Characterization of Organic Solar Cell Morphology

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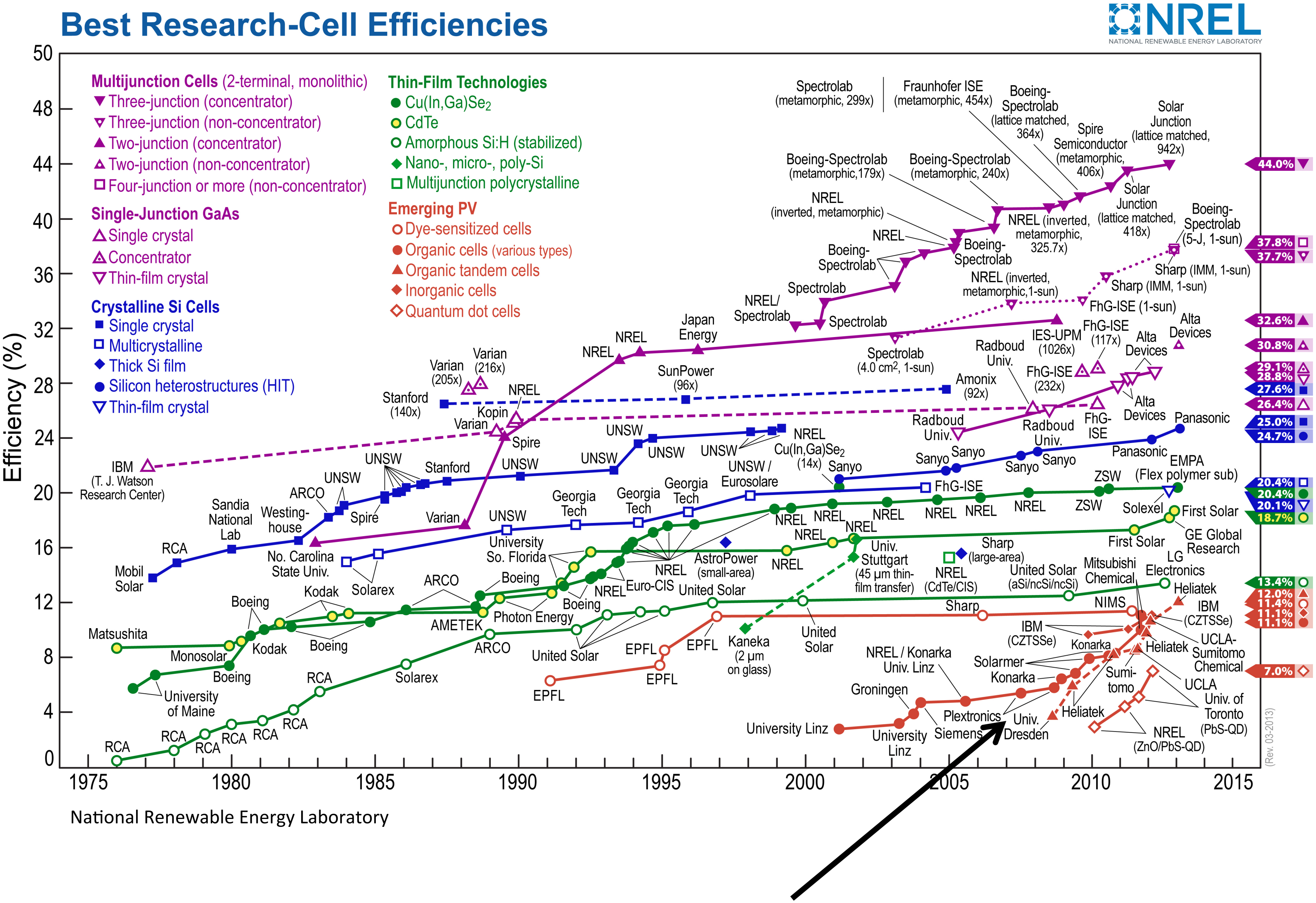


Organic Solar Cells

Benefits of Organics Solar Cells

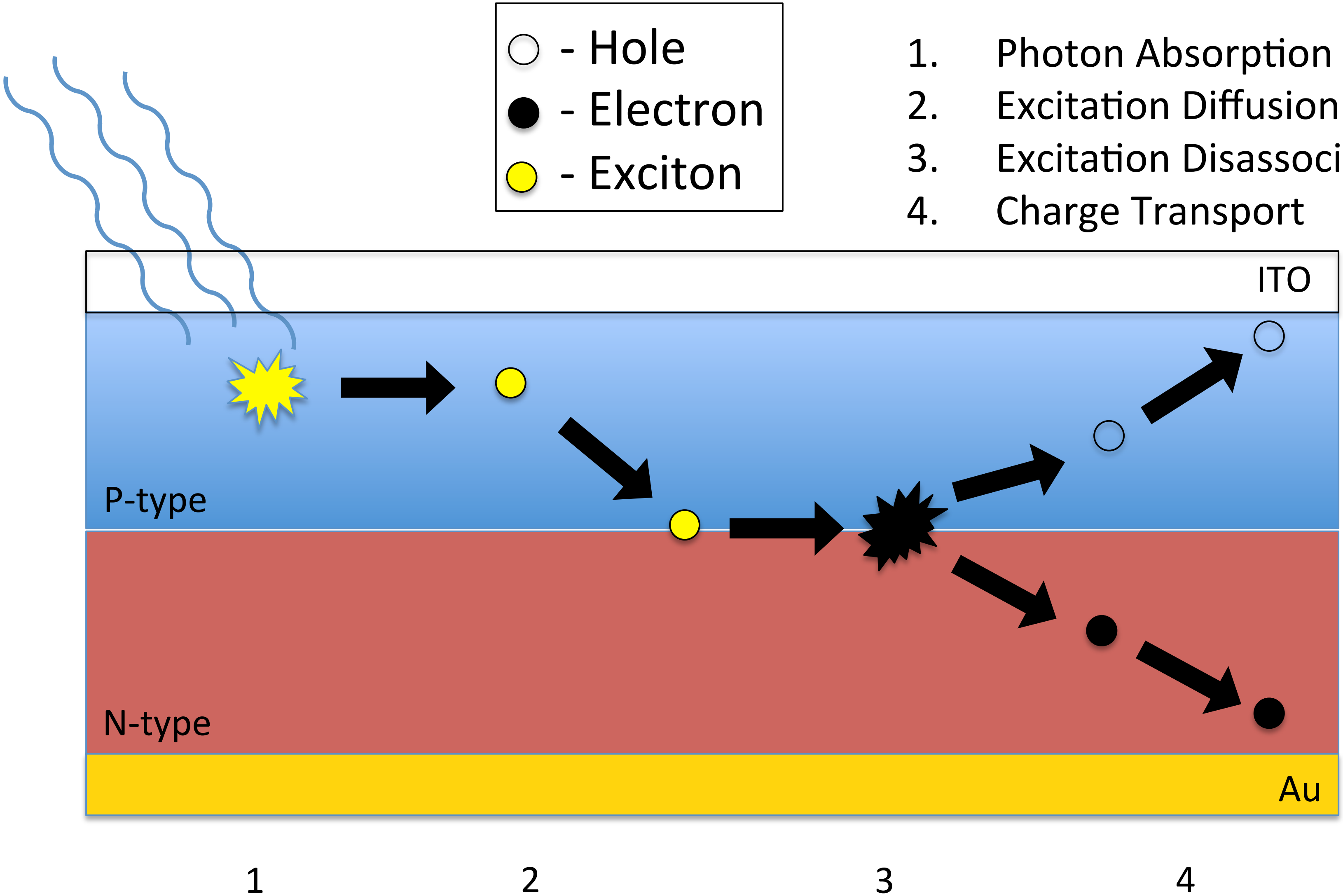
- Solution Deposition
- Flexible Substrate
- Roll to Roll Production
- Thinner Devices
- Light Weight
- Cheap Installation & Transportation

