Marrying Reaction Chemistry to Surfaces

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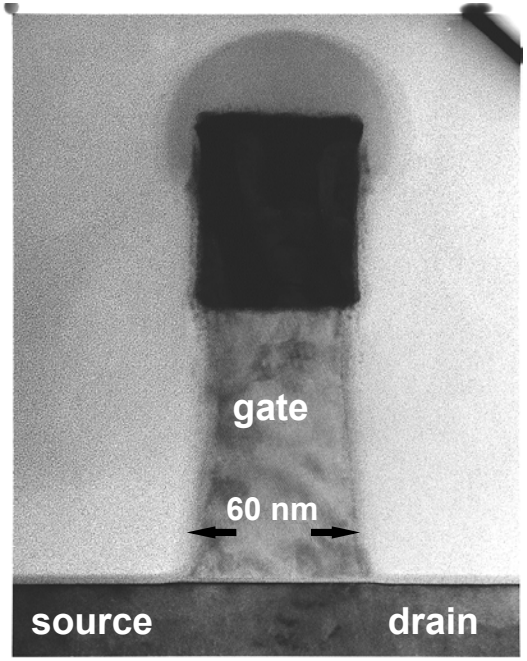
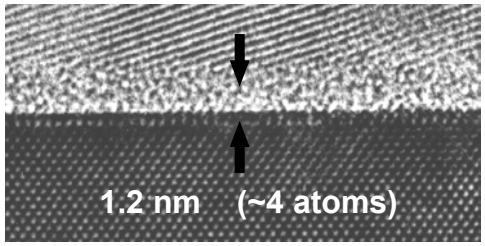
NNI-Washington
June 17, 2005

Electronics: Smaller, faster, and cheaper

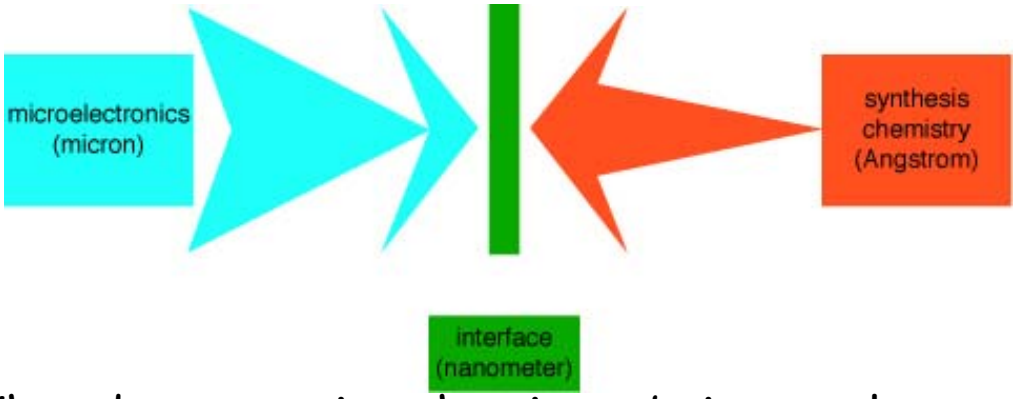




A real Field Effect Transistor

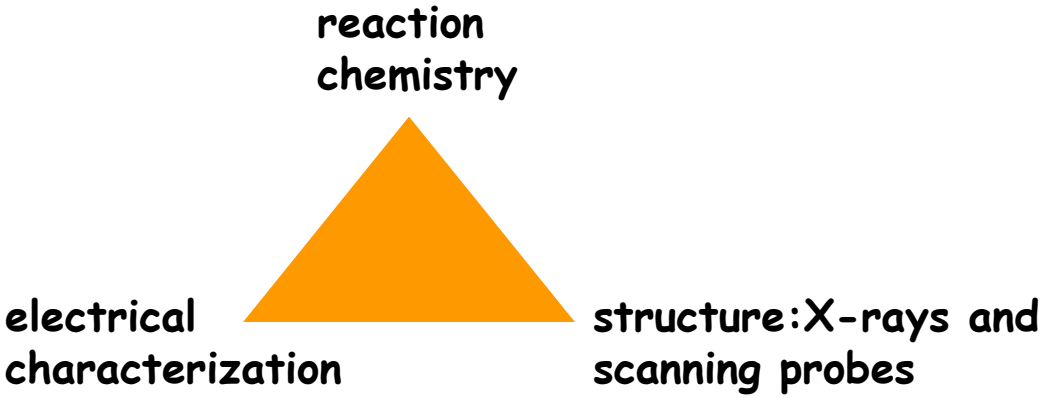
Next Generation of Devices will be a Network of Interfaces

The Nexus of Fabrication and Synthesis is Interfaces

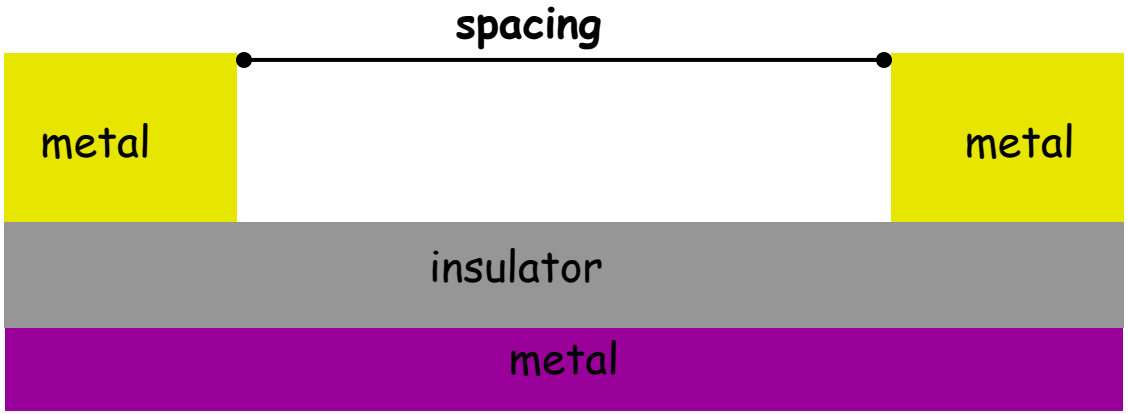


What does reaction chemistry bring to electronics?

