Cohesion and Phase Separation in Organic PV Heterojunction Layers

Vitali Brand, Reinhold H. Dauskardt
Department of Material Science & Engineering, Stanford, CA 94305

STANFORD MATERIALS SCIENCE AND ENGINEERING

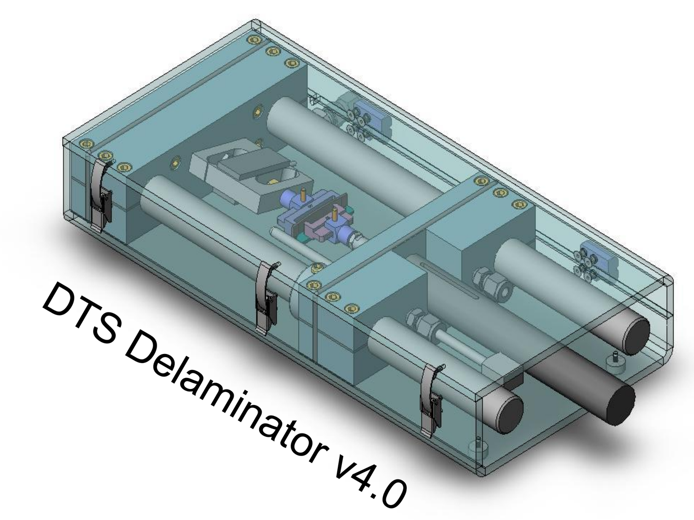
KAUST King Abdullah University of Science and Technology

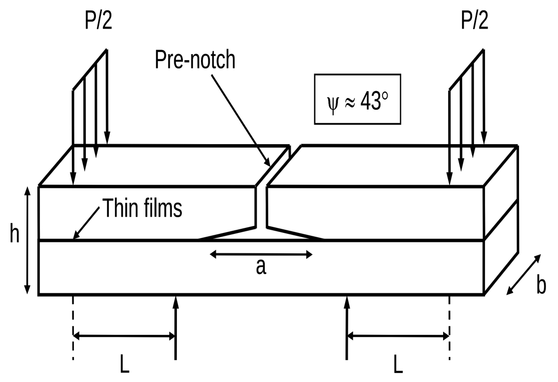
CAMP Center for Advanced Molecular Photovoltaics STANFORD UNIVERSITY

Objectives for OPV Reliability Thrust

- The objective of our research is to establish a well-defined relationship between the durability of the solar cell and the environmental factors effecting it
- Develop quantitative methods to characterize basic thermomechanical properties (e.g. adhesion, cohesion)
  - Effect of composition of the heterojunction layer
  - Effect of heterojunction layer thickness
  - Effect of annealing
- Are degradation processes coupled and how?
- Leverage from more mature area of reliability physics in microelectronics
  - mechanisms, kinetic models, accelerated testing and life prediction

