

Towards an All-Organic Trilayer MTJ Device

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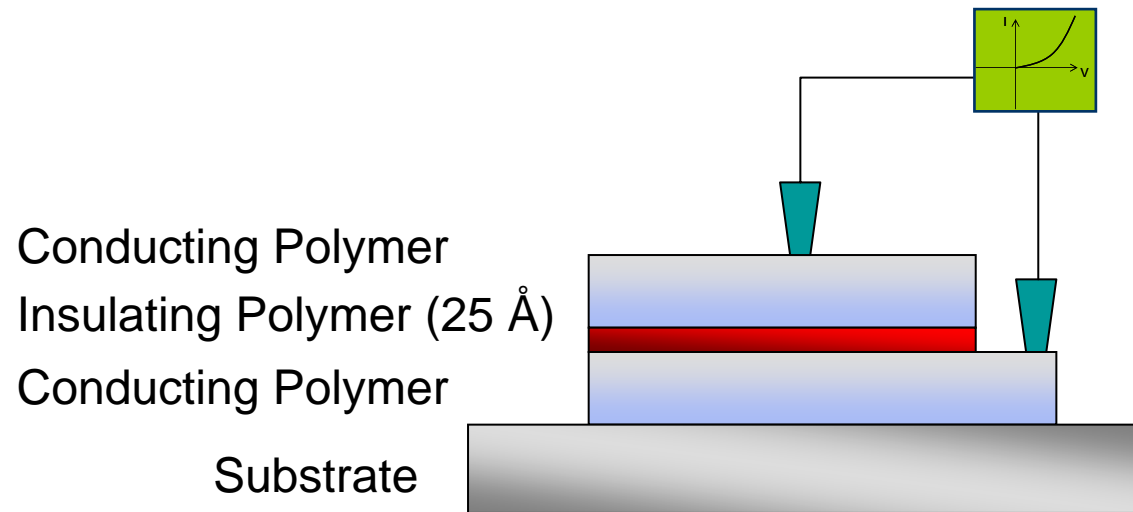


Overview

- Concept of an all-organic MTJ
- Issues to be addressed:
 - Smooth layers
 - Thin insulating layer
 - Abrupt interfaces
- Experiments with PEDOT:PSS
- Concept for a one step bilayer
 - Initial experiment
- Future Plans

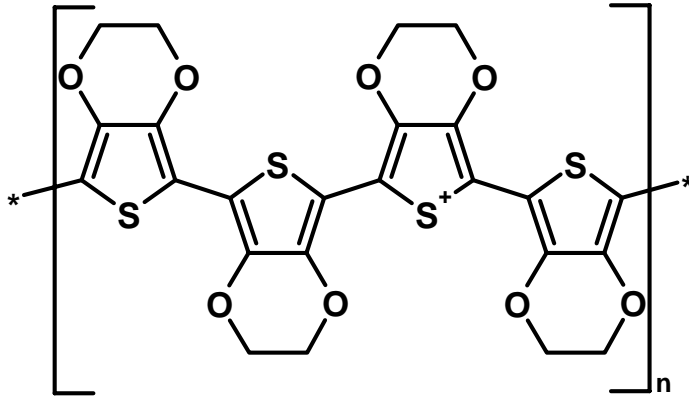


All-Organic MTJ Concept



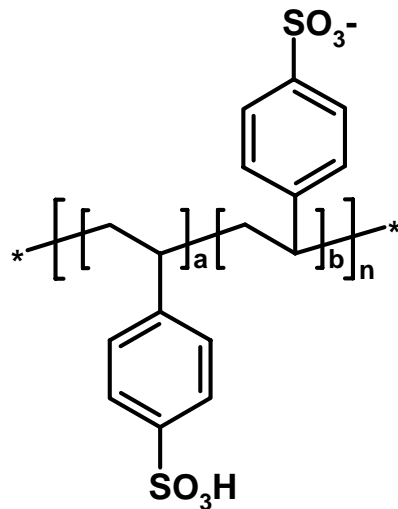
- Key issues:
 - Smooth layers and abrupt interfaces
 - Is substrate roughness telegraphed through polymer layers?
 - What processing conditions will result in smooth films?