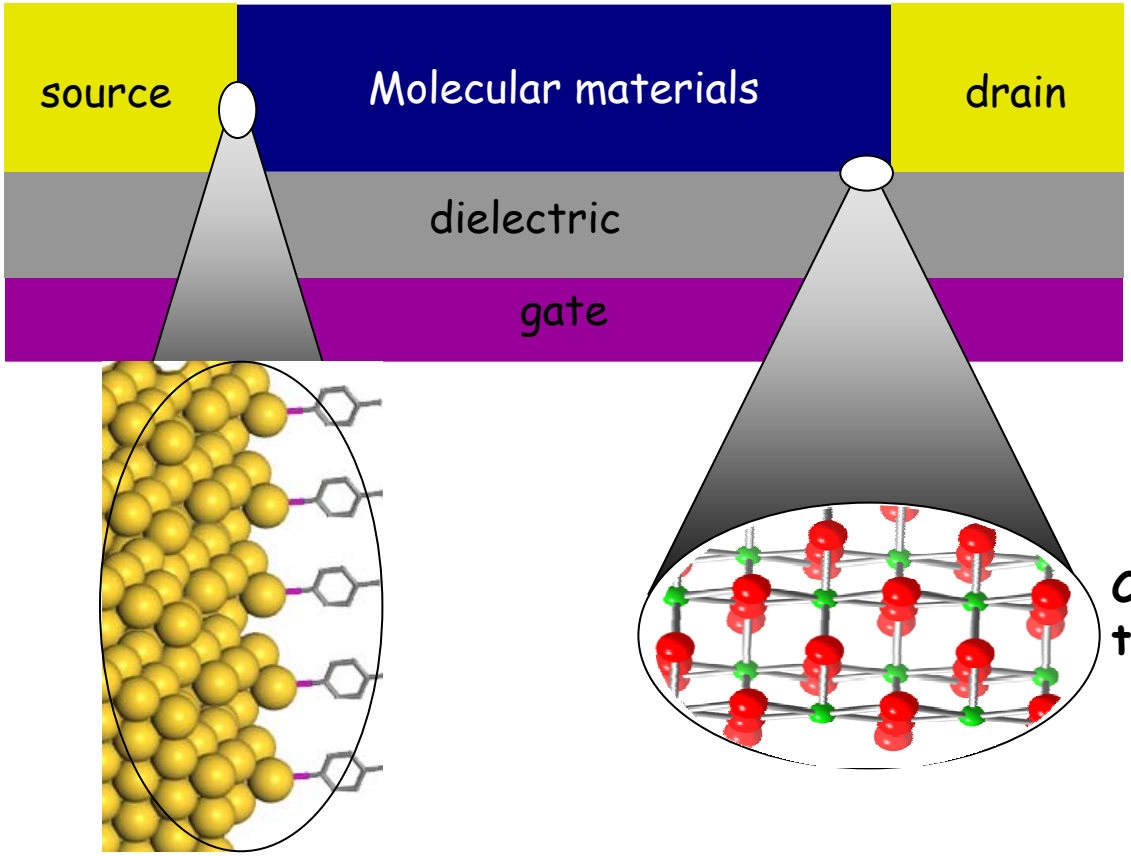
- Self-assembly: programmed complexity
- Recognition
- Programmed reactivity (growth and in-plane):
- Functionality



Integrating Reaction Chemistry with Devices

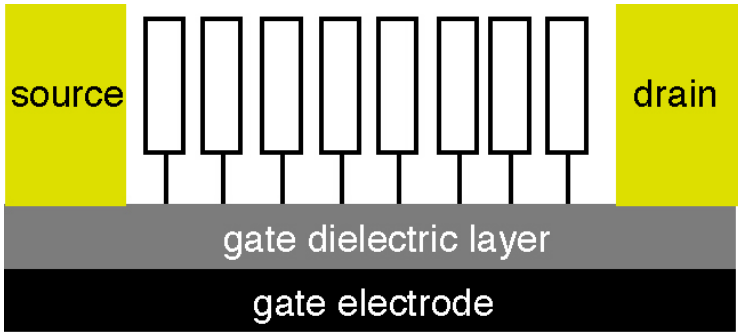


A diverse set of materials available: metals, semiconductors, and oxides
A range of sizes: atoms to centimeters
A sensitive reporter for assembly: *nothing* more sensitive
A sensitive reporter for chemical reactions
Technology: thin film, molecular, and hybrid devices



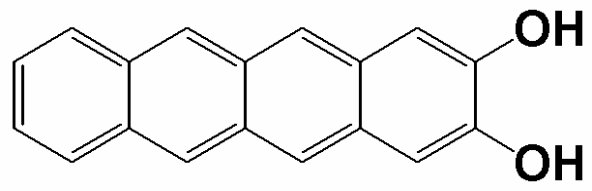
Can we synthesize this interface?

