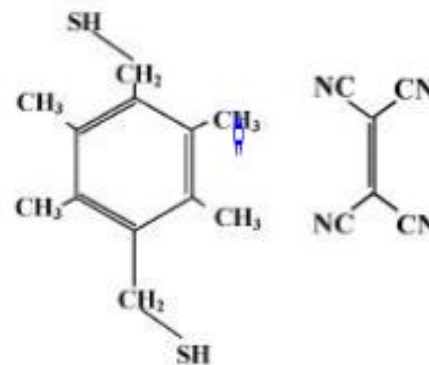
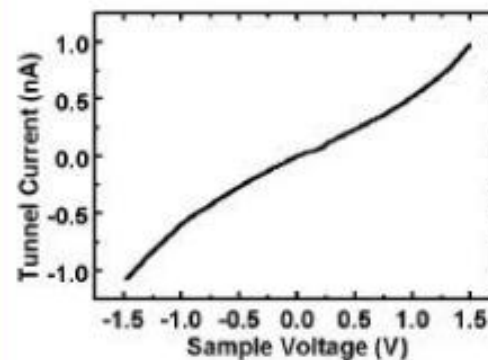
Calixarene

Semiconducting



PMBT

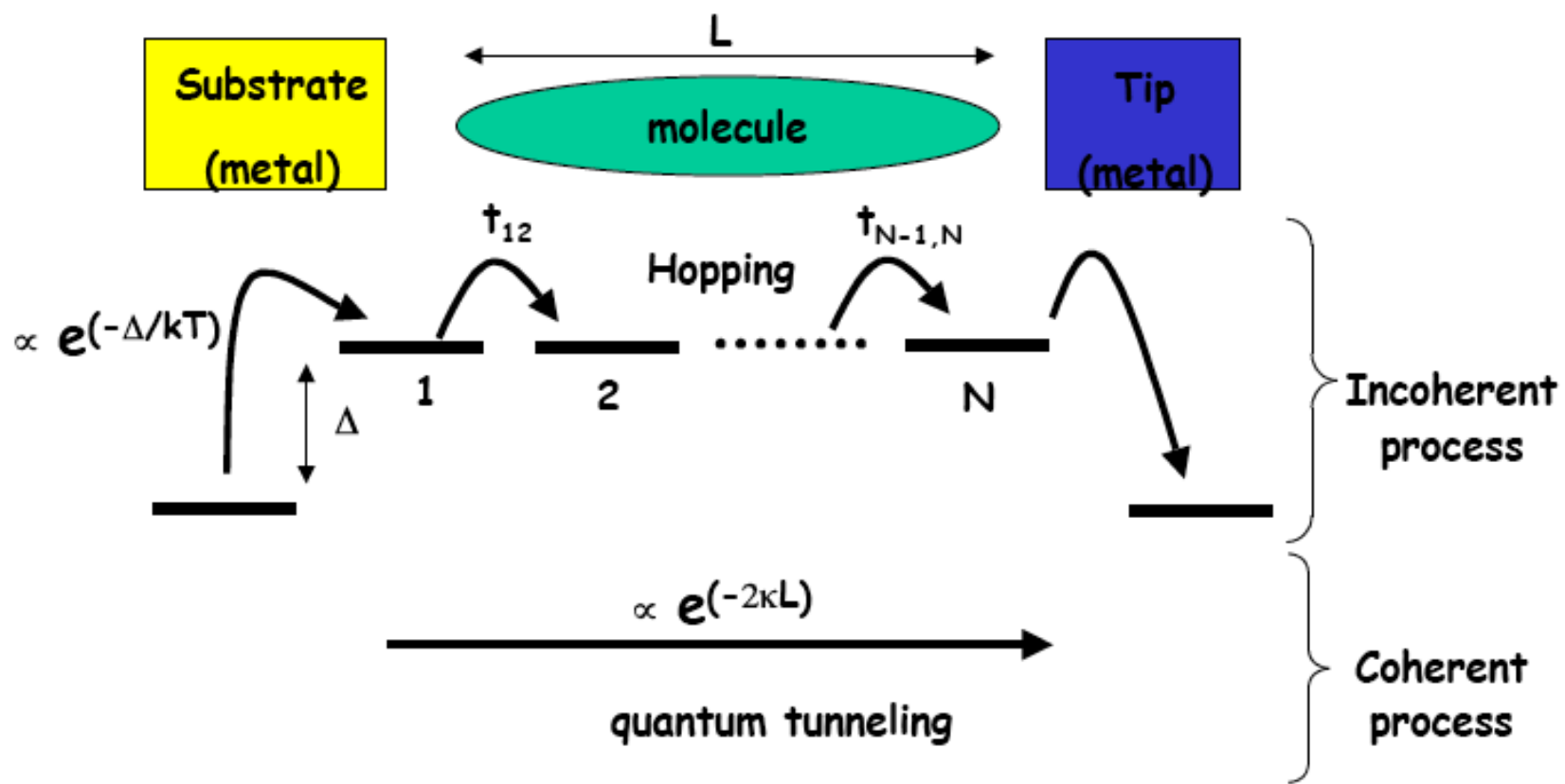
Ohmic



TMXYL  $\leftrightarrow$  TCNE