University of Cambridge

Siemens

How Solar Cells Work

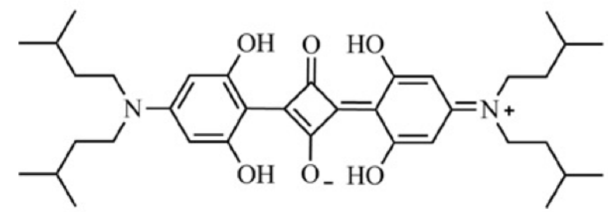
1. Photon Absorption
2. Excitation Diffusion
3. Excitation Disassociation
4. Charge Transport



Fabrication Process

- Dissolved in chloroform 3:7 N to P ratio
- Spin Coating on $(24mm)^2$ glass slides
- Bulk heterojunctions (BHJ)
- Annealing times of the device was varied
- Morphology of the BHJ was studied for multiple anneal times

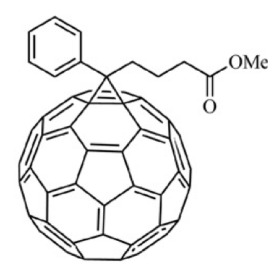
P-type



DiPSQ(OH)$_2$

1,3-bis[4-(N,N- diisopentylamino)-2,6-dihydroxyphenyl]squaraine [DiPSQ(OH)2]

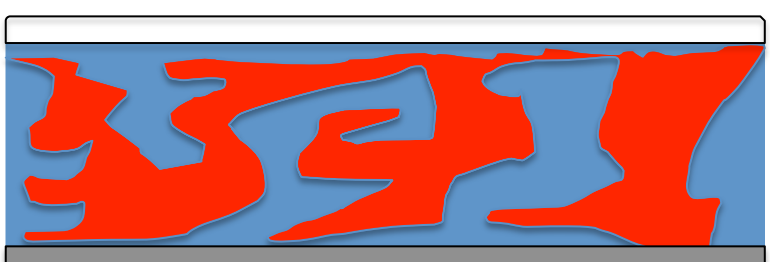
N-type



PCBM

phenyl-C61-butyric acid methyl ester (PCBM)

