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Introduction to the

Laboratory for Surface Modification

and

Experimental Measurements of Band Alignment

R.A. Bartynski

Director, Laboratory for Surface Modification
Rutgers University
Department of Physics and Astronomy
136 Frelinghuysen Road,
Piscataway, NJ 08854

PPPL June 09

Laboratory for Surface Modification

NanoPhysics Laboratory

Laboratory for Surface Modification (LSM)

A Cross-disciplinary Laboratory at Rutgers University

www.physics.rutgers.edu/LSM

The LSM:
a multi-departmental group of researchers, centered in the Rutgers NanoPhysics Laboratory, whose primary mission is to promote research and education in the science and technology of surfaces and interfaces

Faculty Membership

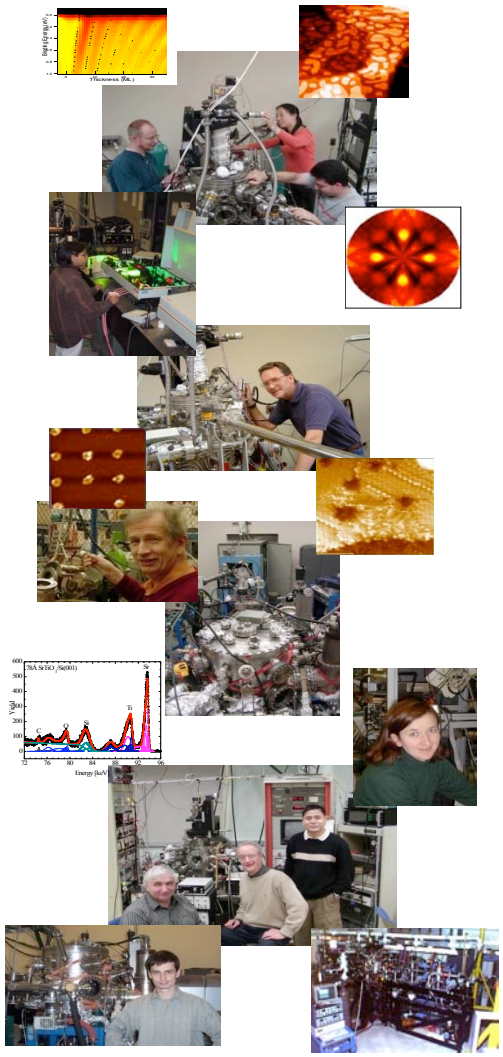
- Physics & Astronomy – Bartynski (Director), Feldman, Gustafsson, Langreth, Madey, Vanderbilt, Zimmermann
- Chemistry and Chemical Biology – Garfunkel, Hinch, Uhrich
- Electrical and Computer Engineering – Lu, Zhao
- Material Science – Birnie, Chhowalla, Cosandey, Garofalini, Klein
- Chemical and Biochemical Engineering – Moghe

Impact

- Education & Outreach
  (Grad, UGrad, HS, Seminars, Symposium, IGERT)
- Telecommunications
- Micro- and nano-electronics
- Catalysis and Chemicals
- Pharmaceuticals
- Sensors
- Biomaterials
- Coatings

Facilities

Leading national surface analysis facilities. Unique instrumentation for ion scattering, electron stimulated desorption, surface optical spectroscopy, scanning probe microscopy, film growth with in-situ characterization



Research Focus Areas

Surface Physics

- Surface, interface and ultrathin film characterization
- Accurate determination of surface composition, structural, electronic, vibrational and optical properties.

Surface Chemistry and Catalysis

- Surface functionalization
- Organic-inorganic interfaces
- Structure sensitivity of reactions

Theory and Computation

- First principles electronic structure
- Fundamental theory development
- Monte Carlo, molecular dynamics….

Nanoscience

- NanoElectronics
- NanoSpintronics
- NanoPhotonics
- NanoCatalysis
- Molecular Electronics

Advanced Materials & Devices

- Electronic Materials
- Organic Electronics
- Novel Epitaxial Oxides

Energy Materials

- Dye sensitized Solar cells surface passivation
- Organic-inorganic nanowire hybrids
- Single crystal organics
- Energy storage materials

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Facilities

Laboratory for Surface Modification, Rutgers University

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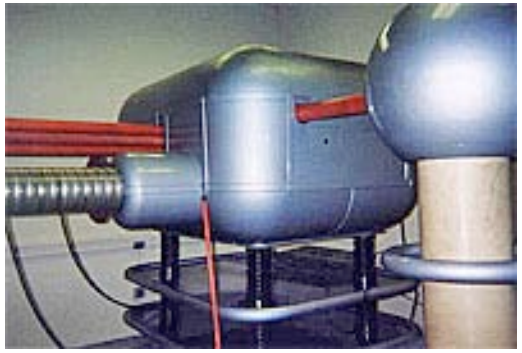
Medium Energy Ion Scattering (MEIS)/Thin Film Growth and Characterization Facility:

- 400 KeV ion scattering with toroidal electrostatic energy analyzer for high energy and angular resolution
- Atomic layer-resolved depth profiling
- in-situ ALD w/FTIR characterization
- Additional growth and characterization modules



Rutherford Backscattering Spectrometry:

- 2 MeV tandetron accelerator with multiple Si detectors
- Elemental depth profiling w/ 10 nm resolution
- H recoil scattering
- Additional growth and characterization modules

Direct and Inverse Photoemission Facility:

- Probes both occupied (valence band) and unoccupied (conduction band) states of sample in single chamber
- Rapid load-lock
- in-situ metallization and gas-dosing capabilities
- Additional surface characterization / surface prep.