Quantitative Adhesion/Cohesion and Debond Kinetics

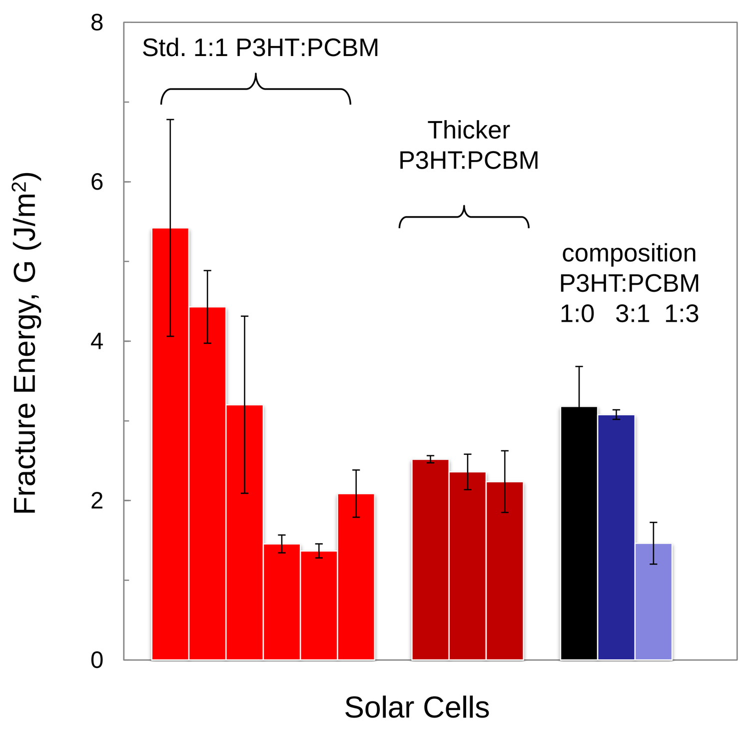




FPB adhesion

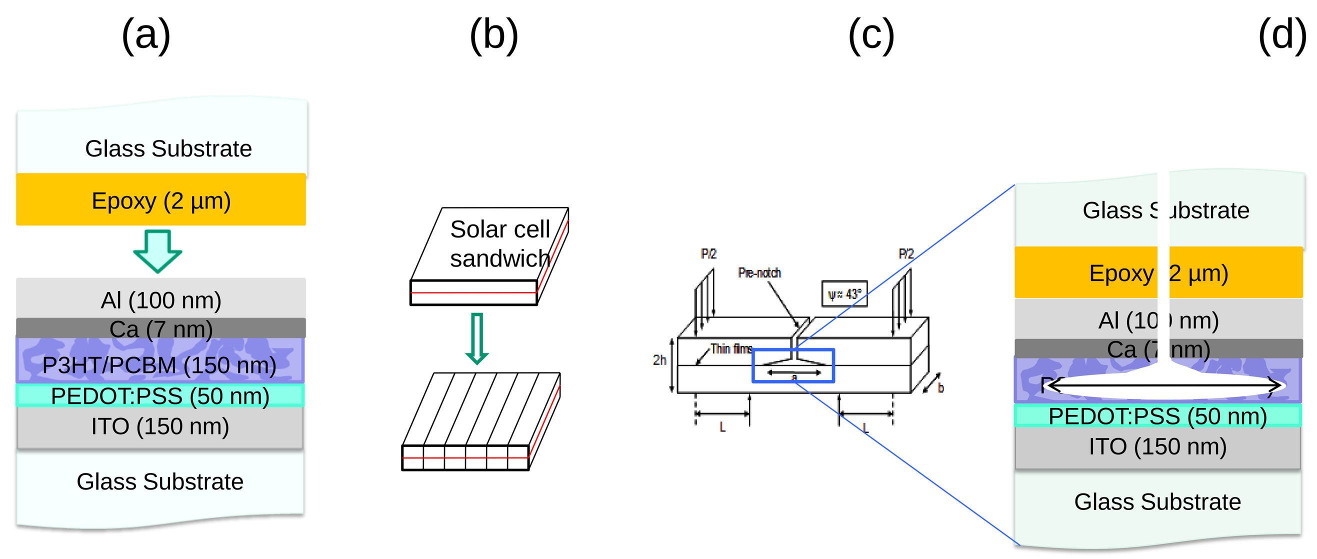
$$\underbrace{G}_{\text{crack driving "force"}} \geq \underbrace{G_c \left[J/m^2\right]}_{\text{cracking "resistance"}} \qquad G = \frac{Z\,\sigma_f^2\,h_f}{E_f}$$

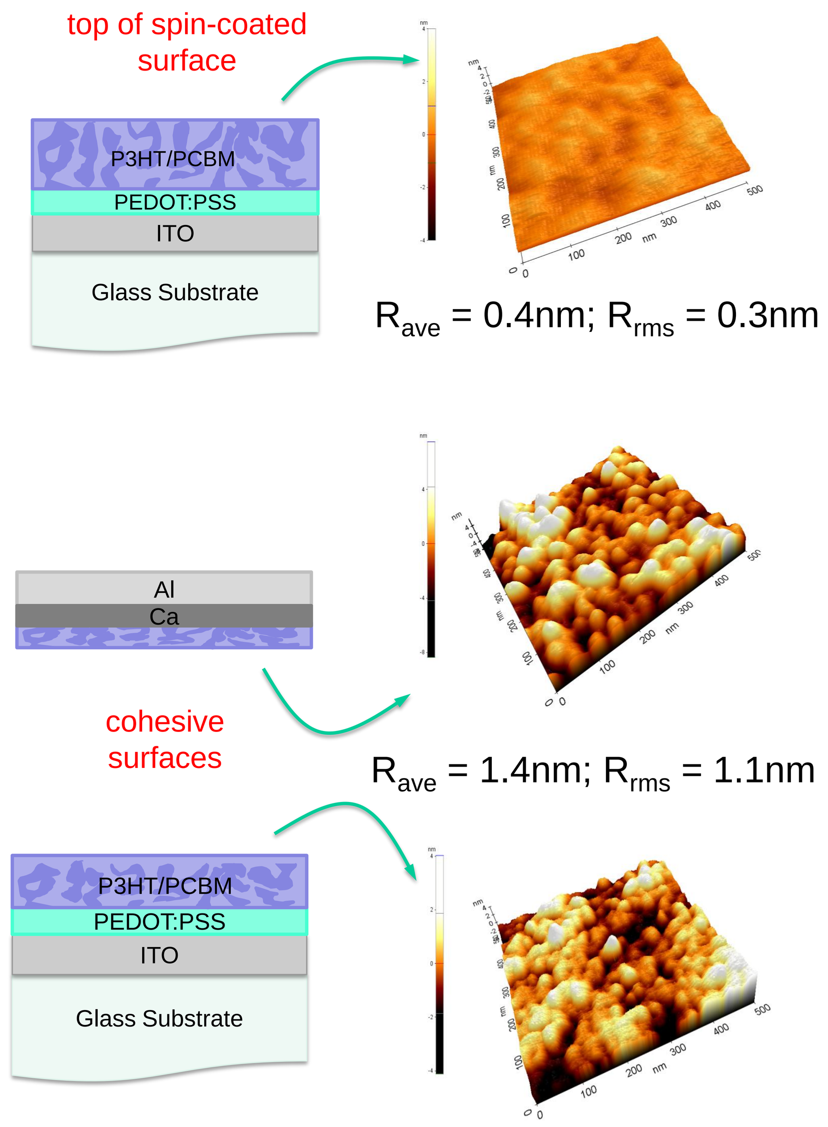
The DTS delaminator is used to measure fracture energy using the 4-point bending (FPB) technique by applying a crack driving "force" that is higher than the cracking "resistance" of the weakest layer in the thin film stack that makes up the solar cell