Conductive Layer: PEDOT:PSS



PEDOT: poly(3,4 ethyenedioxythiophene)

- The right conductivity
- Low surface roughness
- Phase separation with PS
- Commercially available

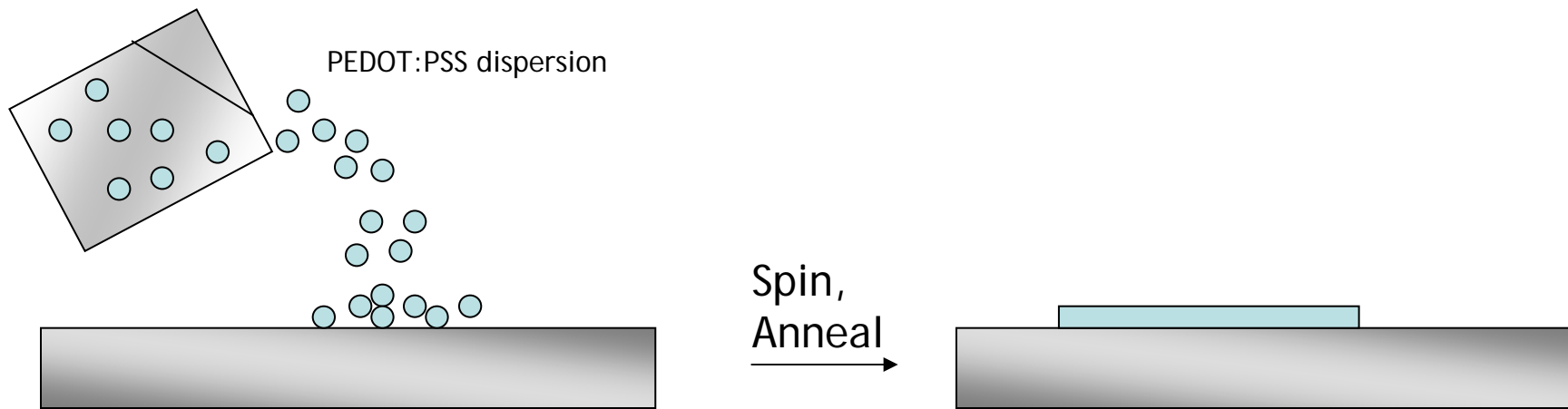


PSS: poly(styrenesulfonic acid)