Facilities

Laboratory for Surface Modification, Rutgers University

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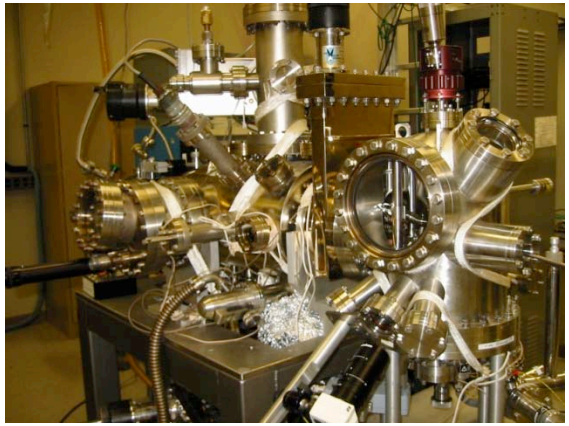
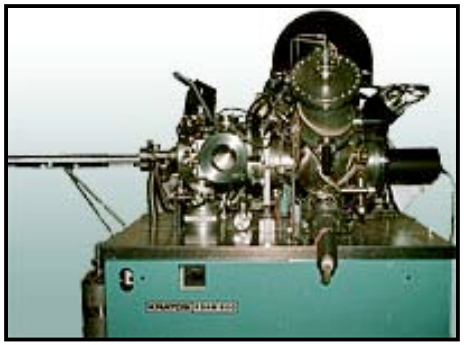
Scanning Probe Microscopy

- Variable temperature STMs
- Atomic Force Microscopes
- MFM, Spin polarized STM
- Low T/High H STM



ESCA Facility

- KRATOS machine
- Rapid sample intro
- Sample prep with UHV sample transfer
- Multiple sample capability



Scanning Transmission Electron Microscopy:

- JEOL 2010F / GATAN
- Field emission source
- EELS
- 1.7 Å resolution

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Facilities

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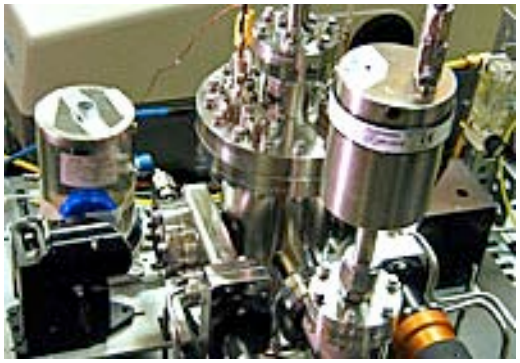
Atomic Layer Deposition (ALD)

- Layer-by-layer conformal growth
- Oxide film growth
- In-situ FTIR characterization
- Si, Ge, GaAs substrates



Oxide MBE

- Atomic layer epitaxial growth
- Metastable oxide systems
- UHV sample transfer
- Multiple source

MOCVD

- Conformal oxide coatings
- ZnO and TM precursors

VLS

- Ge nanowire synthesis

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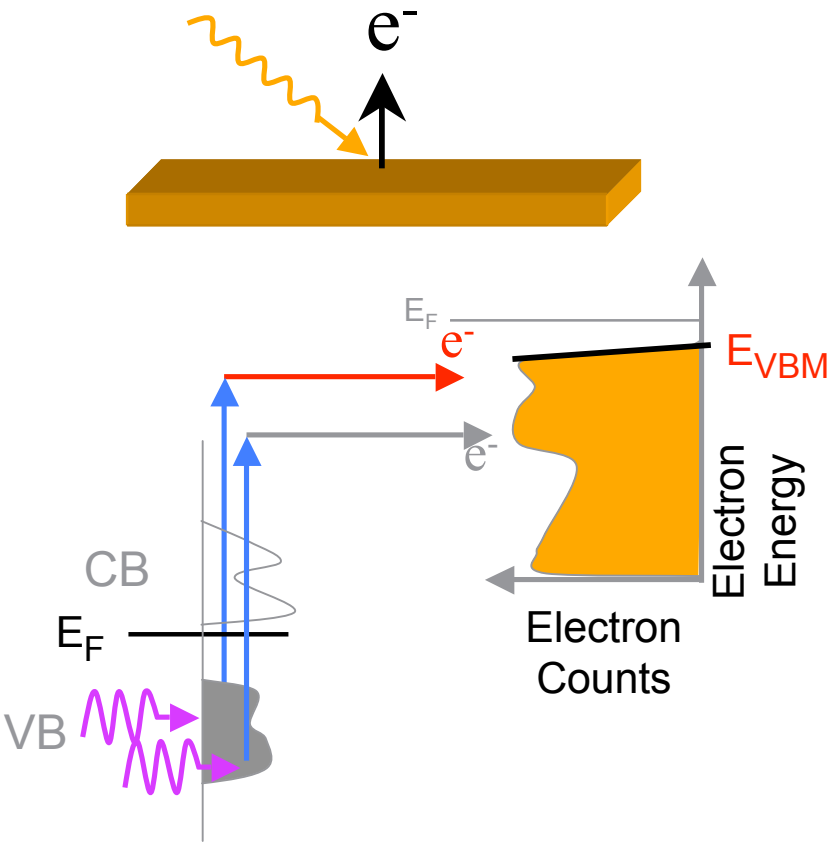
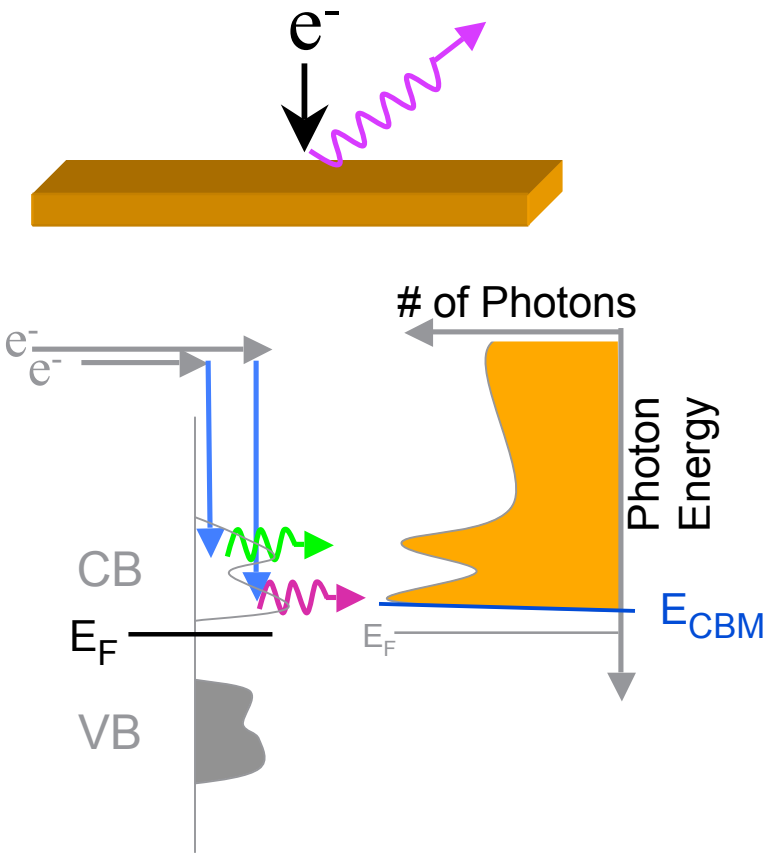
Probing Energy Level Alignment with Direct and Inverse Photoemission