Glass ITO Slide

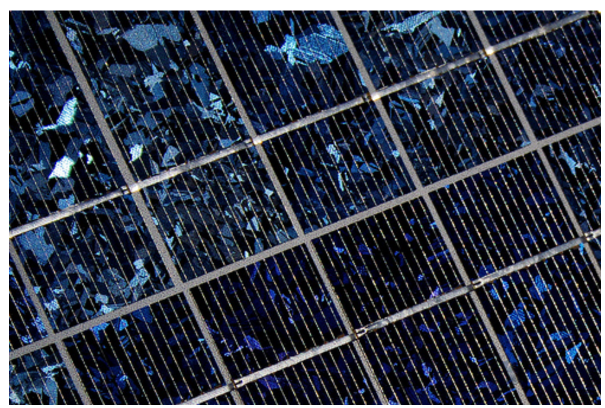


BHJ

Aluminum

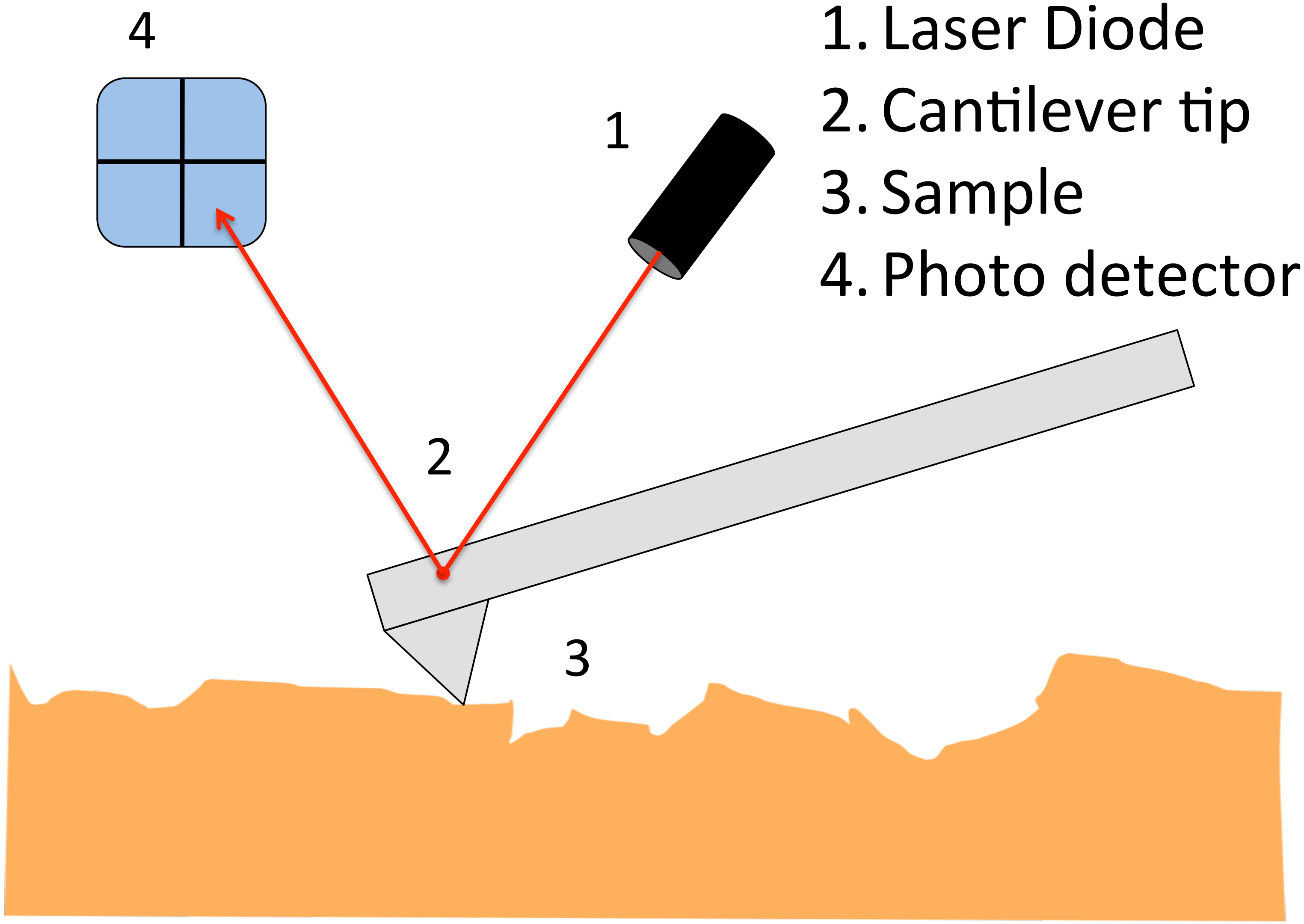
Annealing: Effects on Crystallization

- Increased thermal energy
- Glass transition phase
- Crystals have higher charge mobility, μ
- Improved solar cell efficiencies
- Annealing effects on crystal formation through AFM analysis



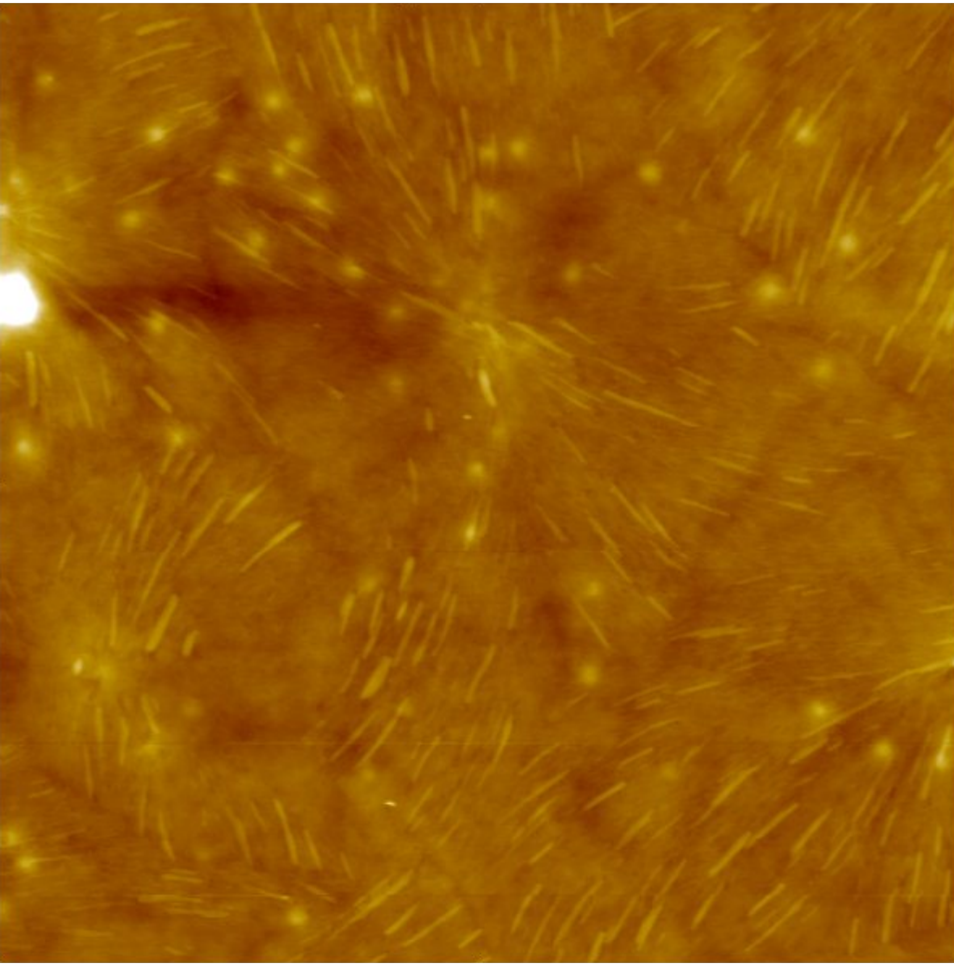
Ecopolitology

Atomic Force Microscopy



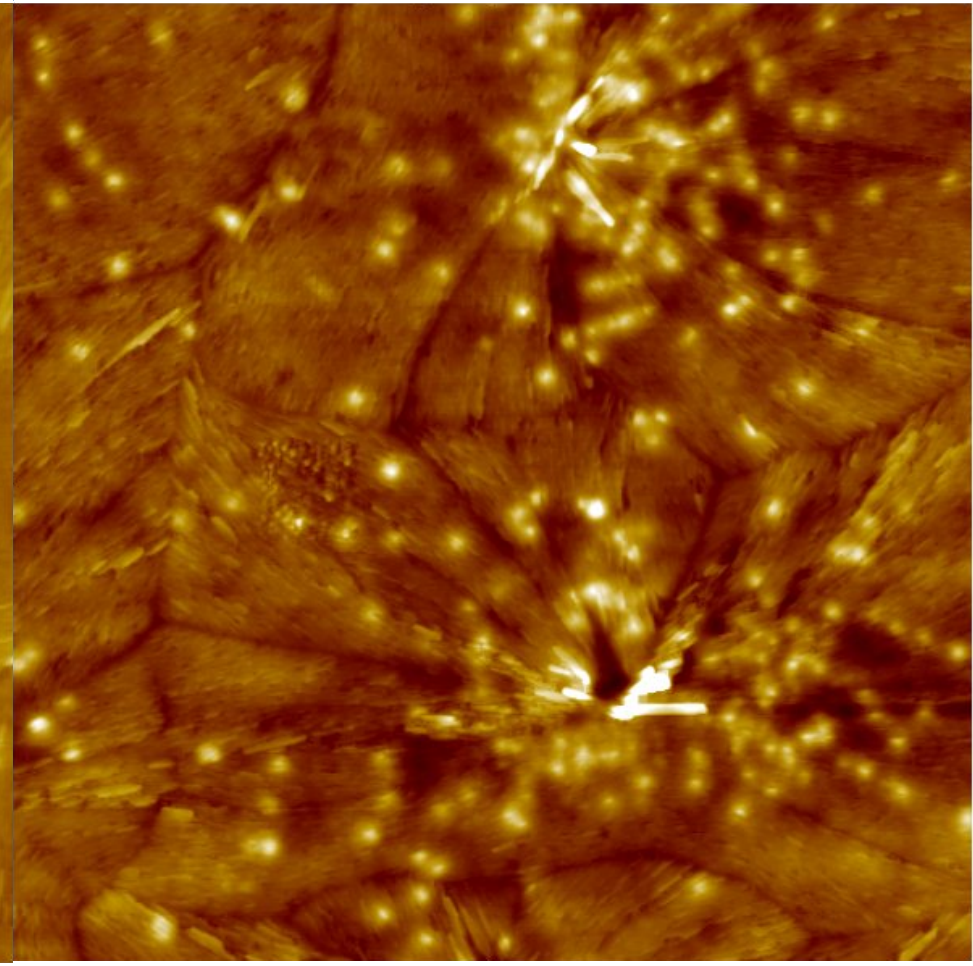
1. Laser Diode
2. Cantilever tip
3. Sample
4. Photo detector

