Reactive Interfaces for Functional Surfaces
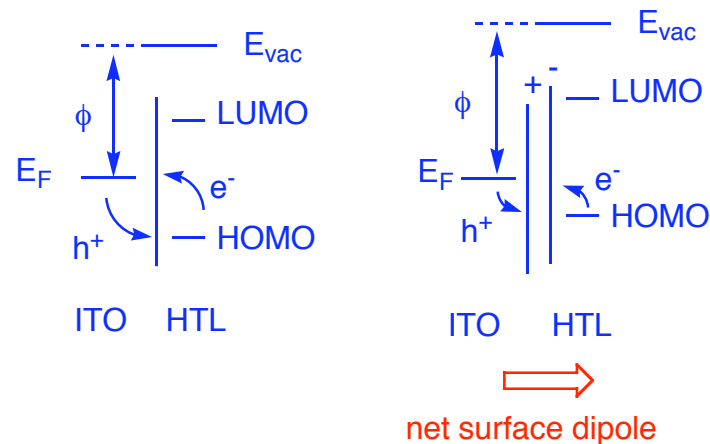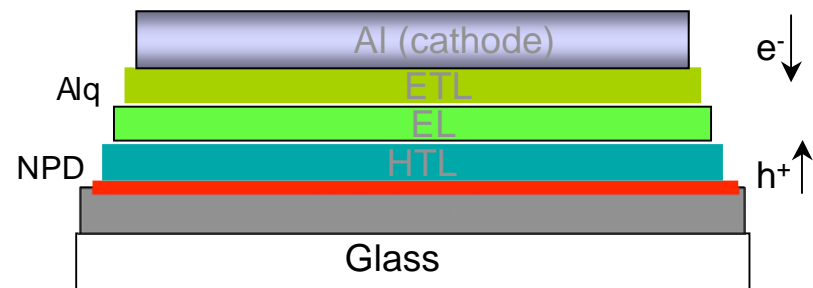
Surface Modification of Electronic Materials:

Controlling Device Properties at the Molecular Level

Surface Modification
to Control the Properties of Electronic Materials

Indium tin oxide (ITO), a common anode material for optoelectronic devices such as OLEDs.

• Barriers to charge transport exist at the interfaces between materials.

• A dipolar layer at the ITO surface oriented "away" should increase the ITO work function, ϕ, and reduce the hole injection barrier.
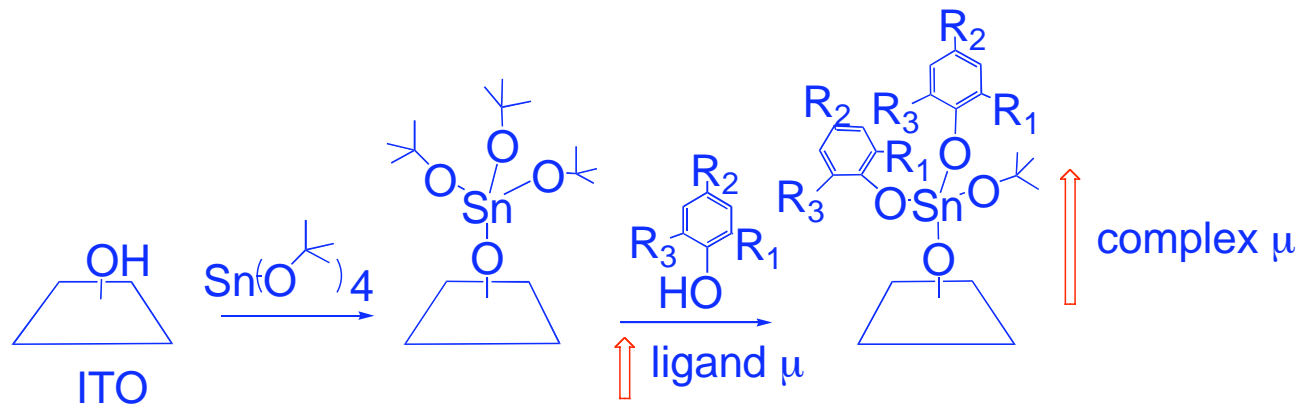
Ishii; Sugiyama; Ito; Seki *Adv. Mater.* **1999**, *11*, 605