# Molecular Conduction

(a competition between two processes?)

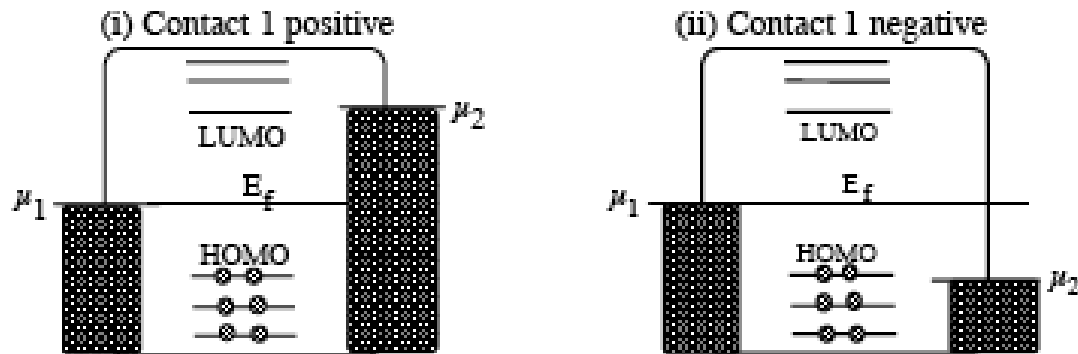




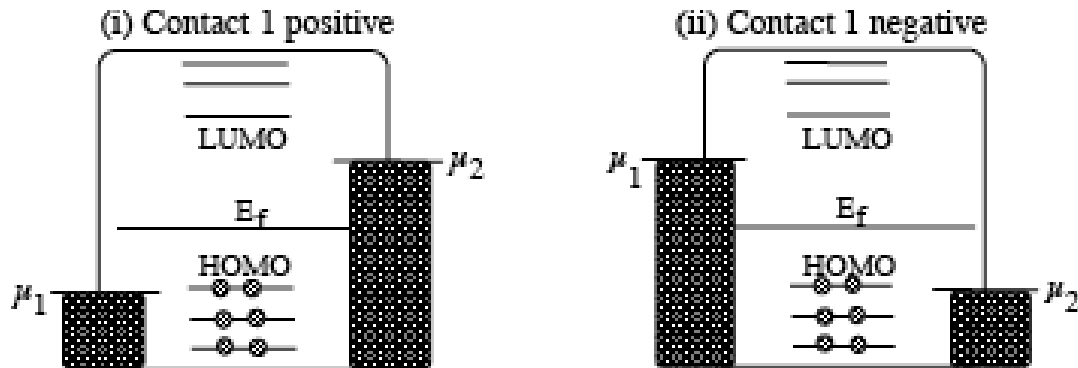
# Energy Diagram



(a)  $\eta=0$ : Molecular levels remain fixed with respect to contact 1.