Strategy



Covalently Attached Monolayers

Self-Assembly on High K-Dielectrics



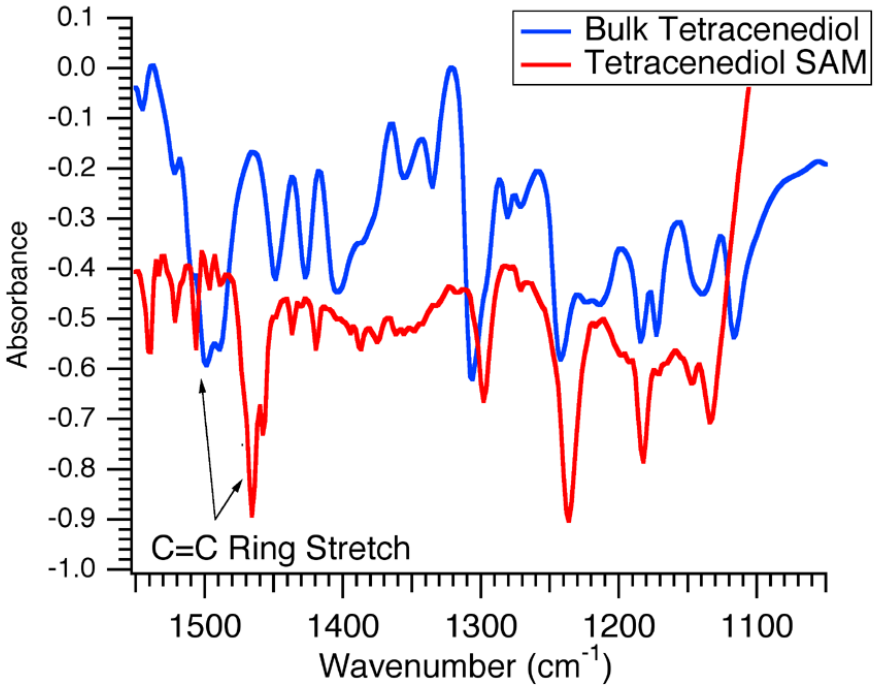
THF solution with
Al_2O_3 Surface

Water Contact Angle:
Advancing = 76°
Receding = 63°

XPS

	15°	35°	70°
O	31.4	36.4	41.2
C	47.1	36.3	26.2
Al	21.4	27.2	32.5
C/Al	2.20	1.34	0.81

IRRAS Measurement

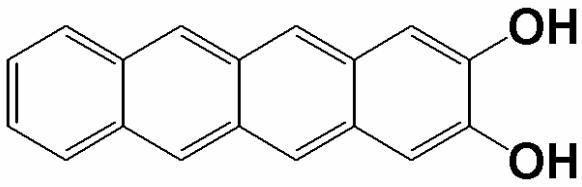


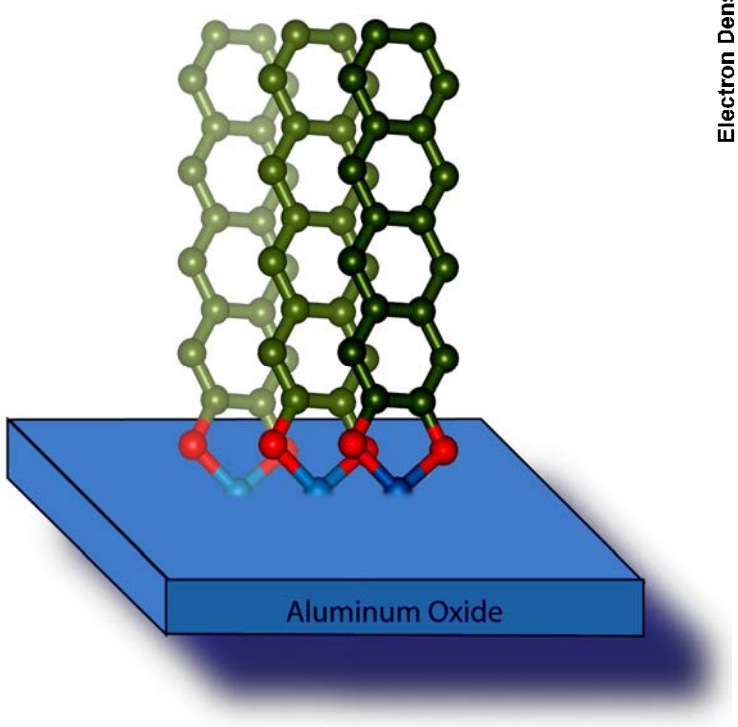
Ellipsometry:
Measured Thickness =14.8 Å
Calculated: 14 Å