Al (cathode)
ETL
EL
HTL

Alq
NPD
Glass

e^-
h^+

E_{vac}
ϕ
LUMO
E_F
e^-
h^+
HOMO
ITO   HTL

E_{vac}
ϕ
+ -
LUMO
E_F
h^+
e^-
HOMO
ITO   HTL

net surface dipole

How can we use molecular properties
to introduce and control this dipole systematically?

# ITO Surface Modification with Tin Complexes

The change in work function correlates with the total surface dipole

The total surface dipole depends on the loading density of surface complexes and the dipole moment of each complex:

• Good news: The dipole moment of the surface complex depends on the dipole moment of the ligand precursor;

• Bad news: The loading density is limited by the number of surface OH groups and the size of the tin reagents (0.2 nmol/cm^2).

Enhanced Behavior of Light-Emitting Diode Devices Correlates with Surface Complex Dipoles

current

volts

CF$_3$

F$_3$C

O

O·Sn·O

O

O

ITO

untreated ITO

A

B
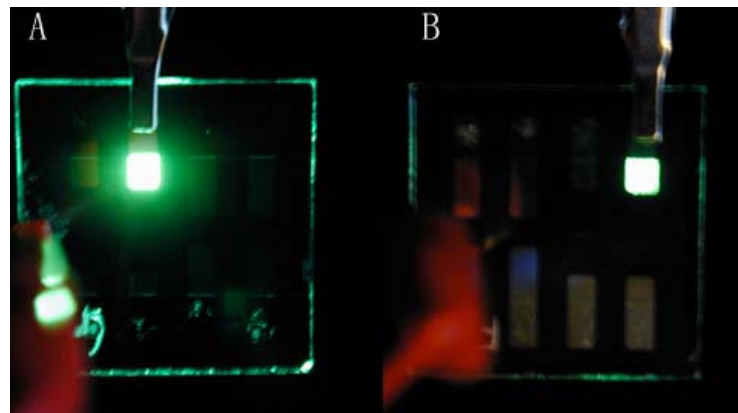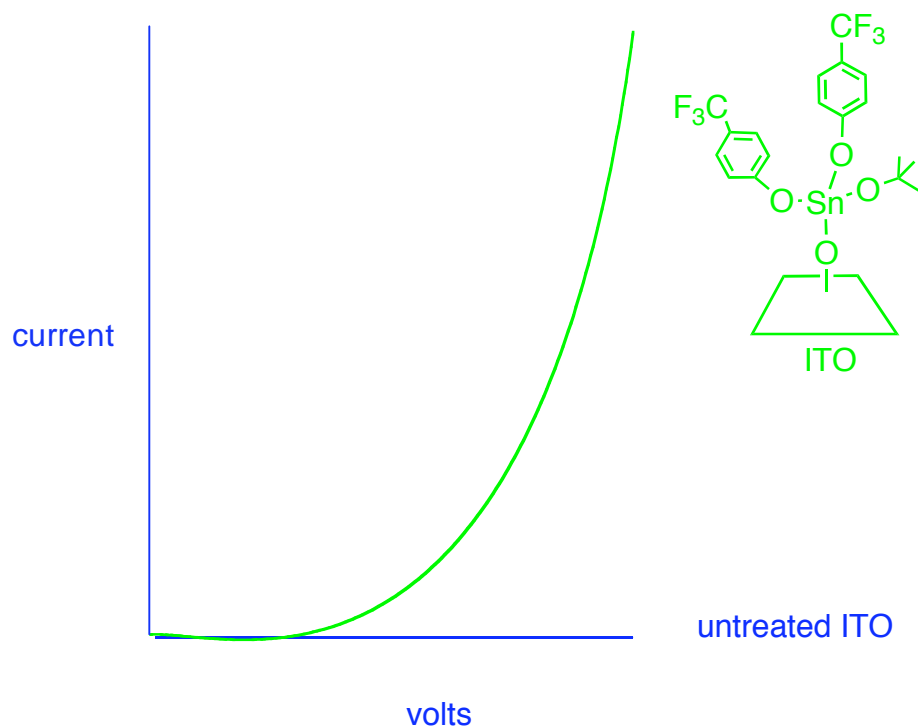
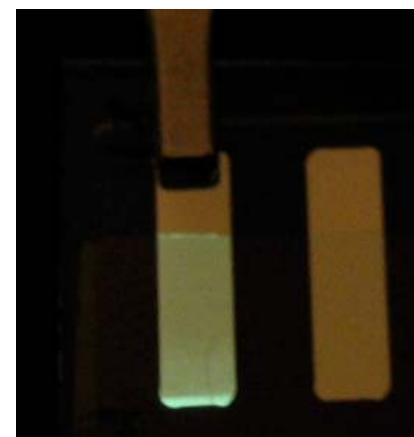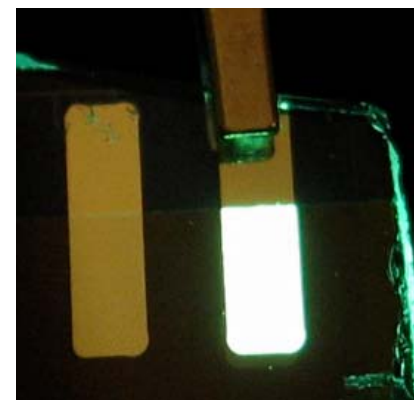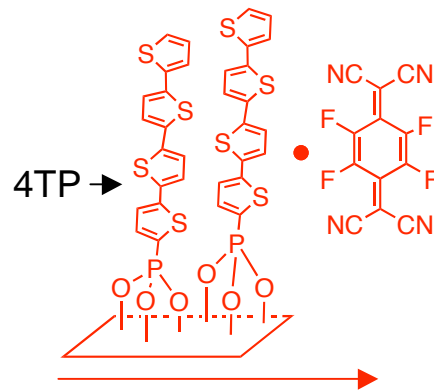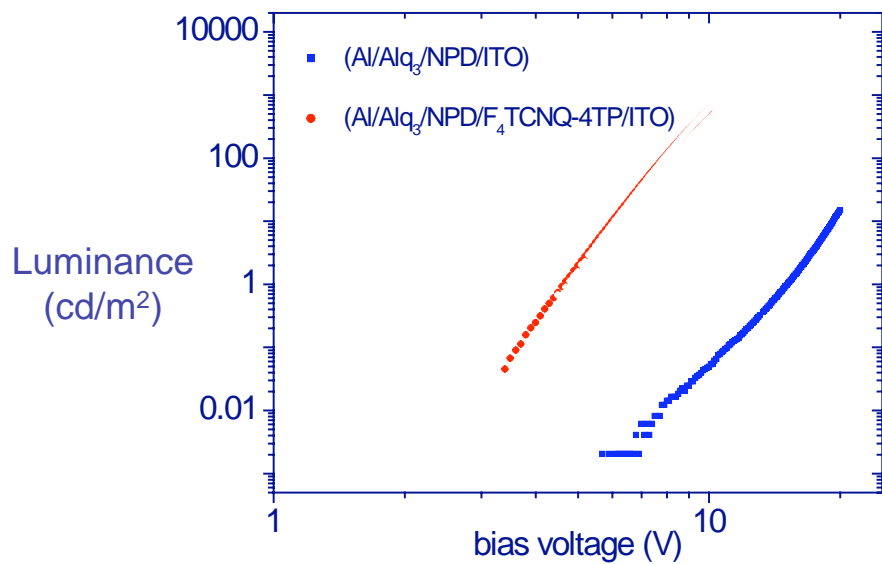Device using ITO treated with the surface tin complex