BHJ: unannealed



- $(10\mu m)^2$ image
- Height range ~103 nm
- Few features/ Flat

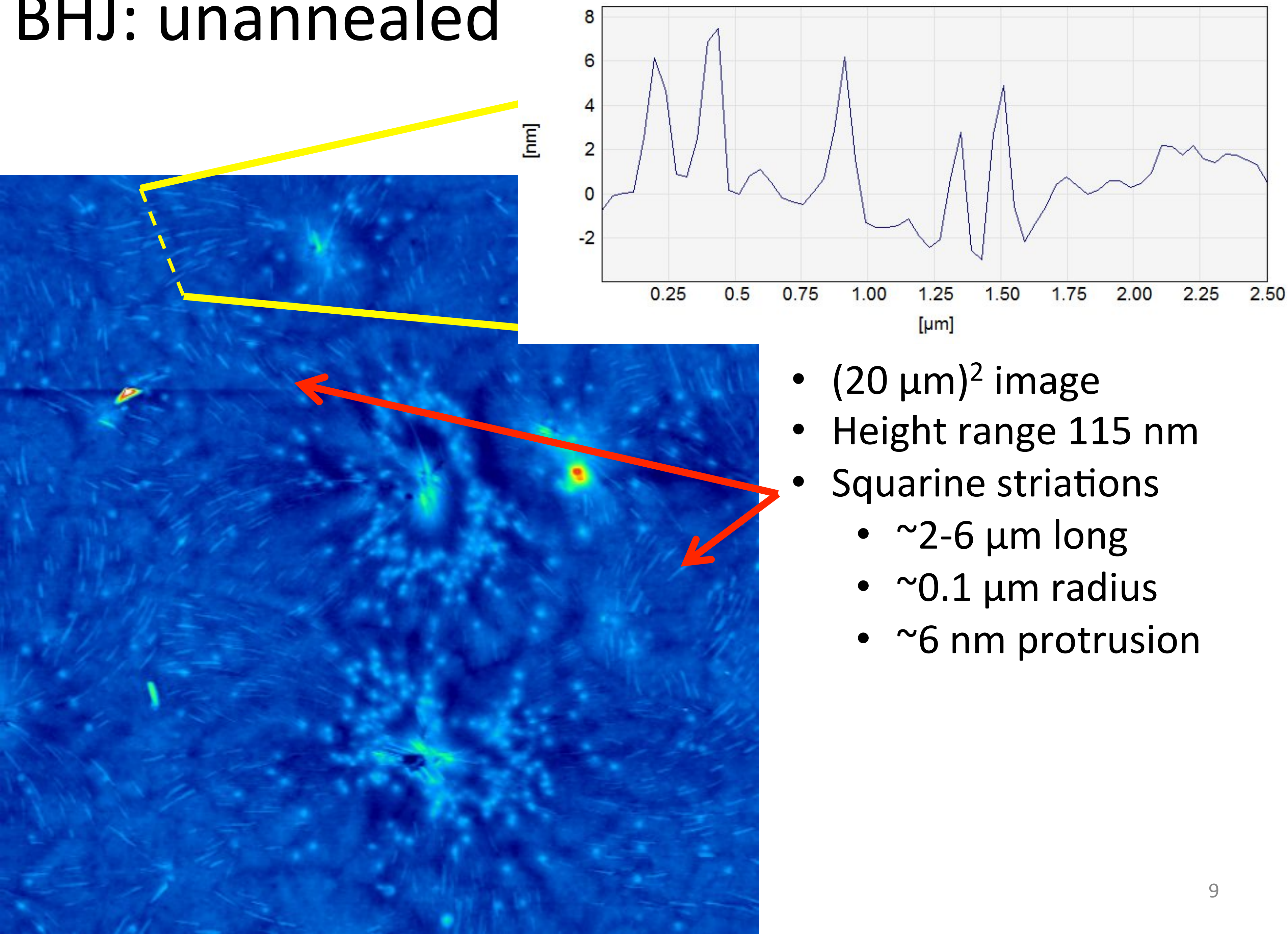
BHJ: annealed



- $(10\mu m)^2$ image
- Height range ~40 nm
- Increased crystallization

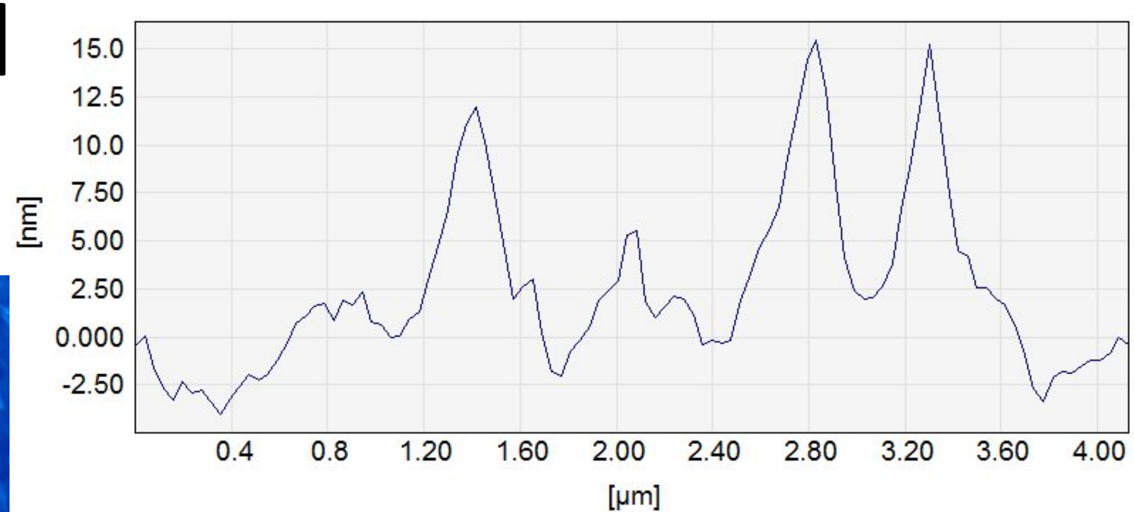
Coffey et al. , Nano Lett, **7**, 738 (2007)