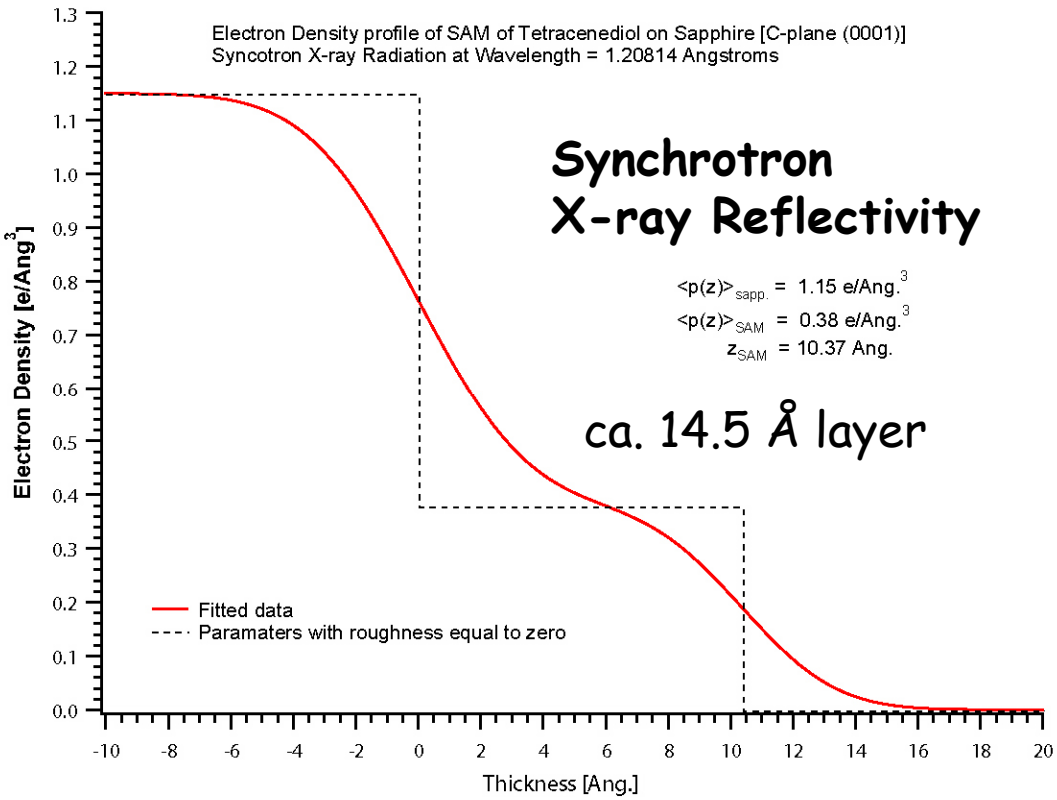
Also: HfO_2, ZrO_2, and Y_2O_3

George Tulevski and Qian Miao

Monolayers on sapphire crystals







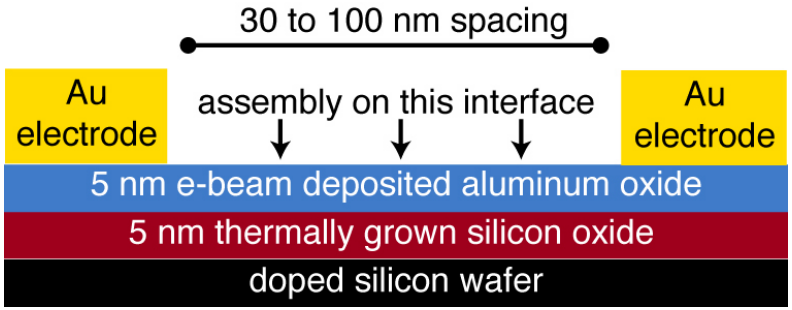
<u>electron density</u>

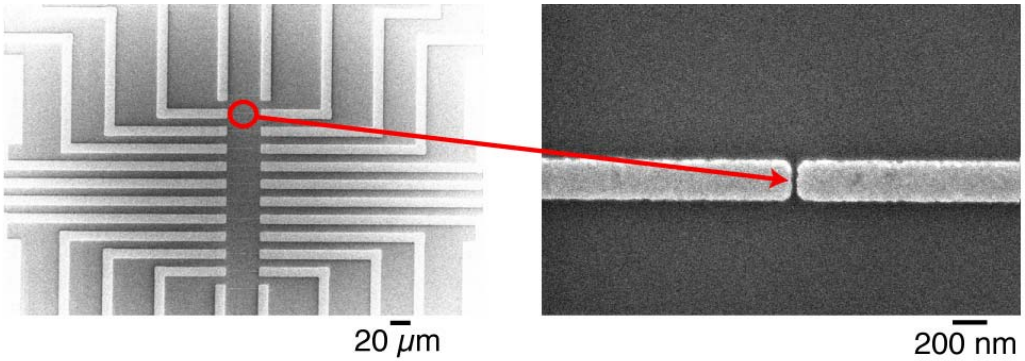
0.38 $e^-/Å^3$ for monolayer

0.39 $e^-/Å^3$ for tetracene crystal

Columbia: George Tulevski, Qian Miao, **BNL:** Masafumi Fukuto, Ben Ocko, Ron Pindak, **IBM:** Cherie Kagan