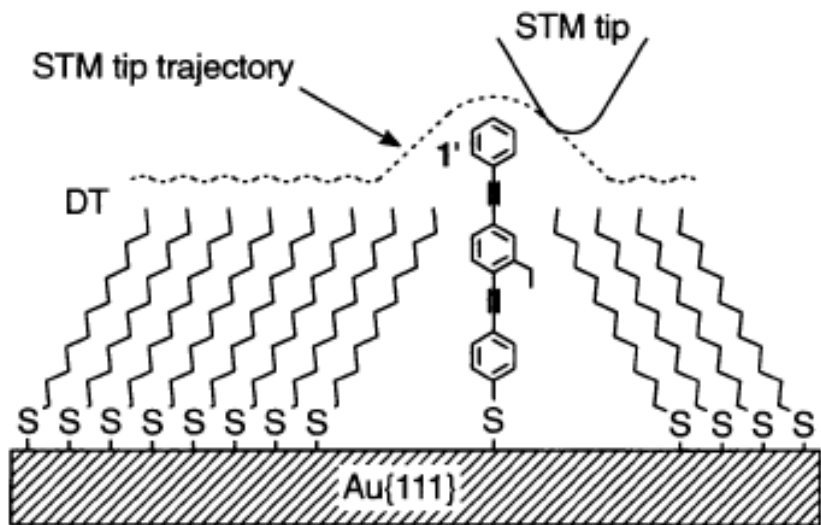
(b)  $\eta=0.5$ : Molecular levels shift with respect to contact 1 by half the applied bias.



# Experiment Test Beds



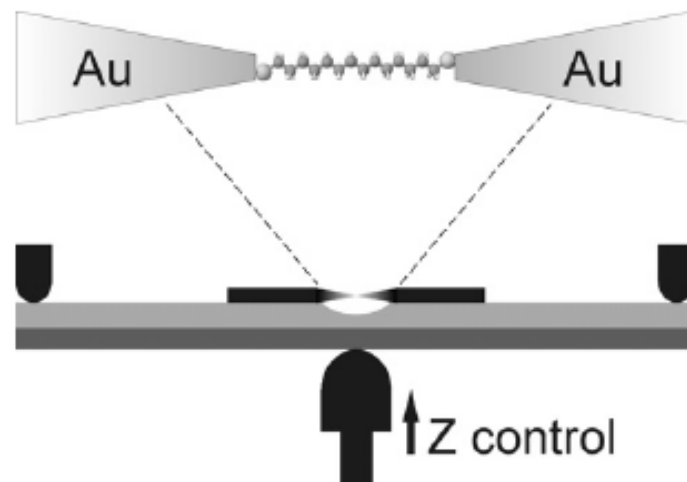
## STM



Measure at specific location, however, not clear about How many molecules, exact size, and morphology.

Current change due to height change or conductance change?