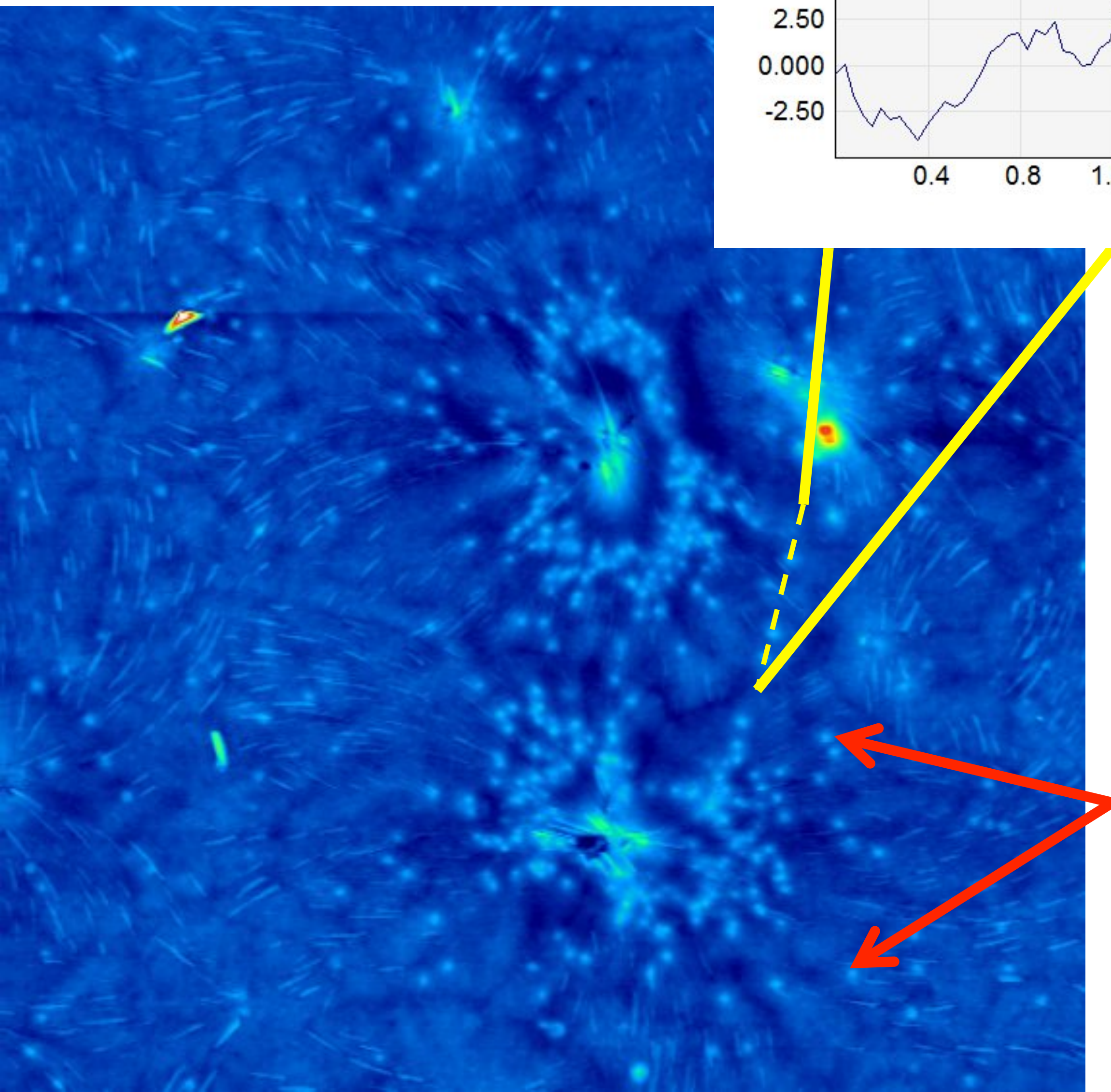
BHJ: unannealed



- (20 µm)^2 image
- Height range 115 nm
- Squarine striations
  - ~2-6 µm long
  - ~0.1 µm radius
  - ~6 nm protrusion