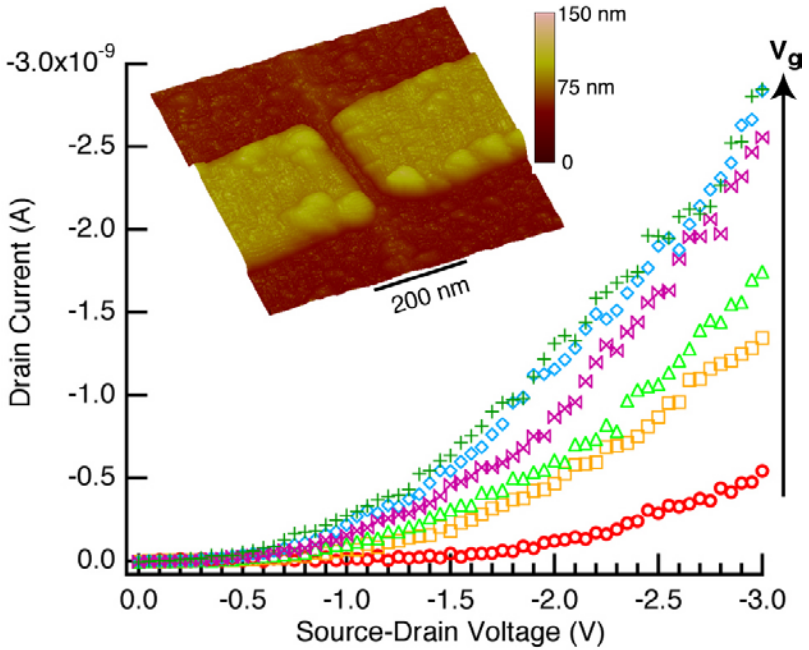
Monolayer devices





500 sets on an 8" wafer

0.5 V steps



Yield: 42/80 devices ≤ 60 nm source-drain
Much lower > 60 nm
Grains of Al_2O_3 are ca. 40 nm in diameter
Control experiments: catechol and naphthalene

40 nm device ~40,000 molecules

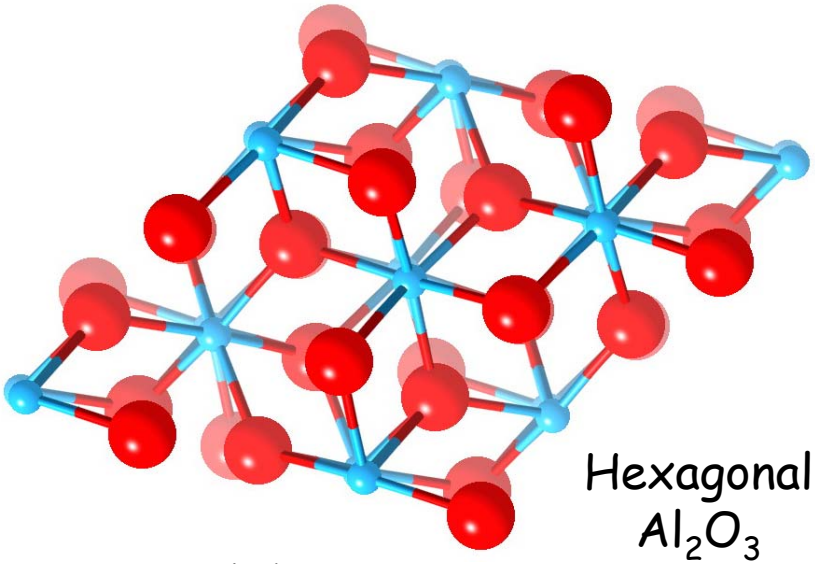
George Tulevski, Qian Miao, Cherie Kagan (IBM)

The next step: tune the three interfaces

Source/Drain:
Metal
Derivatized

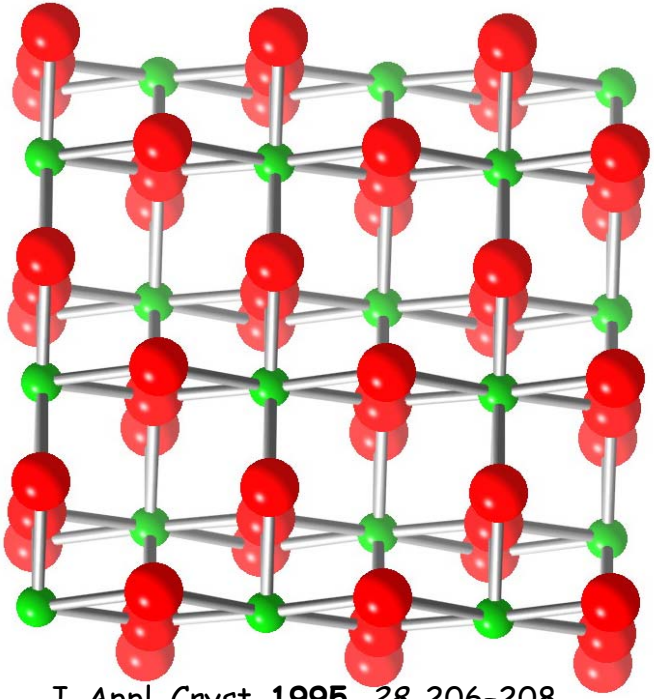
Gate dielectric:
Aluminum oxide
Hafnium oxide
Zirconium oxide
Crystalline

Viewing down the z-axis of Al_2O_3 and ZrO2



Hexagonal
Al_2O_3

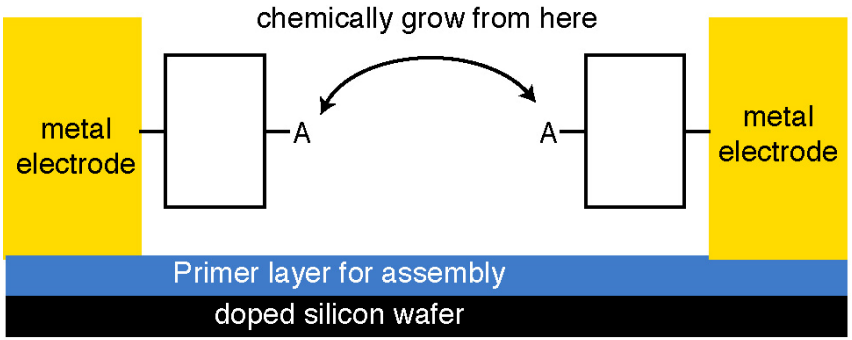
J. Appl. Phys. **1978**, *49*, 5823.