Supplied as a dispersion in water

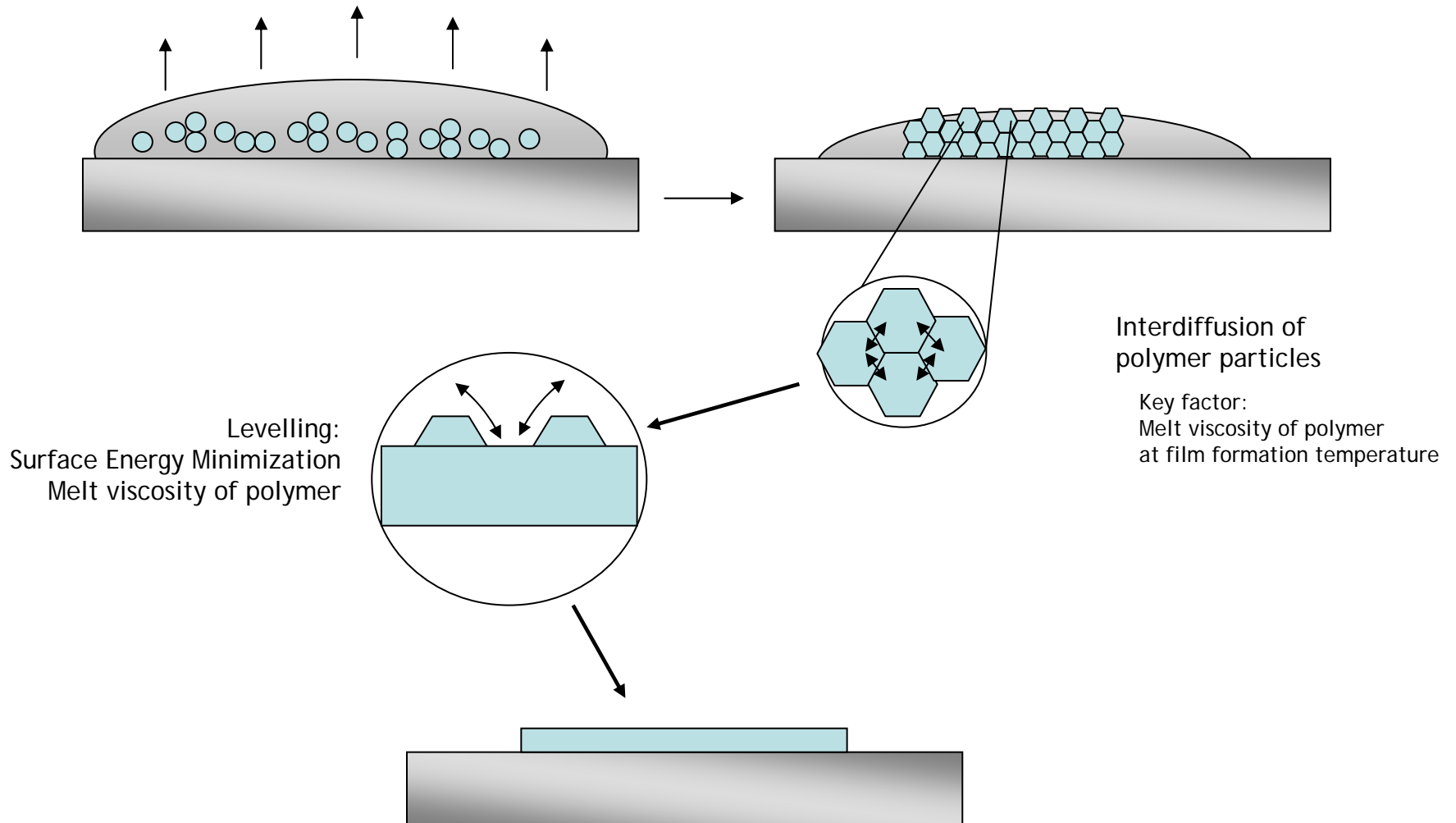


Conducting Polymer Layer



- Variables that affect film formation:
 - Spin coating speed
 - Particle size
 - Particle size distribution
 - Glass Transition Temperature (T_g)
 - Plasticizers
 - Annealing Temperature

Polymer Particle Coalescence



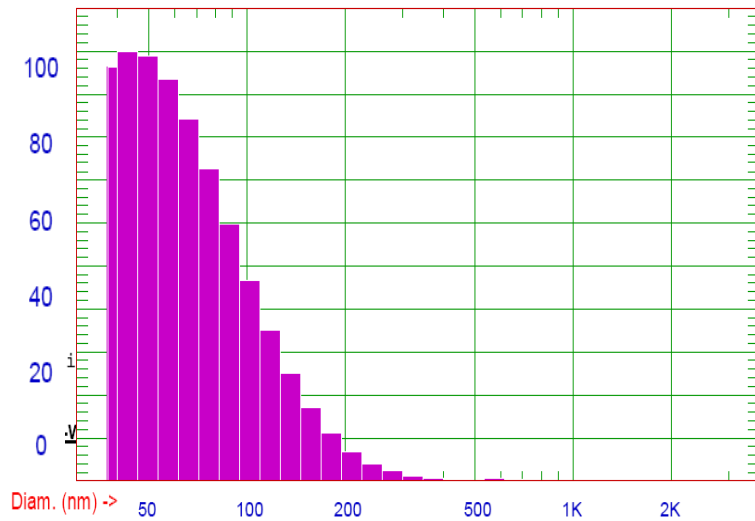
Commercial PEDOT:PSS Properties

Property	Baytron P	Baytron PH 500
Form	liquid	liquid
Odor	odorless	odorless
Color	dark blue	dark blue
Conductivity	max 10 S/cm	min. 300 S/cm (after addition of 5% Dimethylsulfoxid)
Solid content	1.2 to 1.4 %	1.0 to 1.4 %
Na content	max 500 ppm	max. 350 ppm
Sulfate content	max 80 ppm	max. 80 ppm
Viscosity	60 to 100 mPa·s	max. 30 mPa·s
Surface tension	71 mN/m at 20 °C	-
PEDOT work function	approximately 5.2 eV	-
PEDOT :PSS ratio	1: 2.5 (by weight)	1 : 2.5 (by weight)
Mean particle size	d50 approximately 80 nm (swollen)	-
Refractive index, n	1.5228 at 589 nm (dried layer)	-