Experimental Principle

Photoemission
(Occupied States)



Inverse Photoemission
(Unoccupied States)



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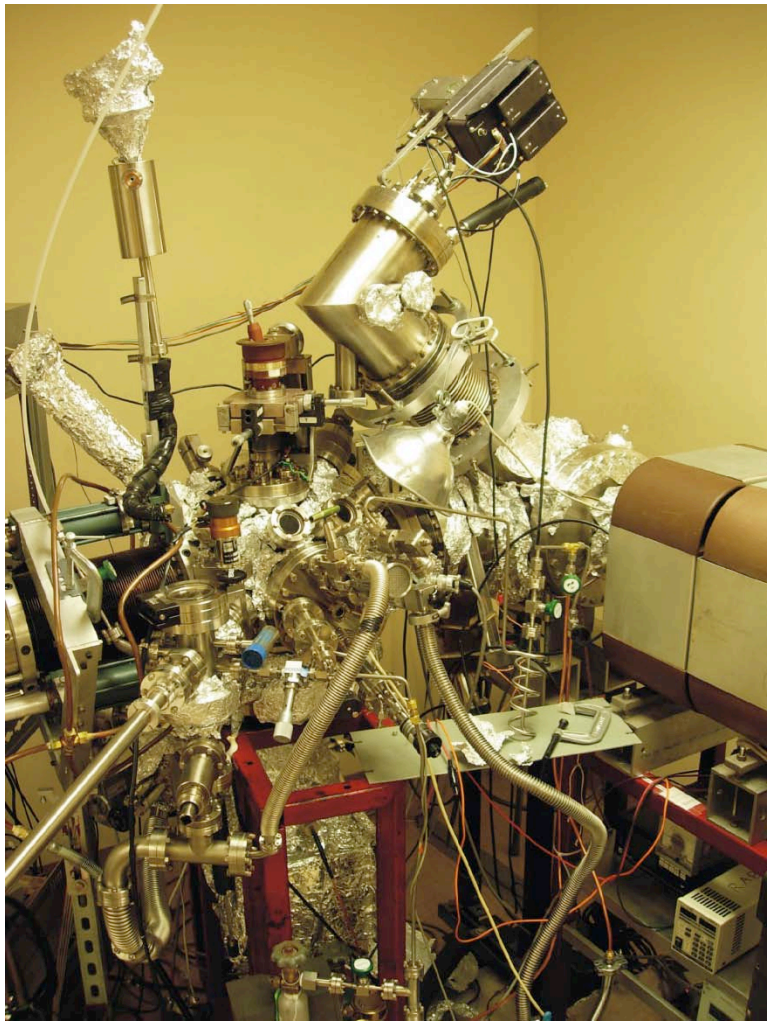
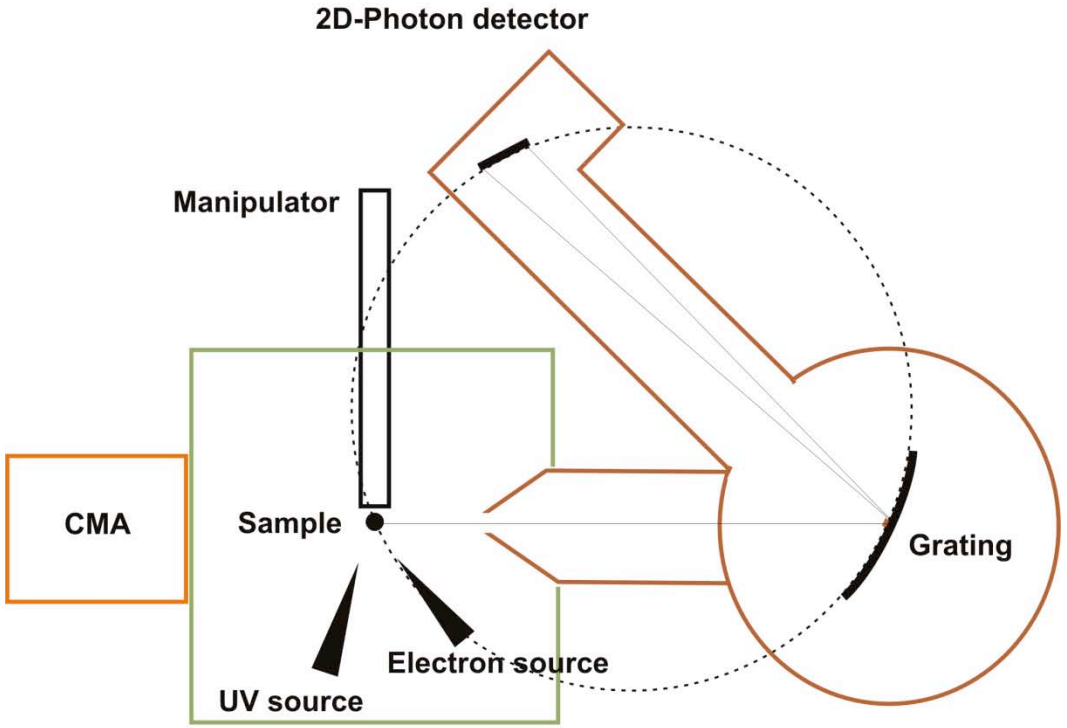
Experimental tools