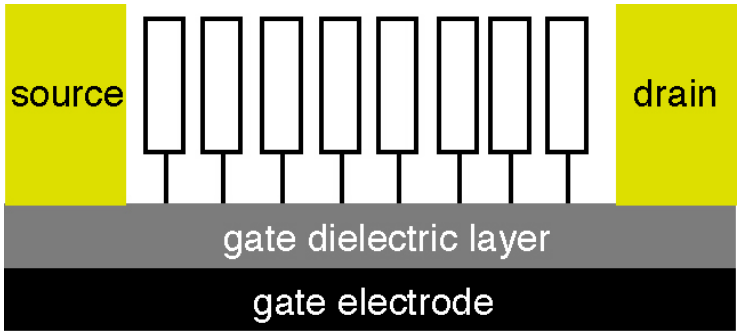


tetragonal
ZrO_2

J. Appl. Cryst. **1995**, *28*, 206-208

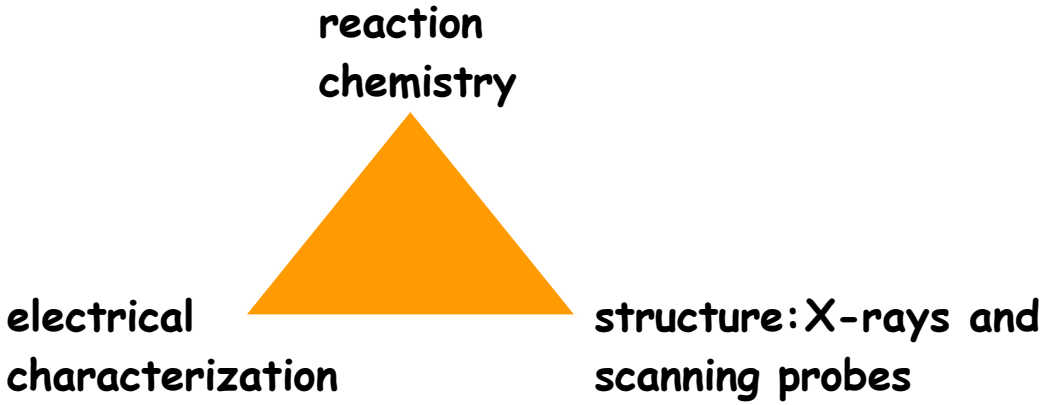
Marry the two approaches



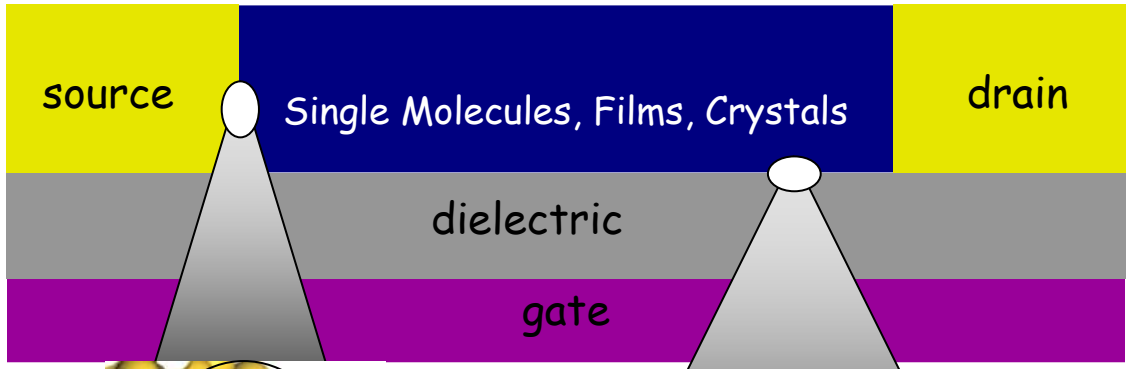


In situ chemical reactions

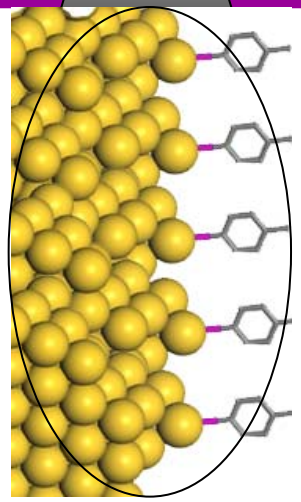
Synthesis of interfaces

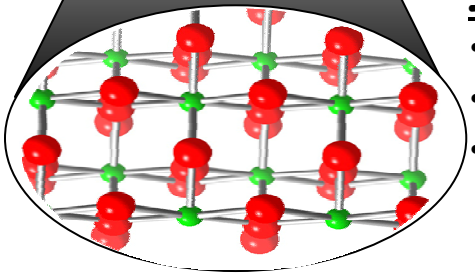


Interfaces



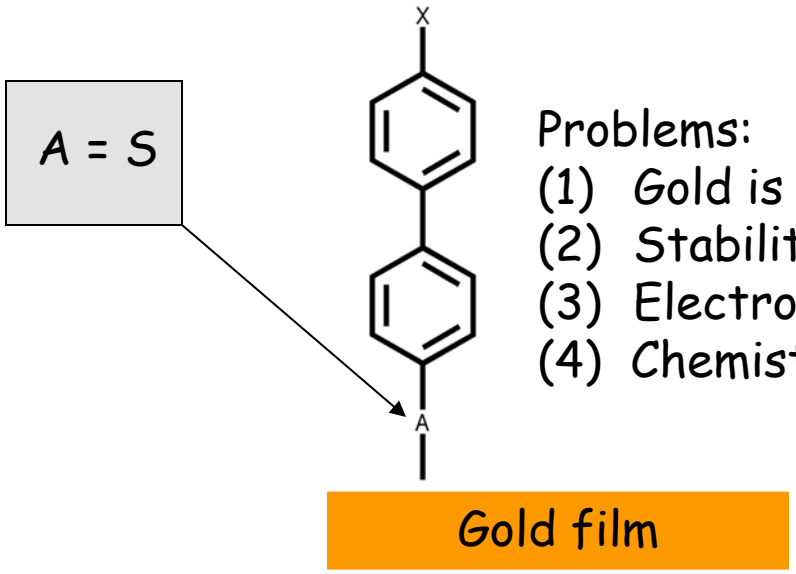