www.hcstarck.com, accessed on Feb. 15, 2006

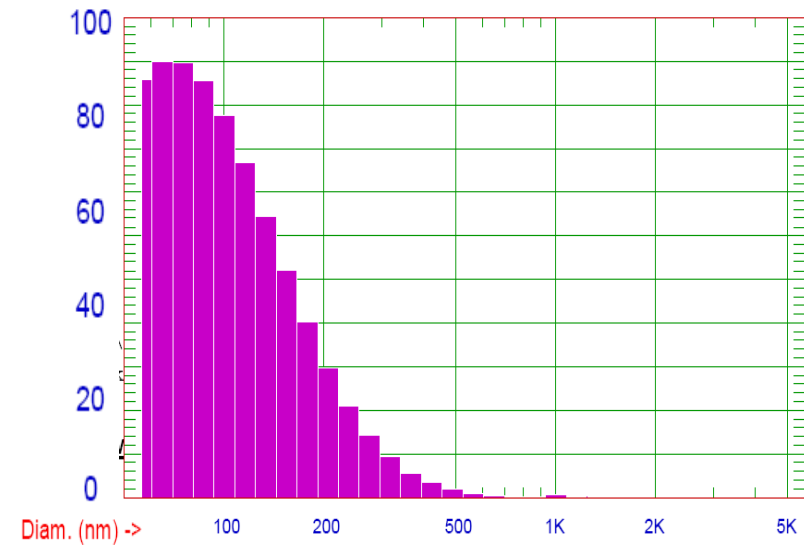
Particle Size of PEDOT:PSS

Baytron PH500



Mean Diameter : 56.0 nm
Std. Deviation : 37.4 nm

Baytron P



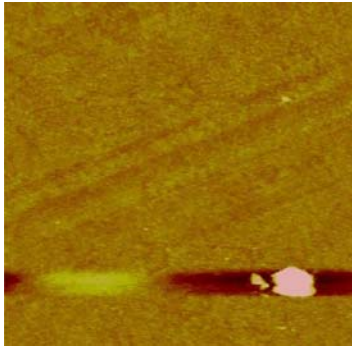
Mean Diameter : 88.8 nm
Std Deviation : 61.6 nm