UPS, IPS in single UHV chamber

Metallization, gas dosing, Auger, LEED, sputtering, rapid sample intro

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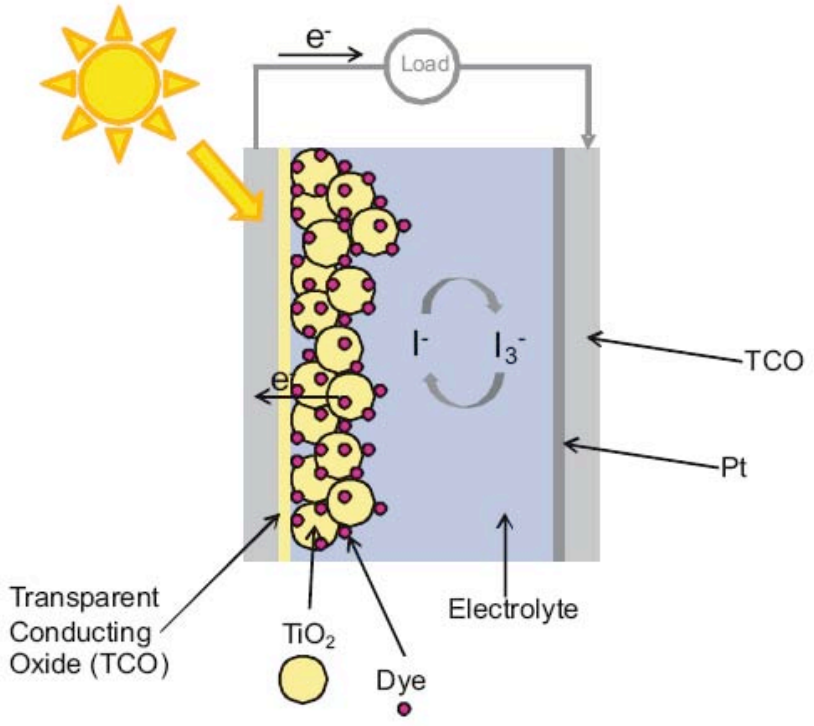
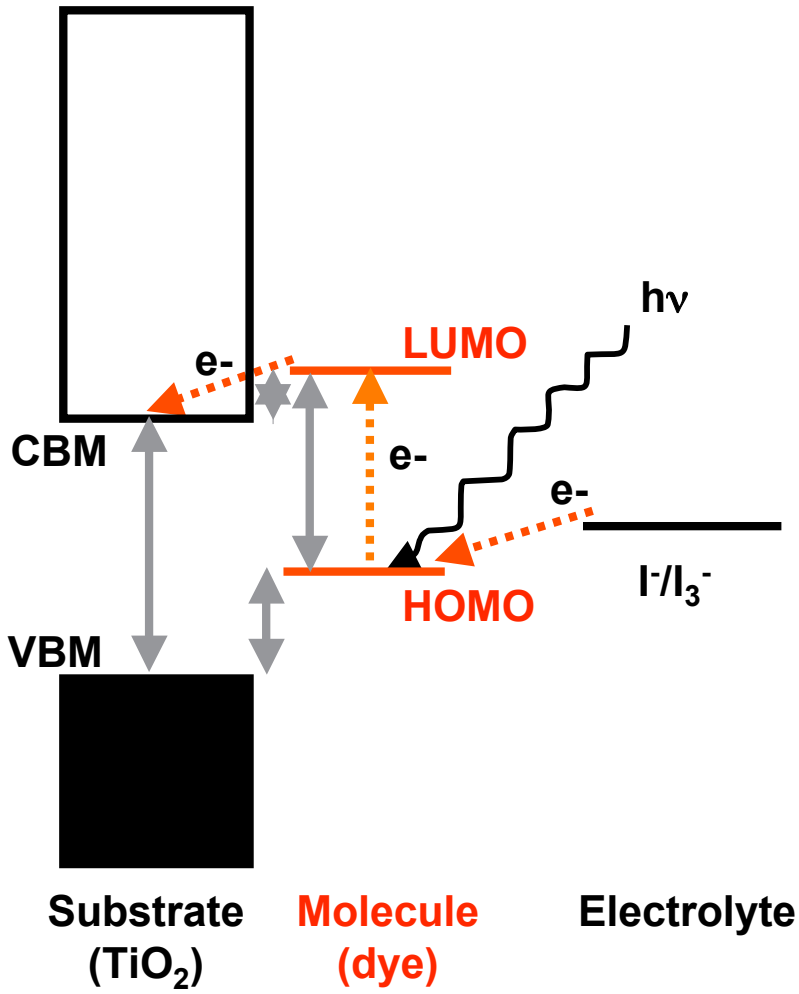
Energy level alignment of dye molecules at oxide surfaces for dye-sensitized solar cell applications