## Break Junction



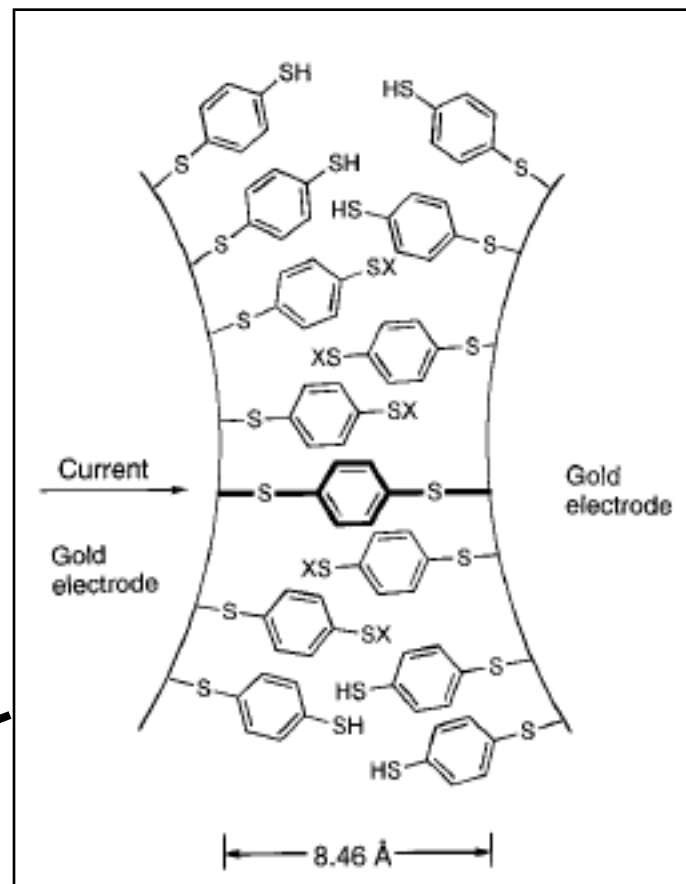
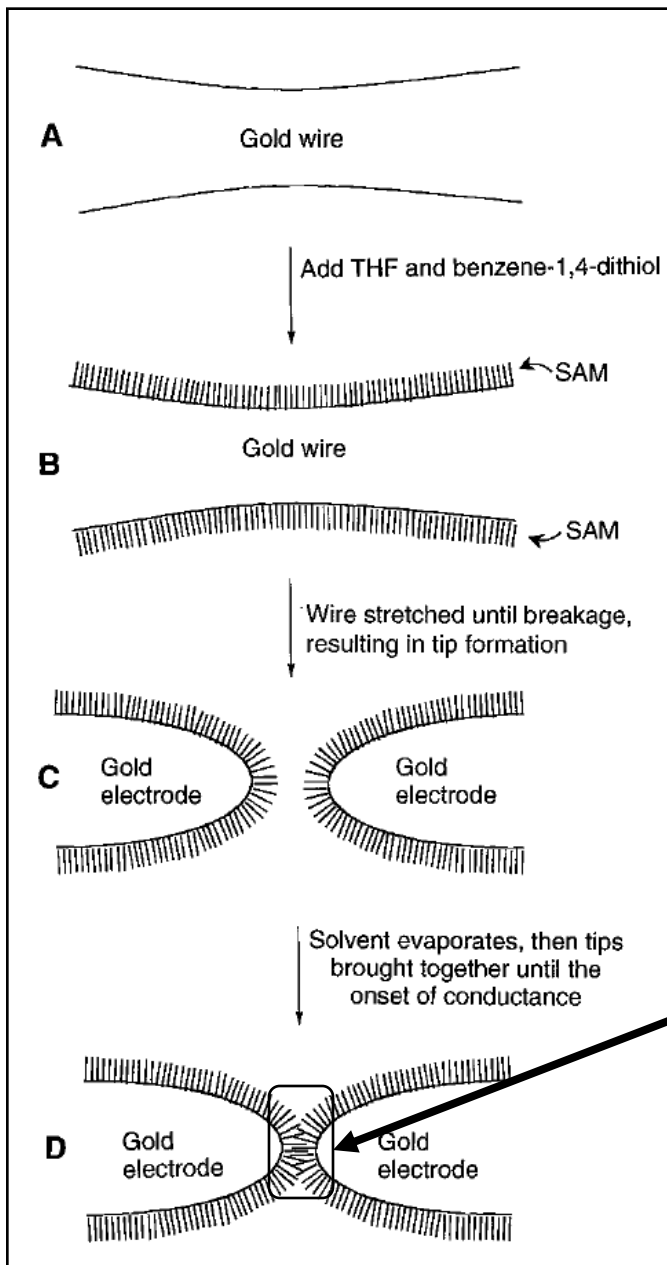
Sub-nm control