Characterized using Photon Correlation Spectroscopy

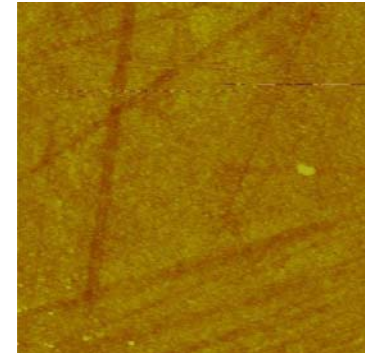


Roughness of Glass Substrates

5 x 5 μm Atomic Force Microscopy Images

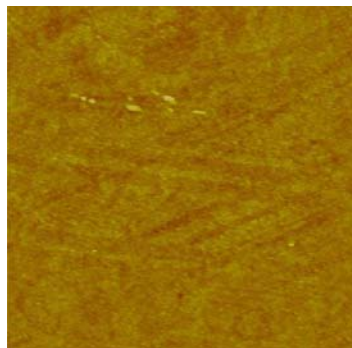


RMS: 1.760 nm
Ra: 0.69 nm



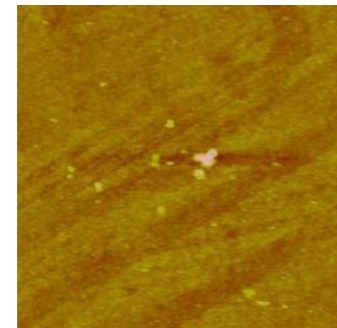
RMS: 0.62 nm
Ra: 0.43 nm

Avg. Roughness < 1 nm



RMS: 0.51 nm
Ra: 0.39 nm

Pirhana solution used
to clean substrates

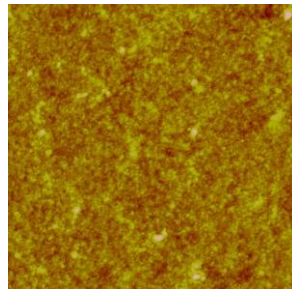
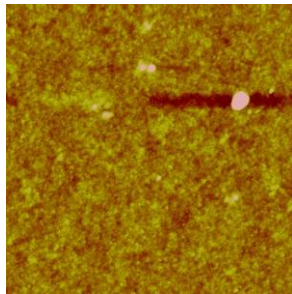


RMS: 0.69 nm
Ra: 0.45 nm

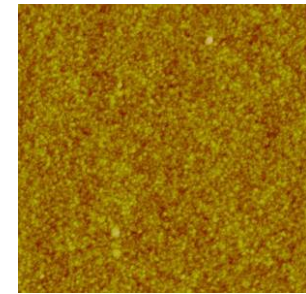
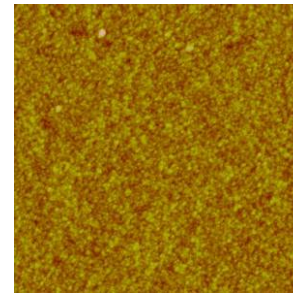


Spin Coating/Annealing Study

- Variables
 - PEDOT:PSS: Baytron P, Baytron PH 500
 - Spin Coating Speed (RPM): 2000, 3000, 4000, 5000, 6000
 - Annealing Temperature (°C): 130, 150, 170, 190
- Characterized using AFM



Baytron P



Baytron PH 500

Conclusions: PEDOT:PSS Study

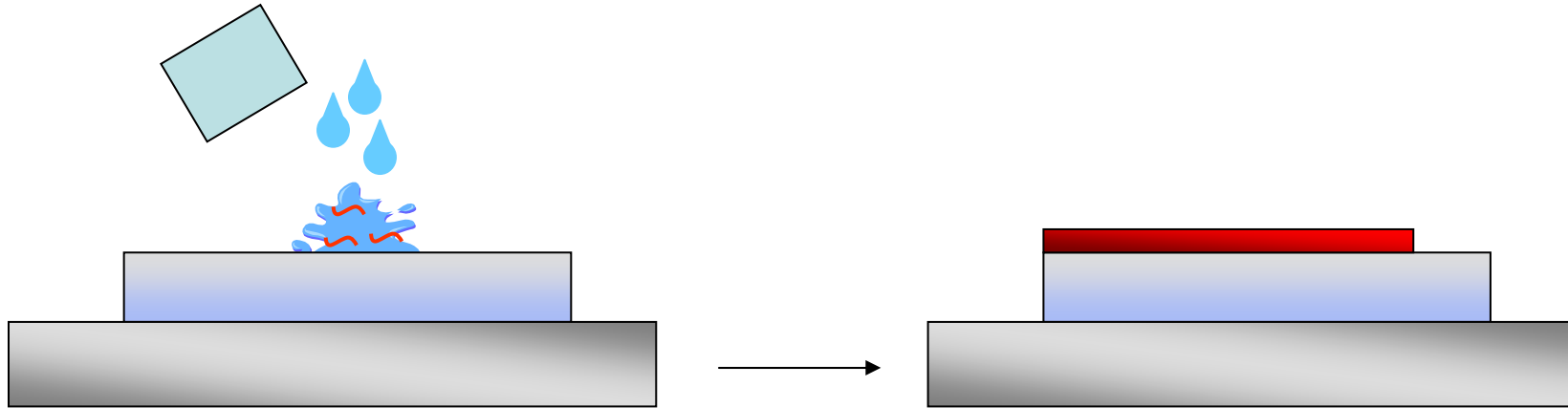
- See poster for details...
- PEDOT:PSS films prepared at NDSU have lower surface roughness than the ones cited in the literature
 - NDSU: ~0.9 nm vs. ~3 nm
- Baytron PH 500 coating films have lower surface roughness than Baytron P films
 - Smaller particle size?
- Possible issue of presence of agglomerated polymer particles can cause increase in surface roughness
 - Filtering of polymer before application?