A Dye Sensitized Solar Cells (DSSCs)

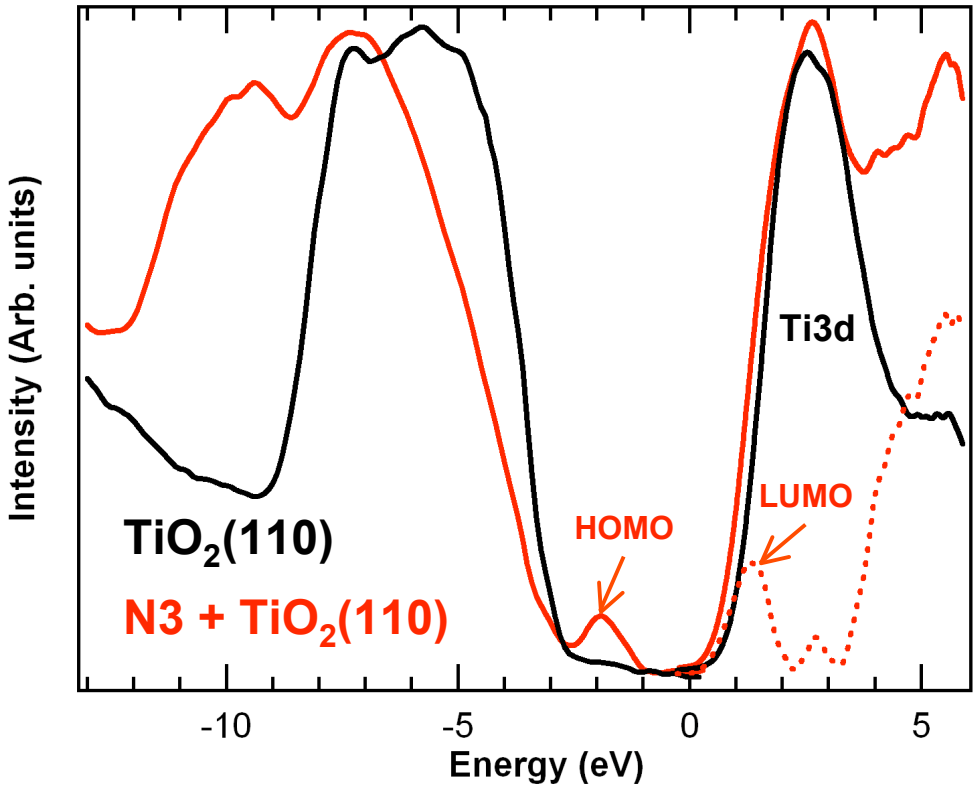
DSSC

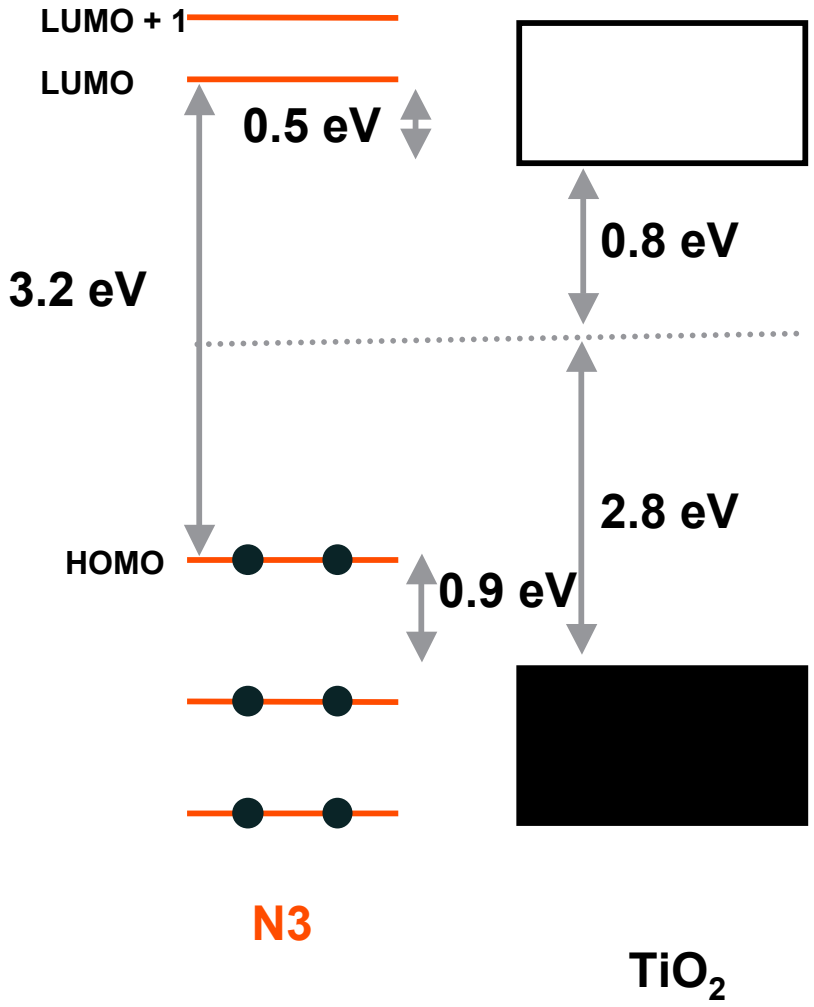


Energy Schematic



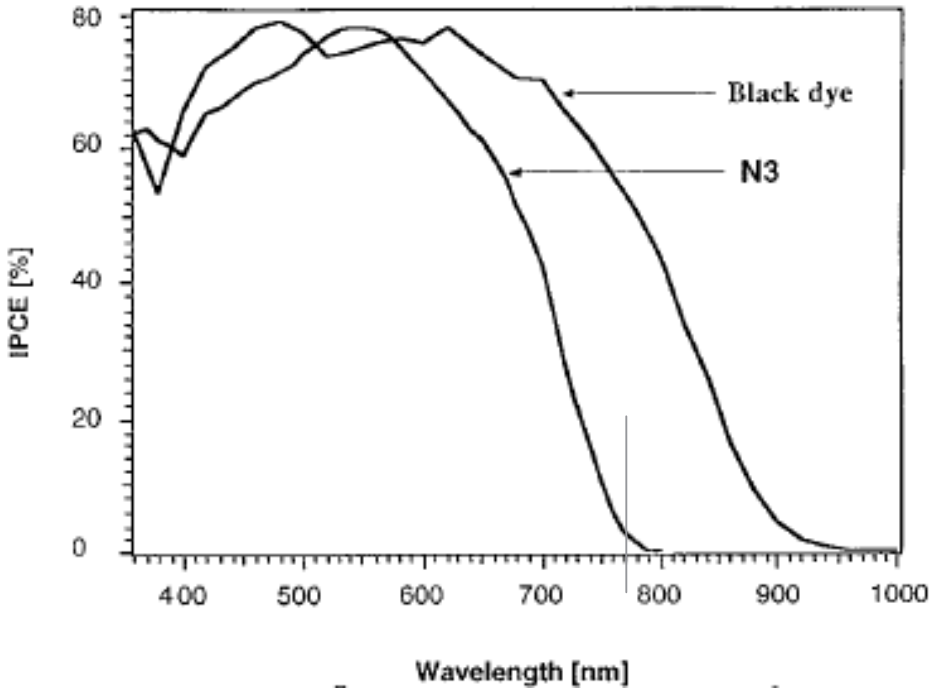