Assemble molecules between leads

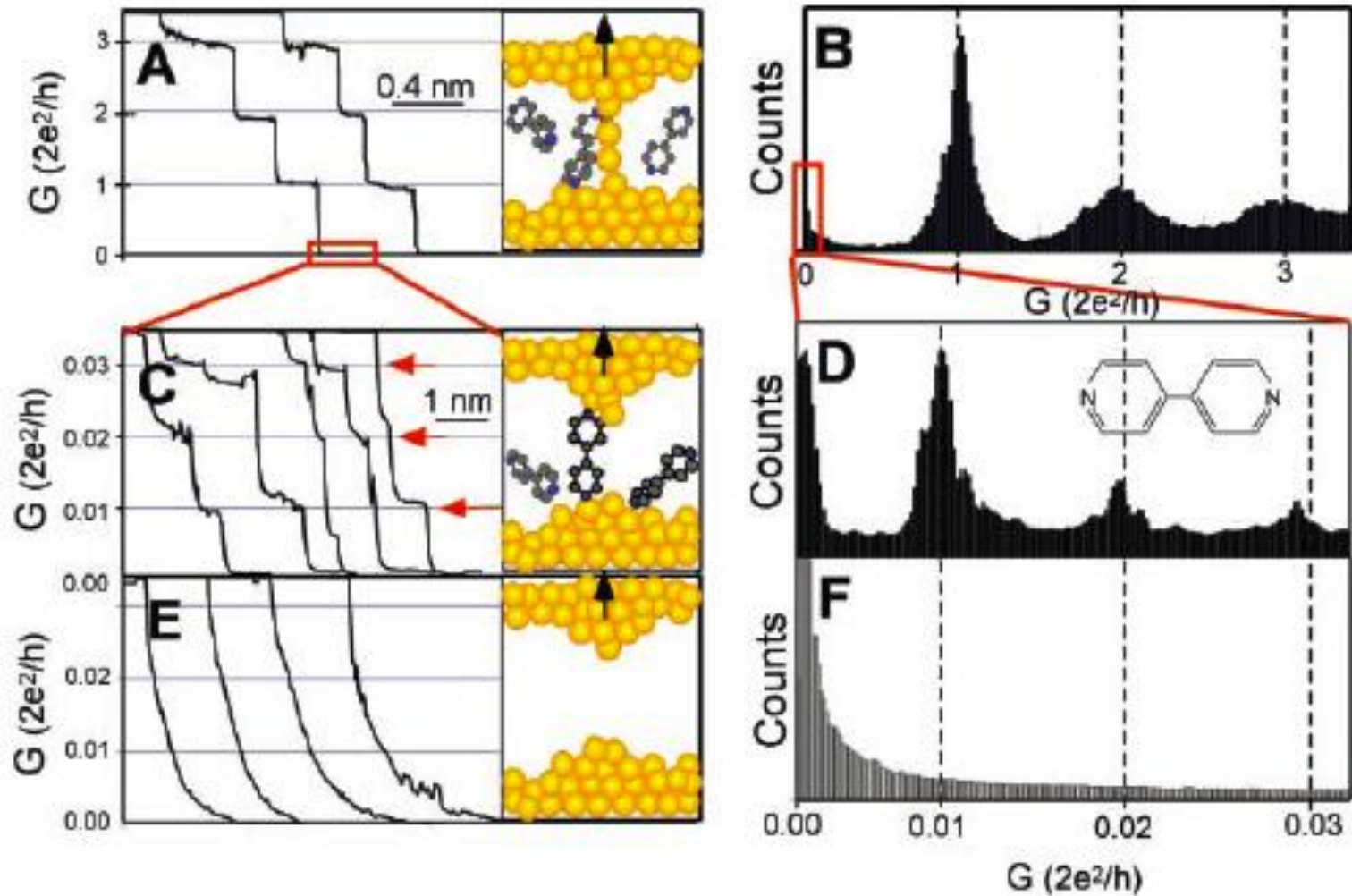
Possible to measure single molecule



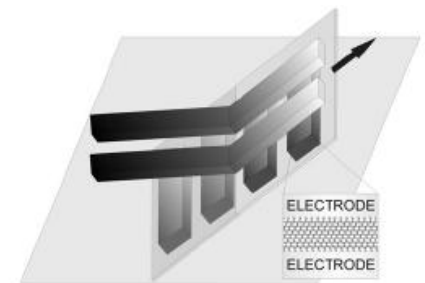
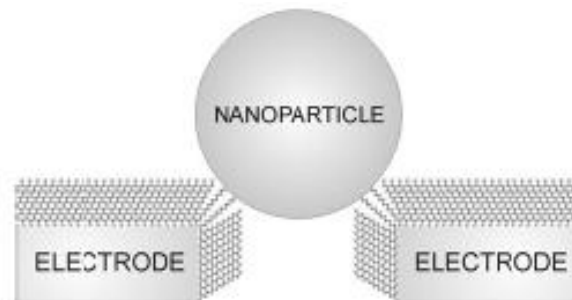
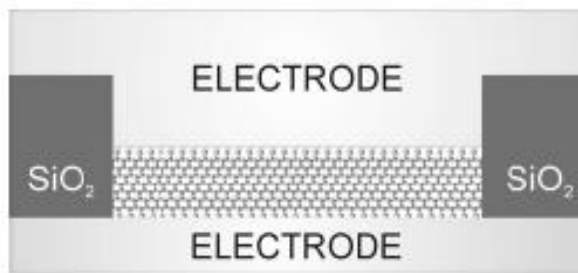
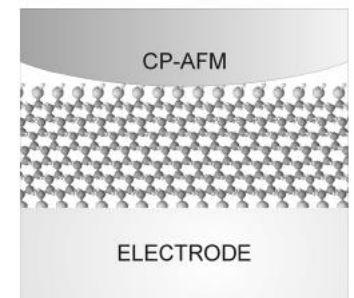
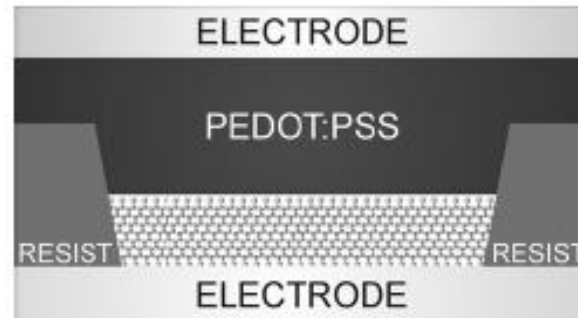
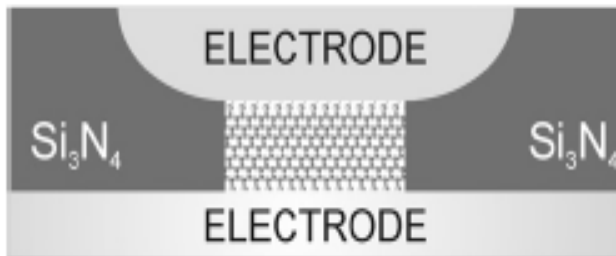
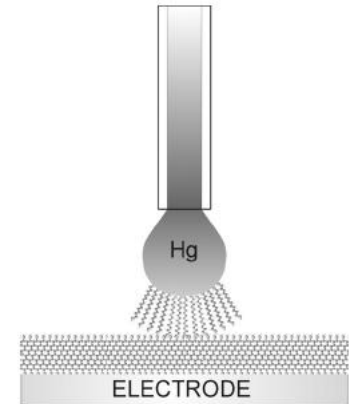
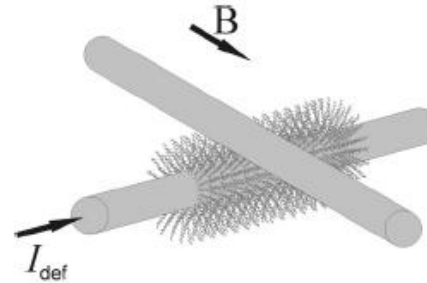
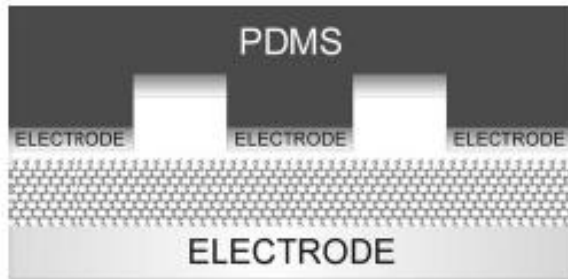
# Break Junction



# STM: Quantized Conductance



# Other Test Beds





# Summary and Prospect

## Summary

- MMM Junction used in conductance measuring
- STM and Break Junction Experiment

## Prospect

- Many Research have been done on single molecule transistor, however, molecule conductance properties are not well understood
- Many Research try to perform molecule memory and nanocell circuits, expect to utilized it on nanocomputer in the future