Future Work

- Addition of “coalescing” solvents to improve film formation
 - e.g. “Texanol”
 - Particle soluble solvent → reduces particle T_g and melt viscosity
 - Evaporates during annealing
- Surface tension modifiers
- Conductivity measurements

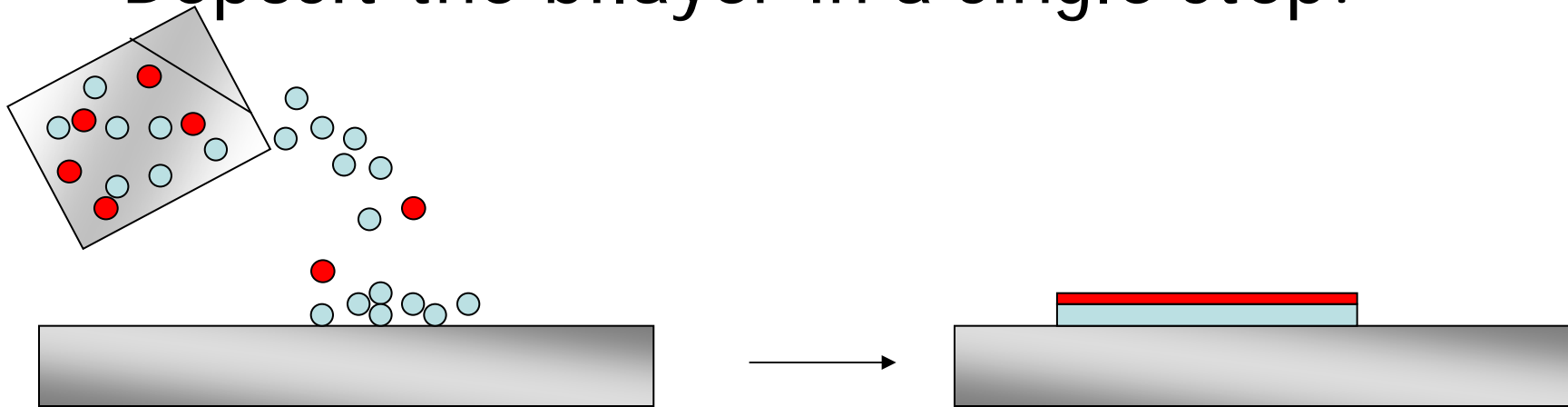
Depositing the Second (Insulating) Layer



- Dilute solution of polymer in solvent
- Issues
 - Polymer selection: PS, PMMA, etc.
 - Solvent
 - Polymer solution has to wet and spread on CP layer
 - No island formation, pinholes
 - Redissolution of conductive polymer layer
 - Diffuse interface
 - How can a film of 25 Å be achieved?

The Self-Assembly Approach

- Deposit the bilayer in a single step:

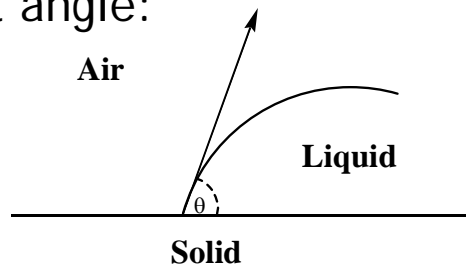


- Dissolve/disperse insulating polymer in PEDOT:PSS system
- Insulating polymer will be incompatible with PEDOT:PSS
- To minimize surface energy, insulating polymer driven to top surface
 - Likely, since PEDOT:PSS system is polar
- Initial experiment: Polystyrene



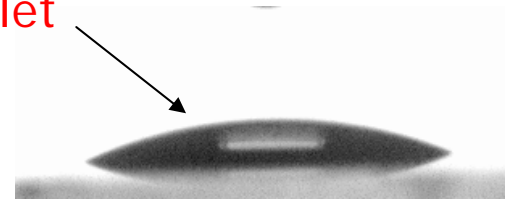
Initial Experiment:

Contact angle:



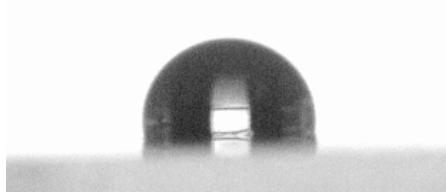
Water droplet

Polymer surface

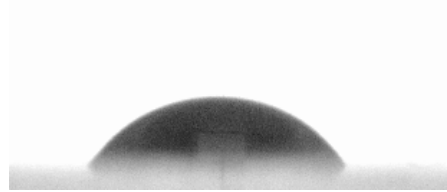


Baytron P WCA = 23°

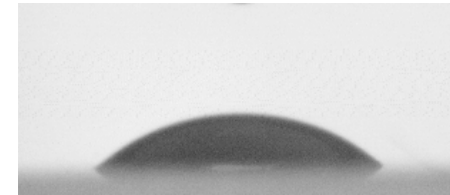
Baytron P + 1.5 % Polystyrene in NMP
PS MW = 200,000



Initial WCA = 97°



24 Hours: 59°



4 days: 42°

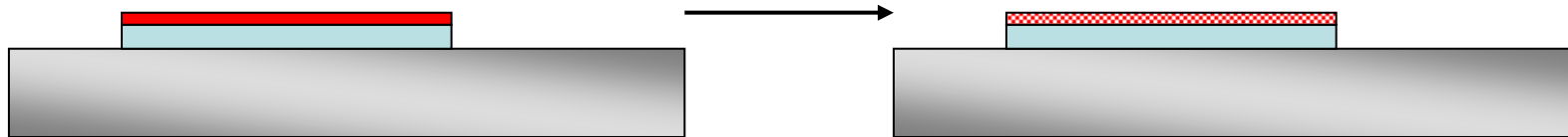
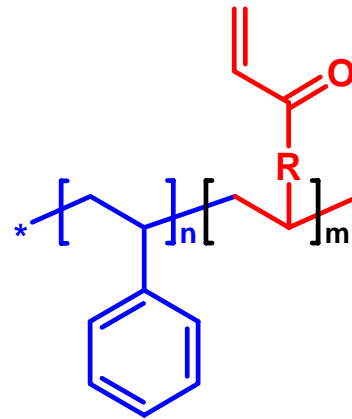
time

WCA data indicates that a bilayer structure was formed initially,
System rearranges over time



Stable Bilayered Structure

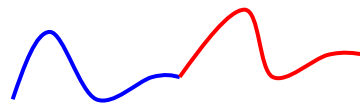
- Crosslink the surface layer:
 - Deep UV to crosslink PS
 - Design copolymer with UV curable groups



Crosslinked polymer layer will be resistant to rearrangement

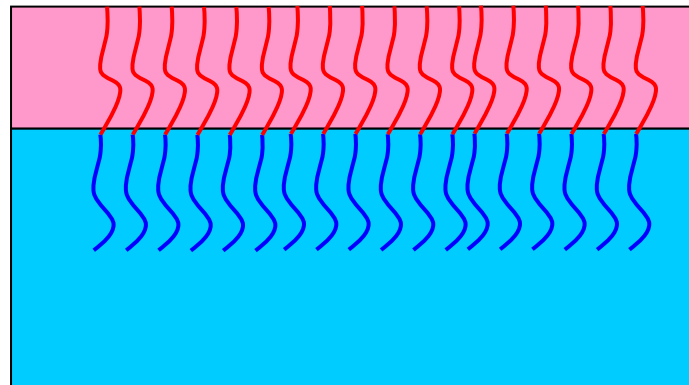
Block Copolymer Approach

- It is well known that diblock copolymers can be used as surface modifying additives