Energy Level Alignment

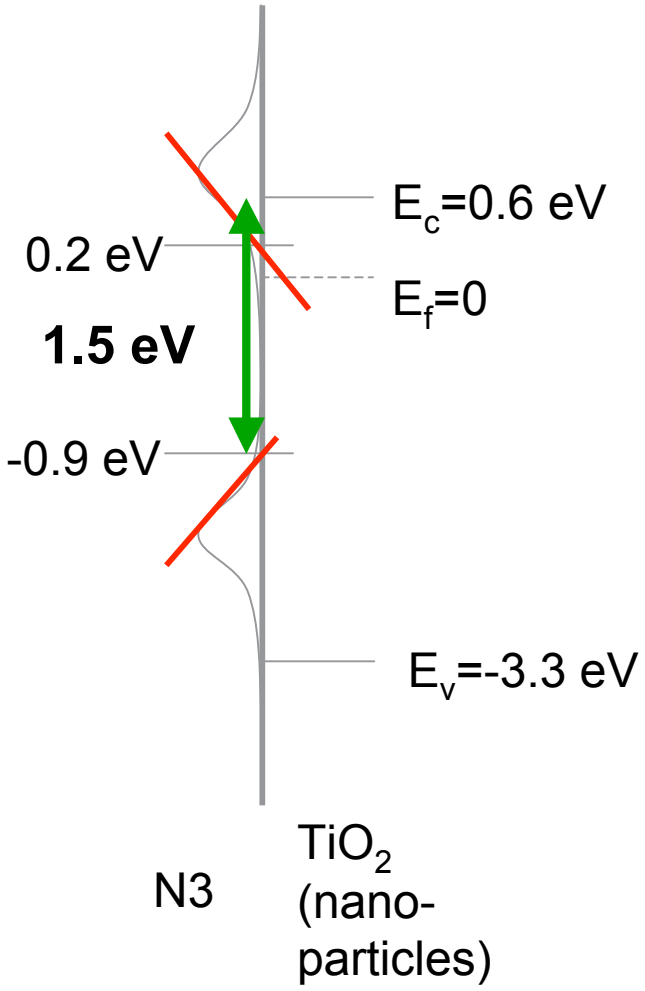




Comparison with DSSC Operation

IPCE vs. E
(Incident Photon to Current Efficiency)





Minimum photon energy that produces current (1.6 eV)