Preliminary measurements showing the range in cohesive fracture energy values for P3HT:PCBM organic photovoltaics

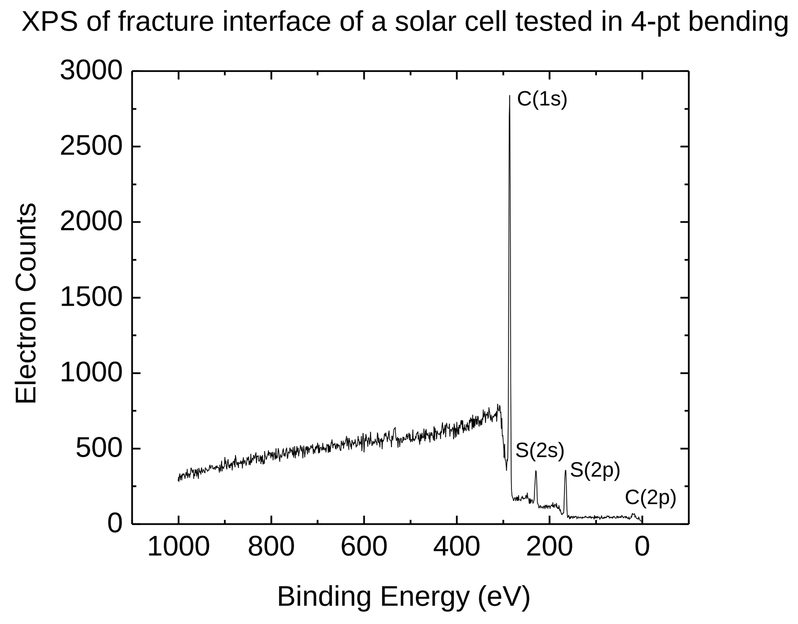
Adhesion/Cohesion Sample Preparation and testing