Composition of bulk polymer
Or, compatible with bulk polymer

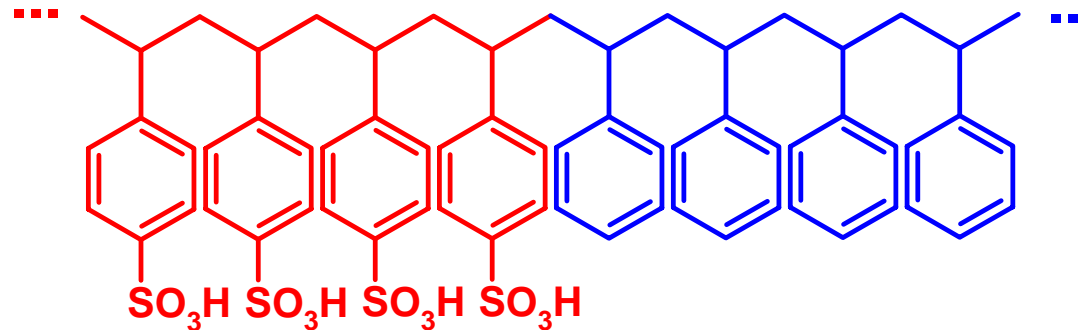
Low surface energy block



Goal: A very thin layer of insulating polymer on top of CP

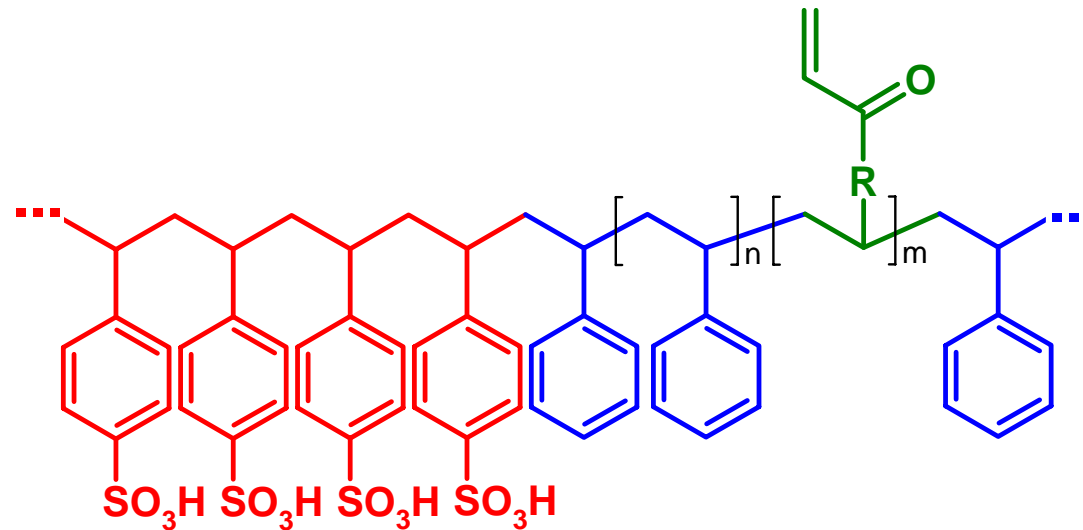


PSS:PS Block Copolymers



- Use a controlled radical polymerization method for synthesis
 - Reversible addition-fragmentation termination (RAFT)
- Can precisely control block lengths
 - Tune the block copolymer for properties

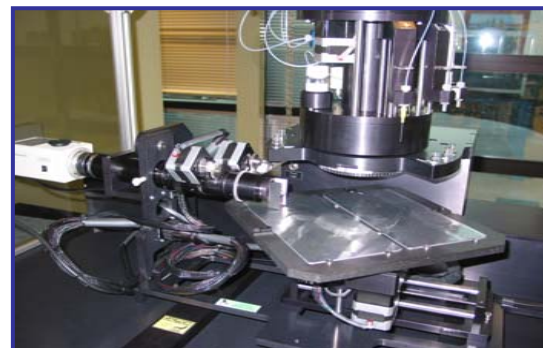
PSS:PS Block Copolymer 2



Block copolymer with photopolymerizable groups
-- Crosslink after bilayer formation to stabilize

Combinatorial Experimentation

- Synthesize block copolymer libraries with systematic variation in block lengths
- Blend with PEDOT:PSS
- Evaluate using AFM, Contact Angle



Summary

- PEDOT:PSS with smooth surfaces can be prepared
- Approaches to a one-step bilayer structure have been identified:
 - Polymer blend
 - Block copolymer