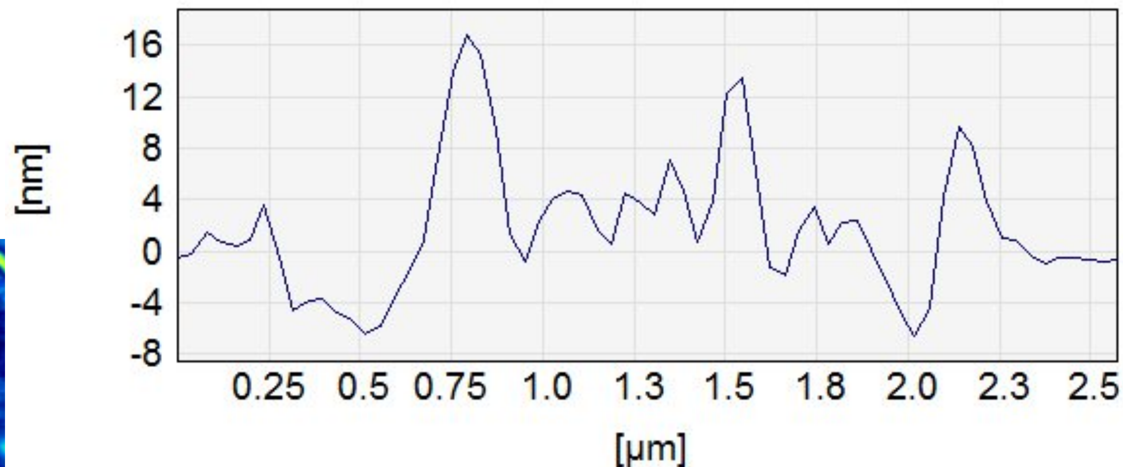
BHJ: unannealed

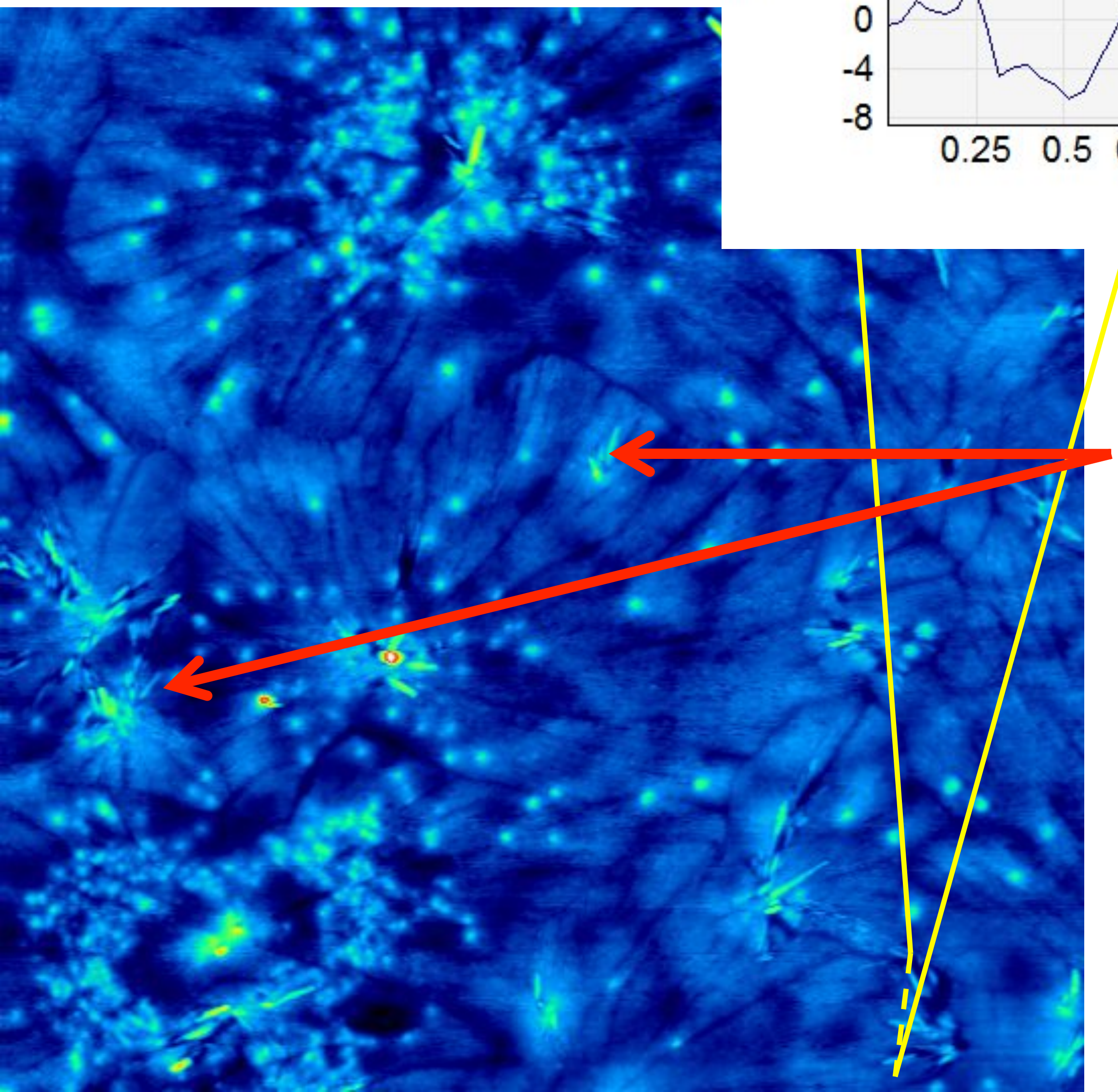




- (20 µm)^2 image
- Height range 115 nm
- Squarine striations
  - ~2-6 µm long
  - ~0.1 µm radius
  - ~6 nm protrusion
- PCBM spheres
  - ~0.2 µm radius
  - ~10-15 nm protrusion