Unreated ITO device

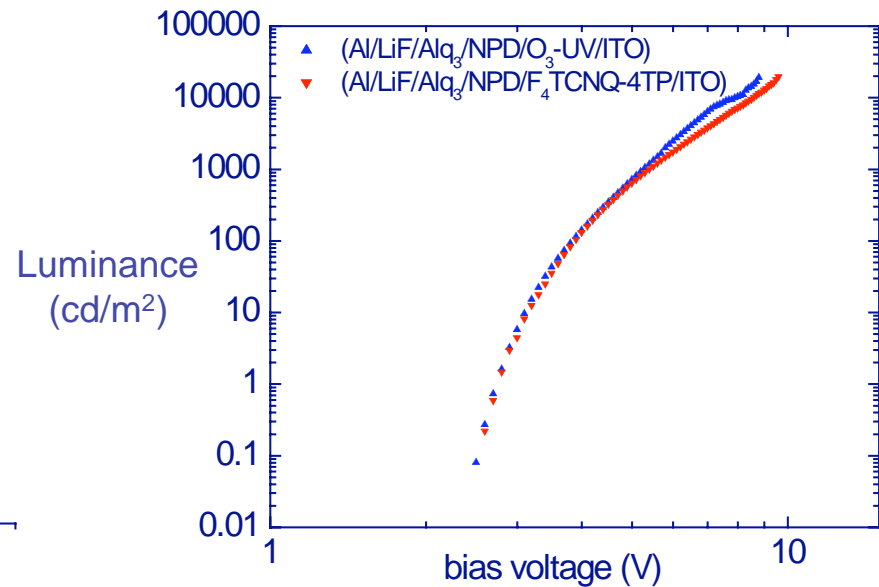Guo; Koch; Schwartz; Bernasek *J. Phys. Chem. B*, **2005**, *21*, 4236-4239
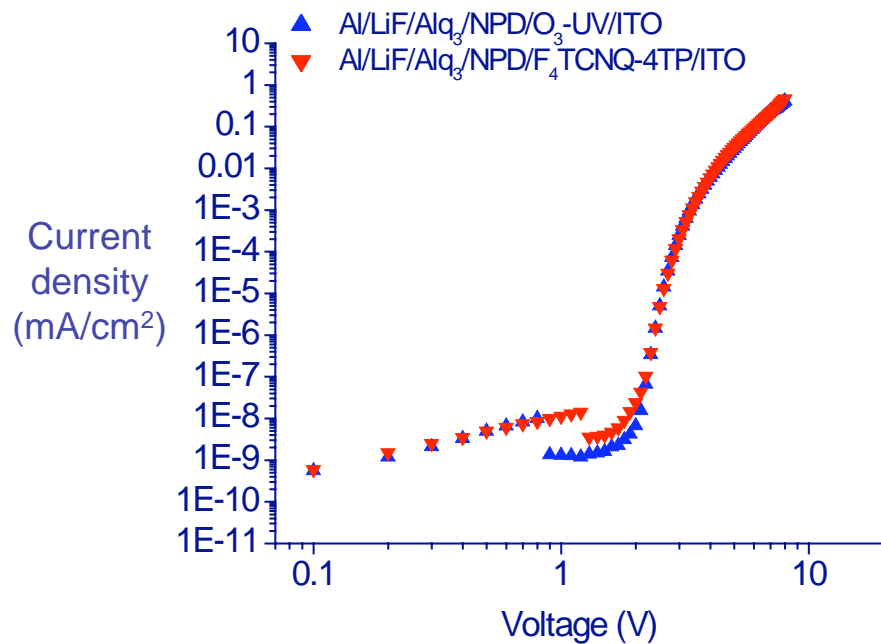
Improved OLEDs Using Doped 4TP SAMPs