Gratzel et al., Progress in Photovoltaics, 8 (2000) 171

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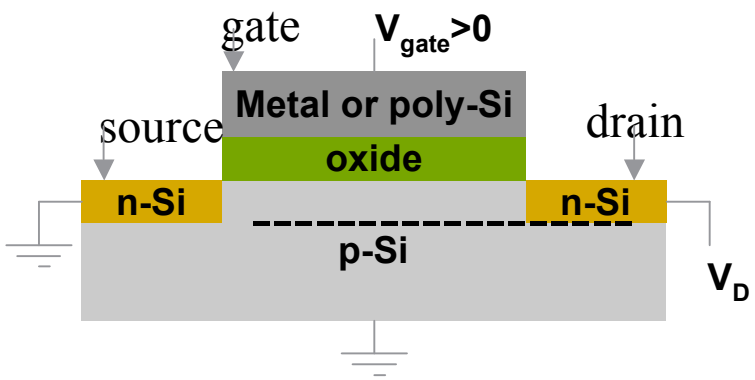
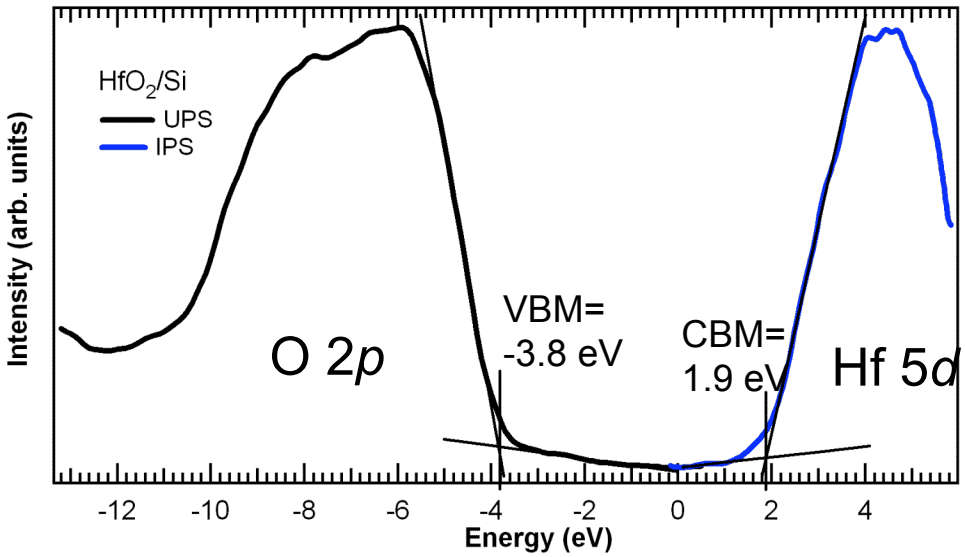
Band alignment in Metal / high-κ / Semiconductor gate stacks