Metal-Molecule Linkage
- CONTACT!
- Order
- Functionality:
  growth, recognition





Interfacial Assembly
- crystalline vs. glassey
- epitaxial growth
- multicomponent films

Are there alternatives to thiol/gold?



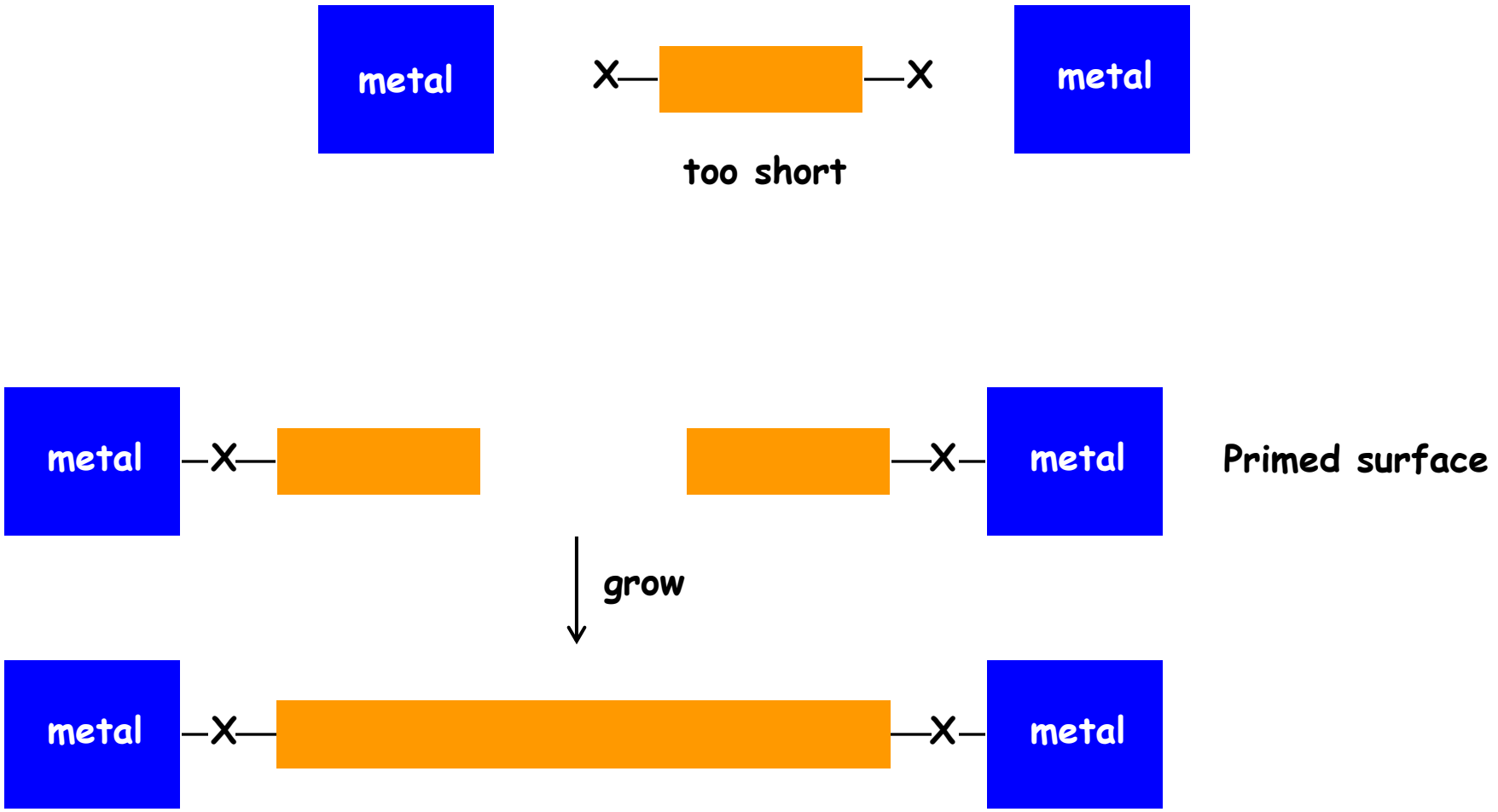
Problems:

(1) Gold is soft and mobile
(2) Stability
(3) Electronics: an insulating link
(4) Chemistry is limited with gold

What do we want?