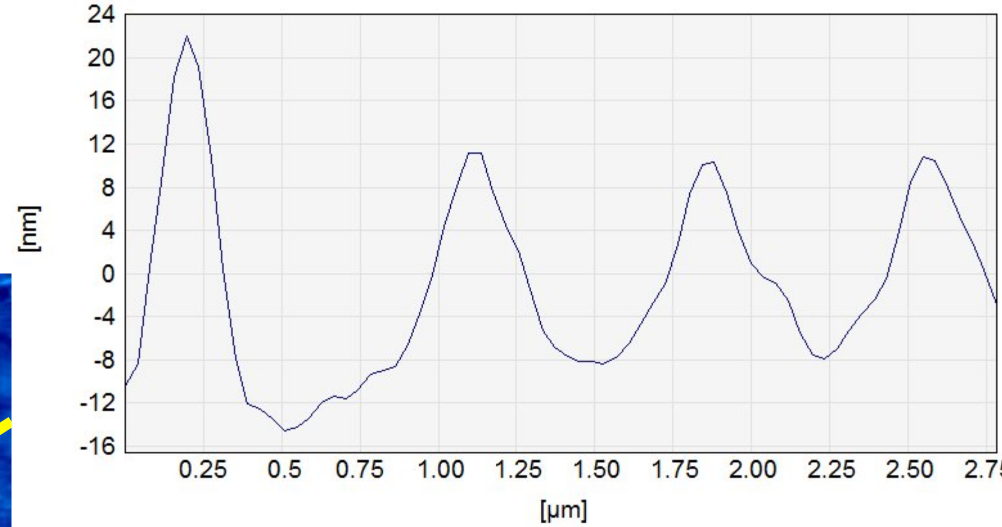
BHJ : annealed

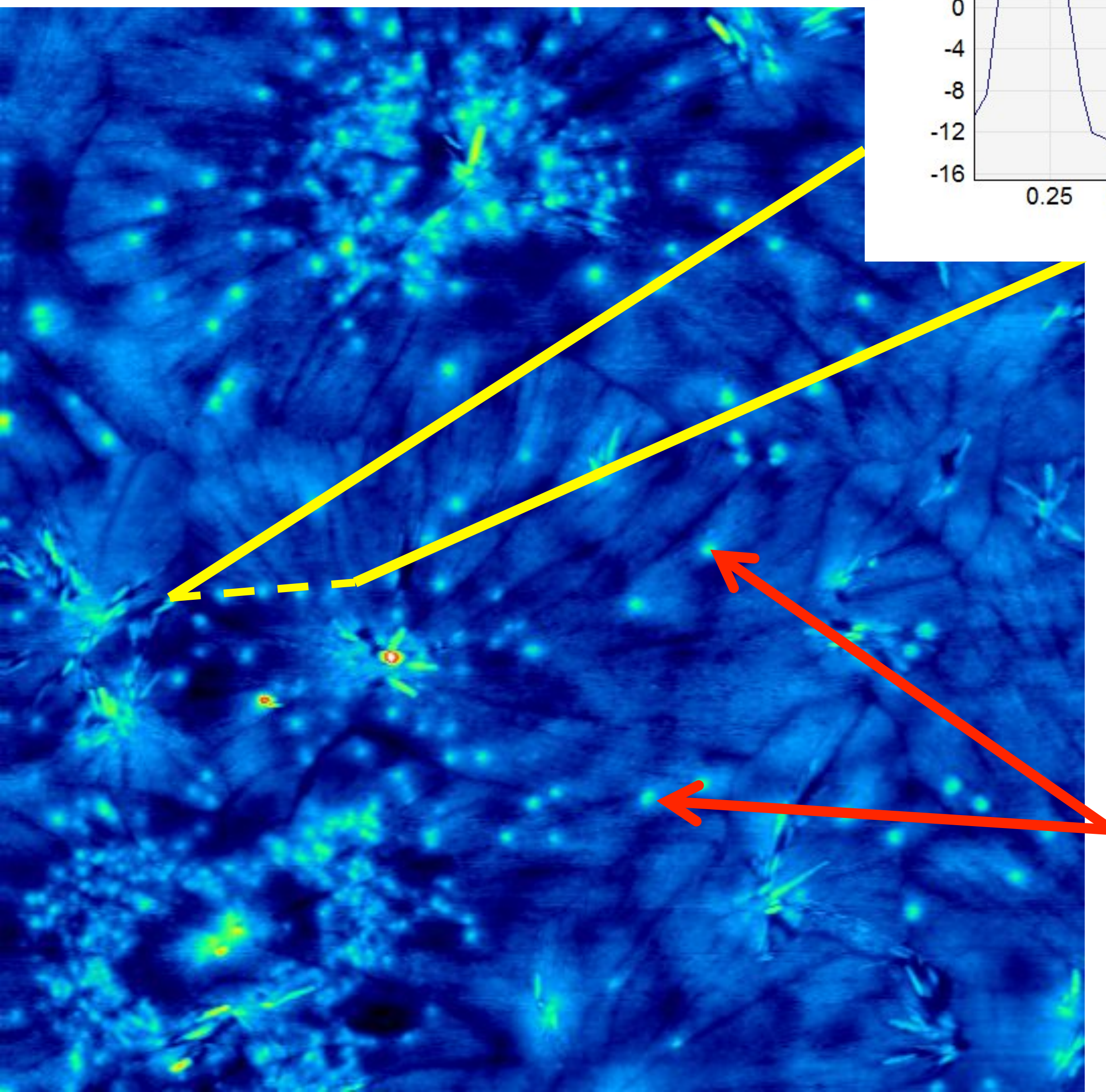




- $(20\ \mu m)^2$ image
- Height range 169 nm
- Squarine striations
  - Very few needles
  - ~2-3 μm long
  - ~0.15 μm radius
  - ~8-12 nm protrusion

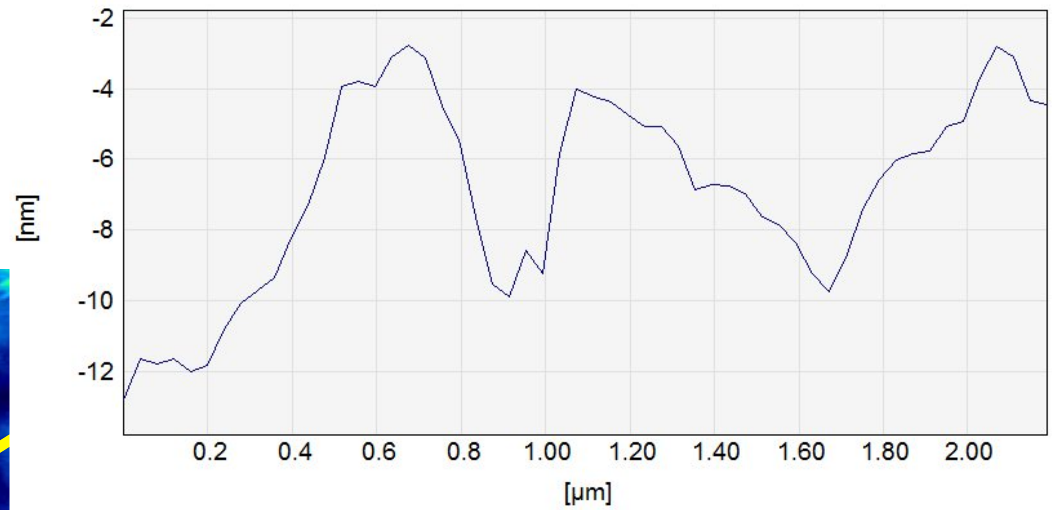
BHJ : annealed

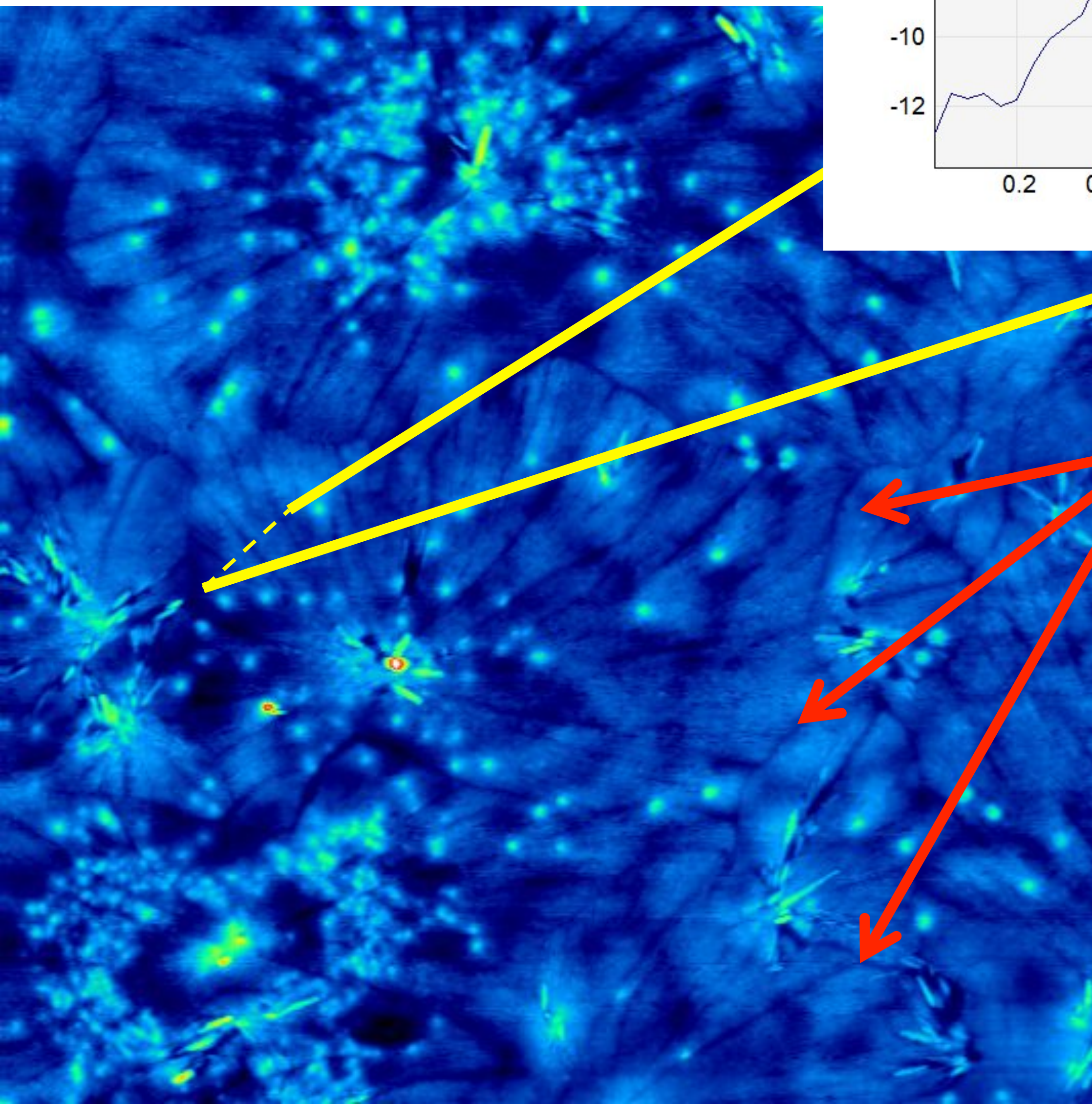




- $(20\ \mu m)^2$ image
- Height range 169 nm
- Squarine striations
  - Very few needles
  - ~2-3 µm long
  - ~0.15 µm radius
  - ~8-12 nm protrusion
- PCBM spheres
  - ~0.25 µm radius
  - ~20-26 nm protrusion