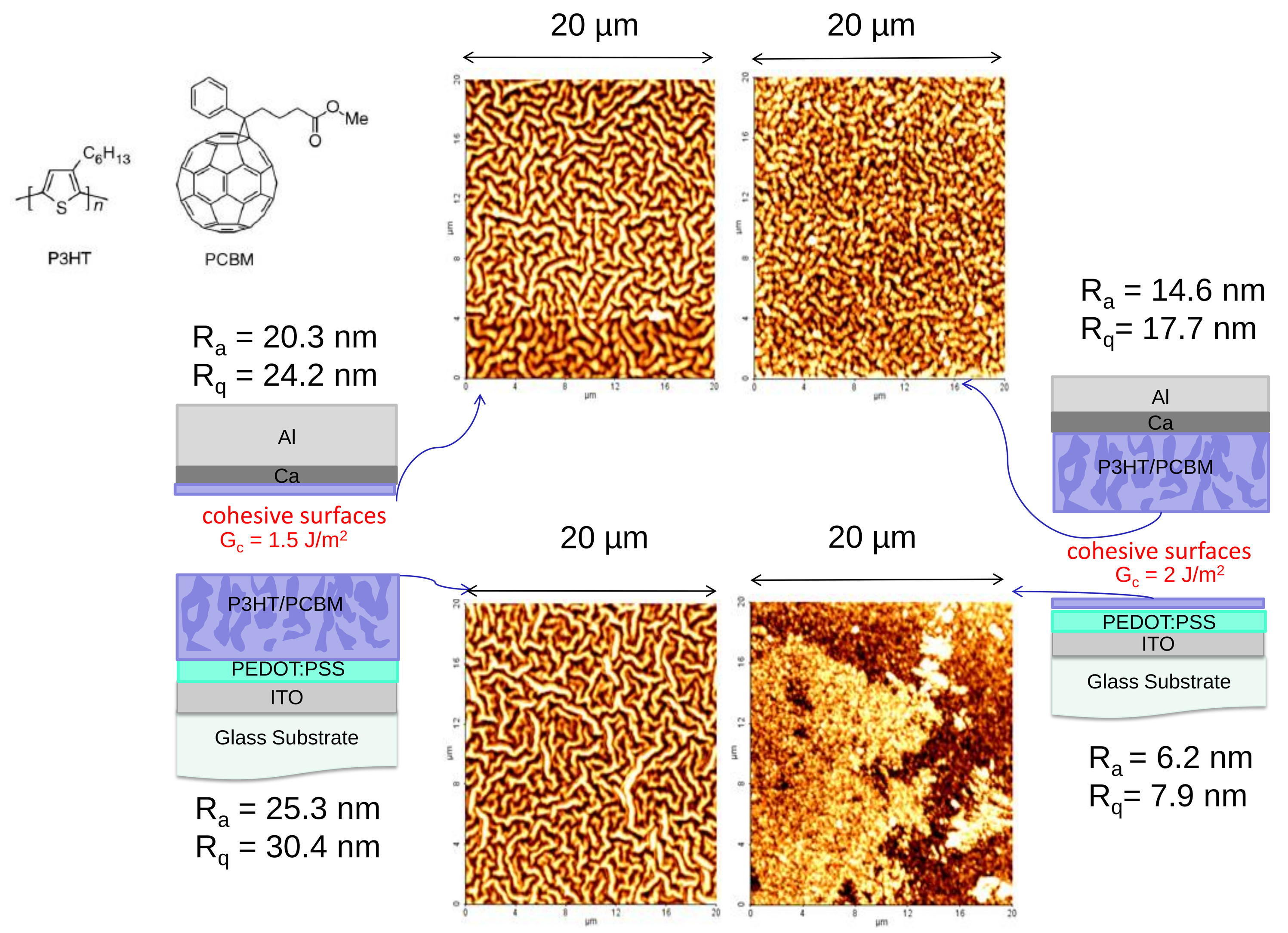




Adhesion specimens are fabricated by *a)* bonding a glass substrate to the solar cell with epoxy to produce a *b)* "solar cell sandwich" which is diced into beams that *c)* form the four point bend (FPB) specimens used to measure the fracture energy G_c by *d)* delaminating the solar cell inside the weakest layer.

Characterization of Cohesive Surfaces



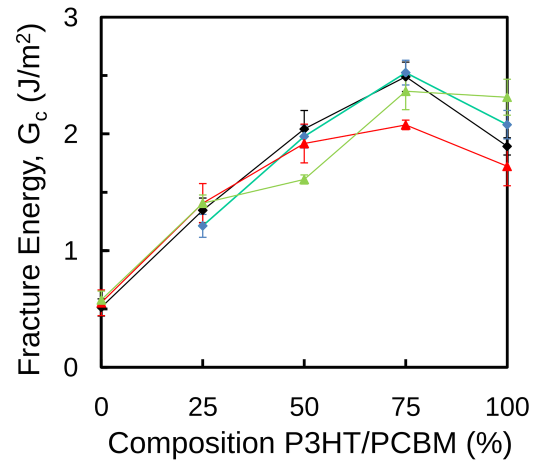


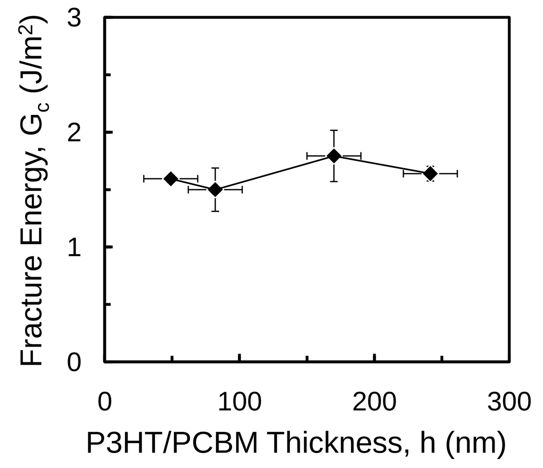
- XPS reveals similar debond path for DCB and 4-pt bend samples
- C ~ 93%, S ~ 7%
- Suggests cohesive failure in PCBM:P3HT layer