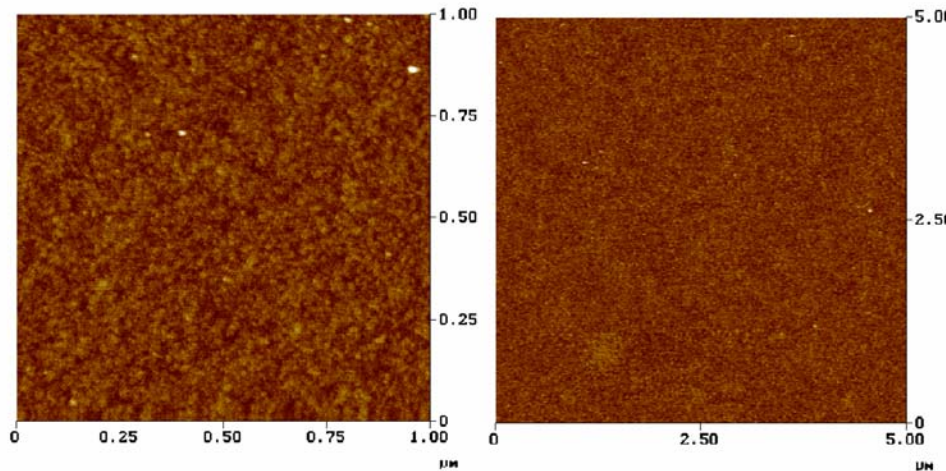Significant increases in charge density and luminance are observed.

Comparison With the State-of-the-Art

The 4TP-F$_4$TCNQ device performs comparably to a state-of-the-art OLED.

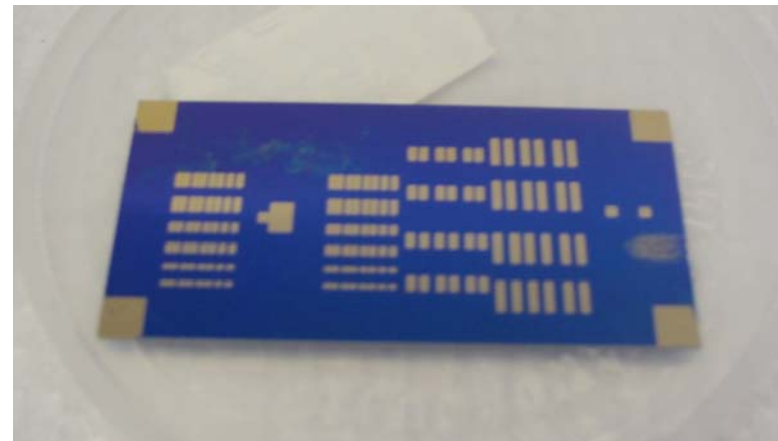(These devices may be electron-injection limited.)

Hanson; Guo; Koch; Schwartz; Bernasek *J. Am. Chem. Soc.* **2005**, *127*, 10058-10062

SAMPs are Good Platforms
for Thin Film Transistors

SAMPs of anthracene- or quarterthiophene phosphonate on SiO_2/Si are quite homogeneous

Pentacene-based thin film transistors were fabricated on SAMP platforms

Thin Film Transistor Platforms:
Pentacene on a SAM
of 9-Anthracenylphosphonate (AP)

pentacene

AP

AP/SiO$_2$/Si

Source/Drain Current (A)

1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
1.00E-10
1.00E-11
1.00E-12
1.00E-13

-30   -20   -10   0   10   20   30
Gate Voltage (V)

1.5 V/decade subthreshold slope

0.2-0.3 V/decade subthreshold slope

All mobilities in the range 0.2-0.5 cm^2/Vs

AP SAM has a much lower "off current" than the control

AP SAM Threshold V=-4.5V

Control Threshold V=+13V

McDowell; Hill; McDermott; Bernasek; Schwartz Appl. Phys. Lett. 2006; 073505