BHJ : annealed



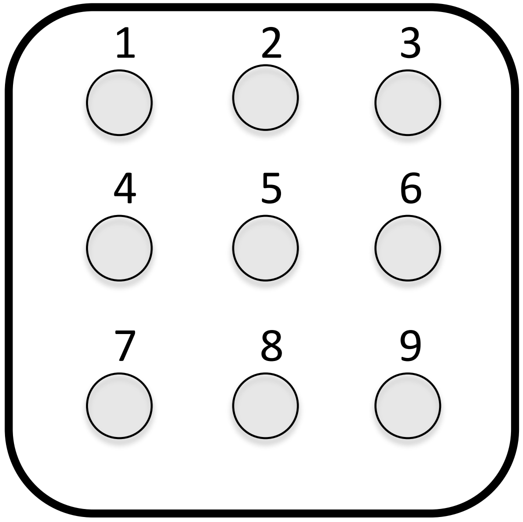


- (20 µm)^2 image
- Height range 169 nm
- Depressions
  - Boundaries between regions or grains
  - ~5 nm deep
  - ~0.30-0.35 µm wide

Roughness Measurements

- Root mean squared roughness measurements

$$RMS_{Roughness} = \sqrt{\frac{x_1^2 + x_2^2 + \cdots + x_n^2}{n}}$$



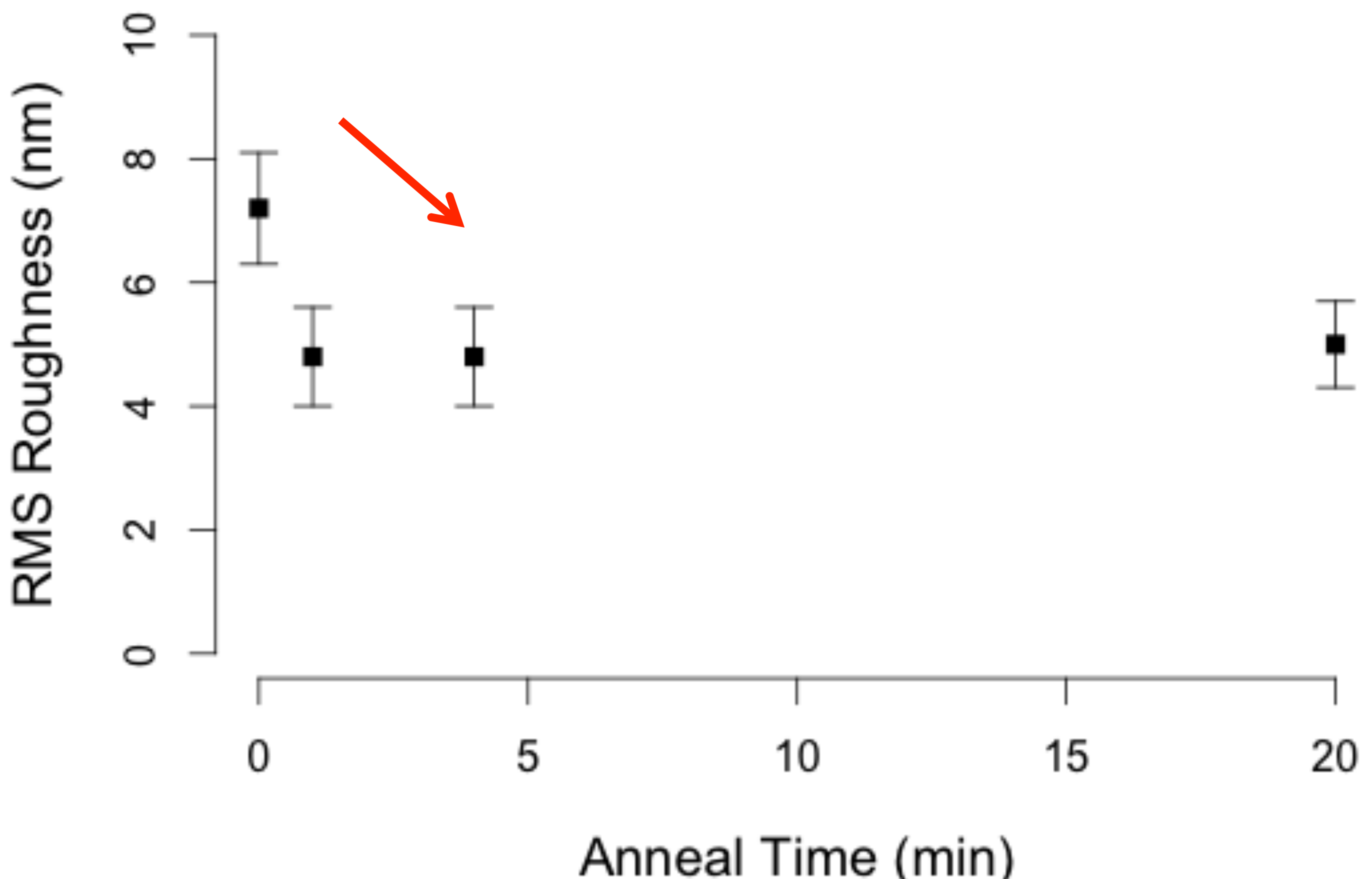
RMS VALUES	BHJ Film(nm)
Unannealed	7.2 ± 0.9
Annealed - 1 minute	4.7 ± 0.8
Annealed – 4 minutes	4.7 ± 0.8
Annealed – 20 minutes	5.0 ± 0.7

Unannealed Average RMS: 7.2 ± 0.9 nm

Annealed Average RMS: 4.8 ± 0.4 nm

Roughness Meansurements

- Crystallinity increases with annealing
- More distinct grains with annealing
- RMS roughness abruptly decreases with annealing by ~2.0 nm



Conclusion

- Squarine offers an alternative p-type semiconductor
- Annealing increase crystallinity of both materials
- Initial RMS roughness decrease with annealing due to thermal smoothing
- AFM analysis can give further insight into nanostructure than RMS roughness alone