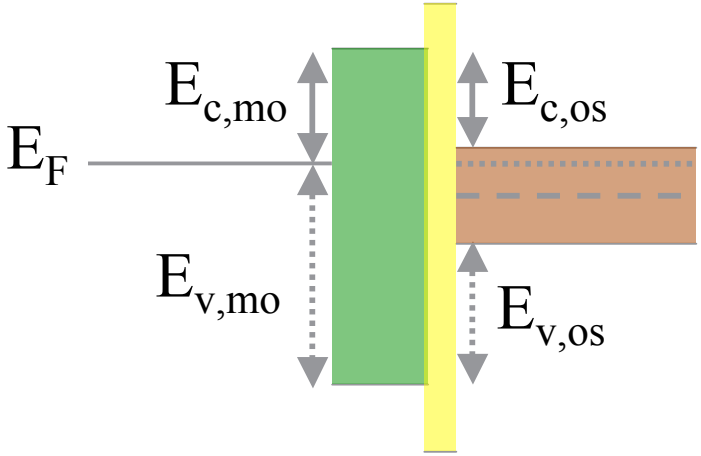
Movitation

MOSFET



metal high-κ SiO_2 Si





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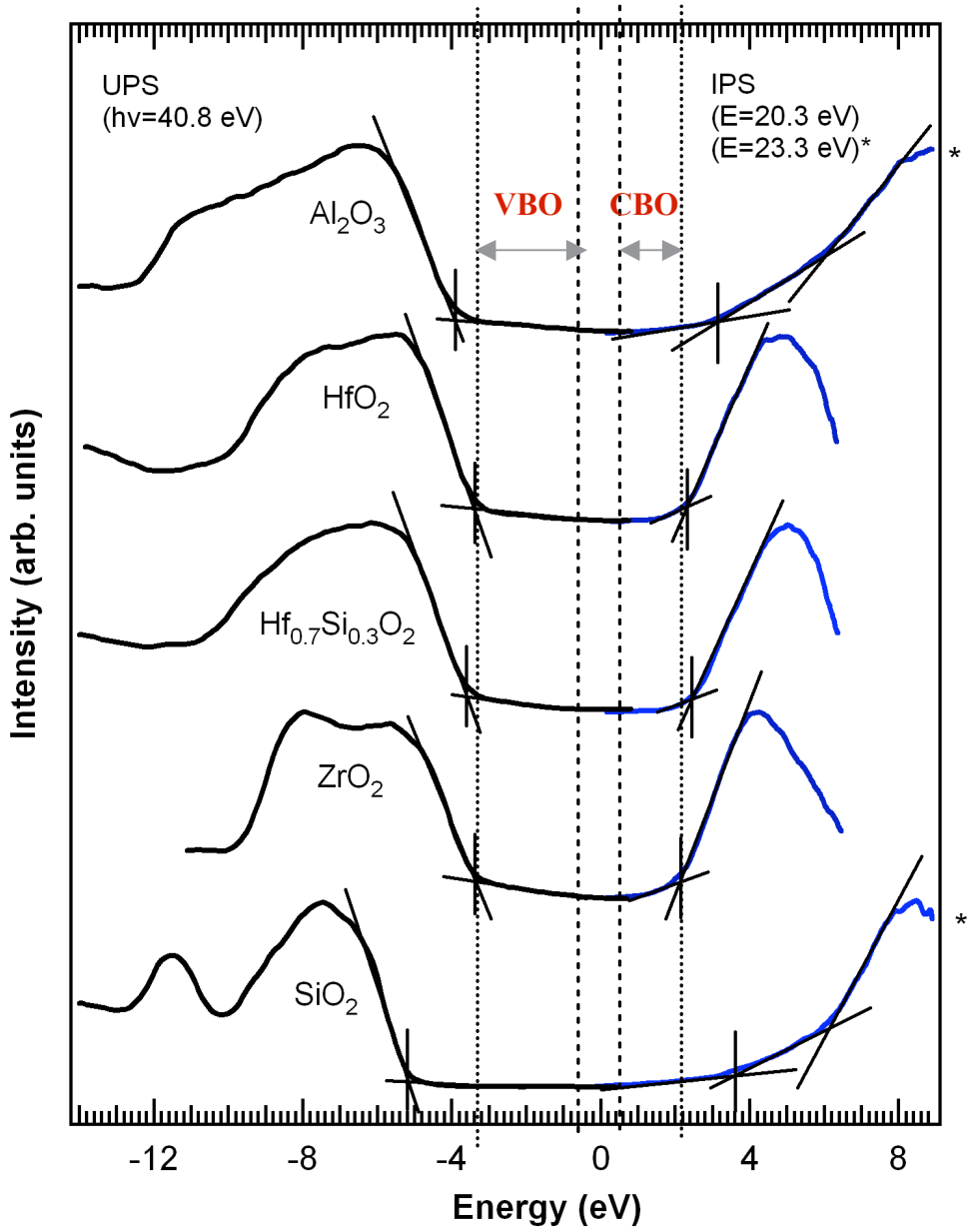
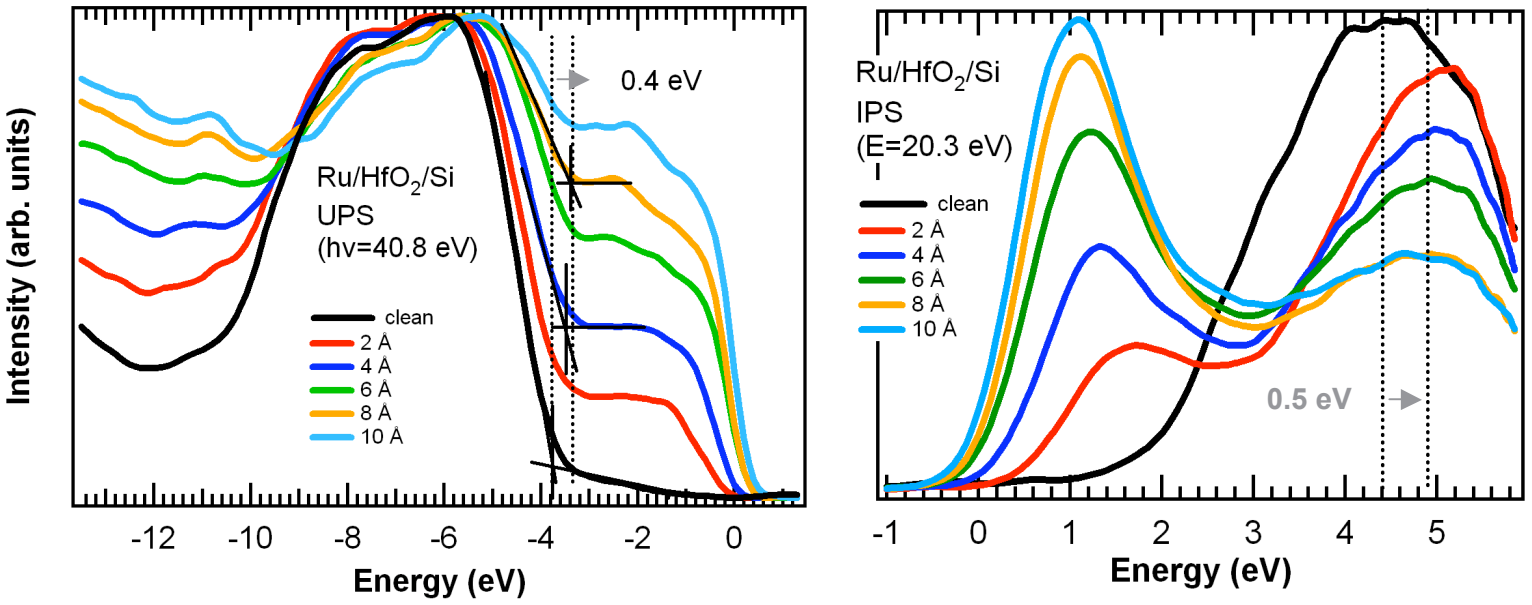
Summary: Oxide-Si Band Offsets



Experimental CBO: Ru/HfO_2



Experimental Ru-HfO_2 CBO:

$$CBO = CBM + E_s$$

$$CBO = 1.9\ eV + 0.5\ eV$$

$$CBO = 2.4\ eV$$

IGS Ru-HfO_2 CBO:

$$CBO = 2.5\ eV$$

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THANKS !!!

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END