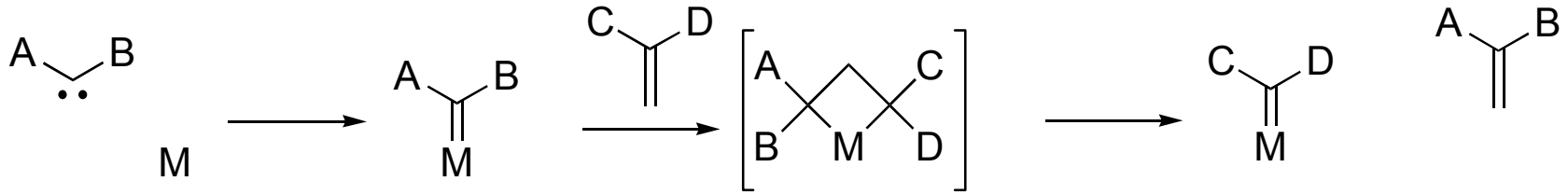
Strong
Chemically Stable
Transparent
Catalytic

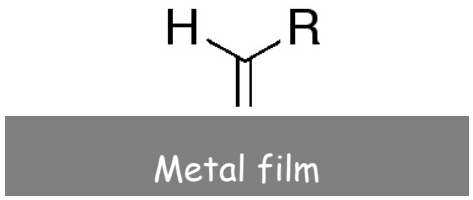
We need to be able to vary the length
Catalytic junctions--growth



Metal-Carbon Multiple Bonds

What do we want?
Strong
Chemically Stable
Transparent
Catalytic

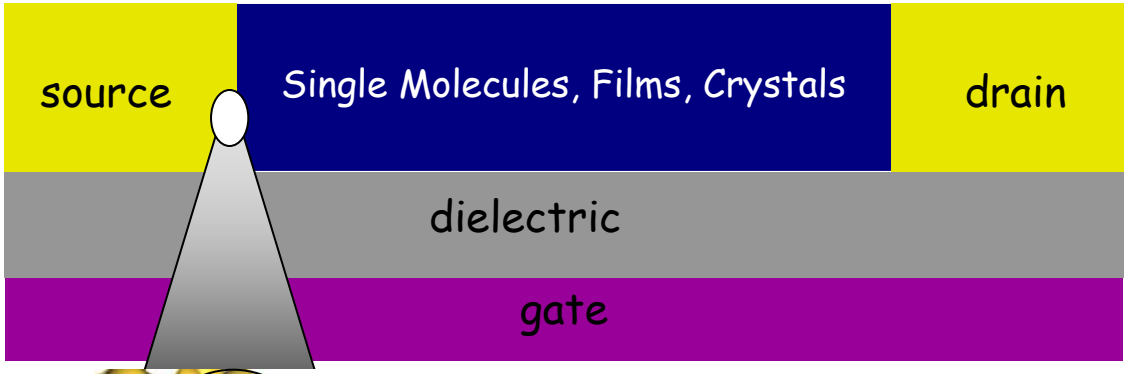


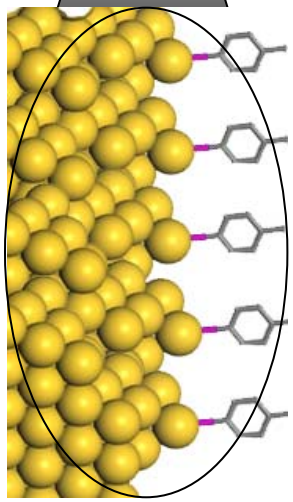


Questions:

Stability?
Which metals are best?
Which carbene substituents ?
What precursor?

Tools that are needed in the toolkit





Metal-Molecule Linkage

- CONTACT!
- Order
- Functionality:
  growth, recognition

Need better tools to interrogate these!

Acknowledgements

Nuckolls Group

Graduate Students

Katherine Allen
Chaya Ben-Porat
Mark Bushey
Matt Carnes
Dana Horoszweski
Jennifer Klare
Michael Lefenfeld
Qian Miao
Matt Myers
Rachel Steiner
Jinyao Tang
Noah Tremblay
George Tulevski
Yiliang Wang
Adam Whalley
Shengxiong Xiao
Wei Zhang

Post-Docs

Bassam Alameddine
Xiang-Zheng Bo
Xuefeng Guo
Sebastien Sanaur

Undergraduates

Tucker Roberts
Terence Choy
Abby Maller

Collaborators

- Dr. Mike Steigerwald, Dr. Mark Hybertsen, Prof. Louis Brus (Columbia)
- Hayn Park and Prof. Tony Heinz (Columbia)
- Gina Florio, Michelle Pasamba, and Prof. George Flynn (Columbia)
- Dr. Jochen Ulrich, Prof. Horst Stormer (Columbia)
- Dr. Cherie Kagan (IBM)
- Dr. Art Ramirez, Dr. Christian Kloc, Dr. Theo Siegrist, Dr. Robert Willett (Columbia/Lucent)
- Dr. Graciela Blanchet (DuPont)

Funding:

- **Alfred P. Sloan Foundation**
- **Camille and Henry Dreyfus Foundation**
- **Dupont Young Investigator**
- **Beckman Young Investigator**
- **J. D. Watson Investigator NYSTAR**
- **National Science Foundation**
  - Nanoscale Exploratory Research Grant
  - CAREER Award
  - **Nanoscience Center at Columbia University**
  - MRSEC at Columbia University
- **U. S. Department of Energy** Nanoscience Initiative
- **American Chemical Society**, Petroleum Research Fund