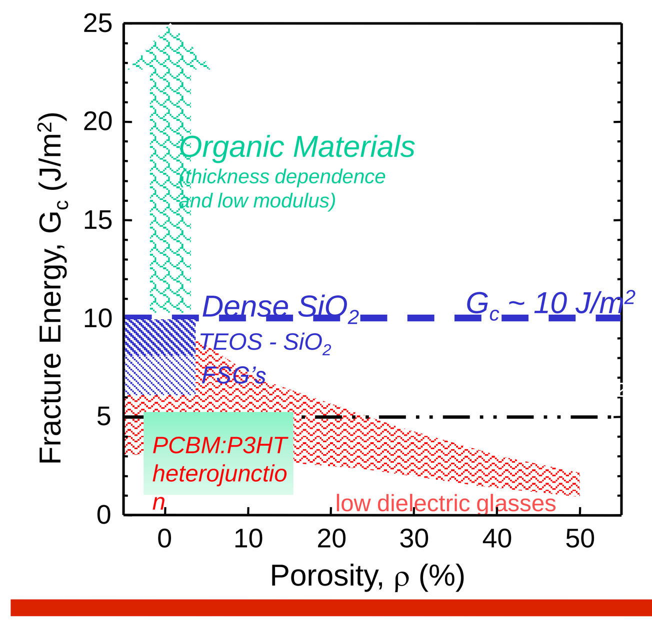
The P3HT:PCBM OPVs generally delaminate at two different locations in the BHJ layer. These locations, as shown above, have a characteristic cohesive fracture energy associated with them, where the top of the BHJ film is generally weaker than the bottom. The presence of ripples on the cohesive surface revealed by the AFM scan provides evidence of compressive stresses.

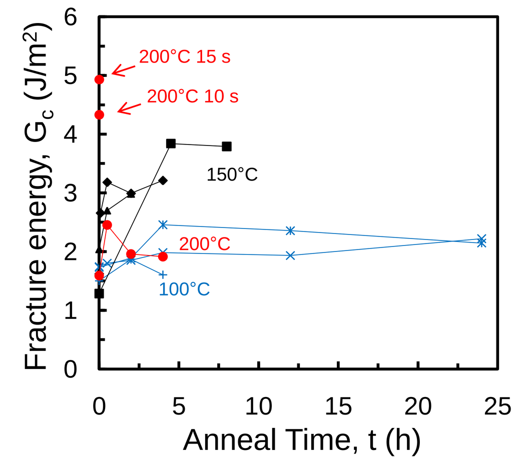
Factors Effecting Cohesion of P3HT/PCBM Layers

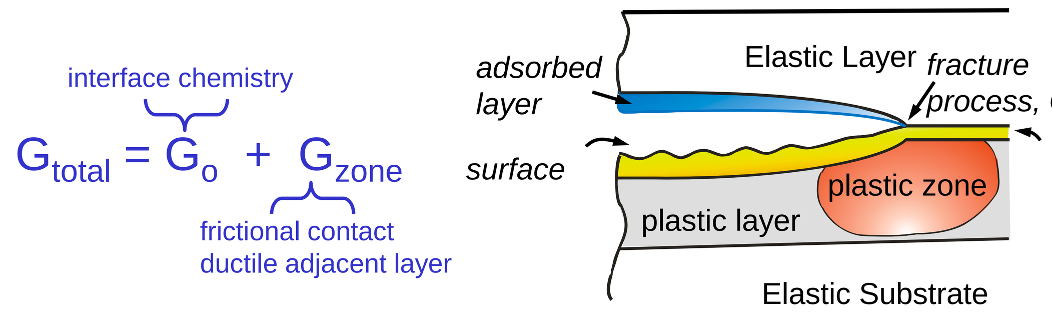
- Composition of the heterojunction layer:
  - Limited bonding to fullerene – expect low cohesion
  - Our measurements indicate higher ratios of P3HT to PCBM make tougher active layer
- Heterojunction layer thickness :
  - does not have a strong effect on cohesion
- Annealing:
  - Morphology of the P3HT:PCBM film changes with annealing, causing increased cohesion

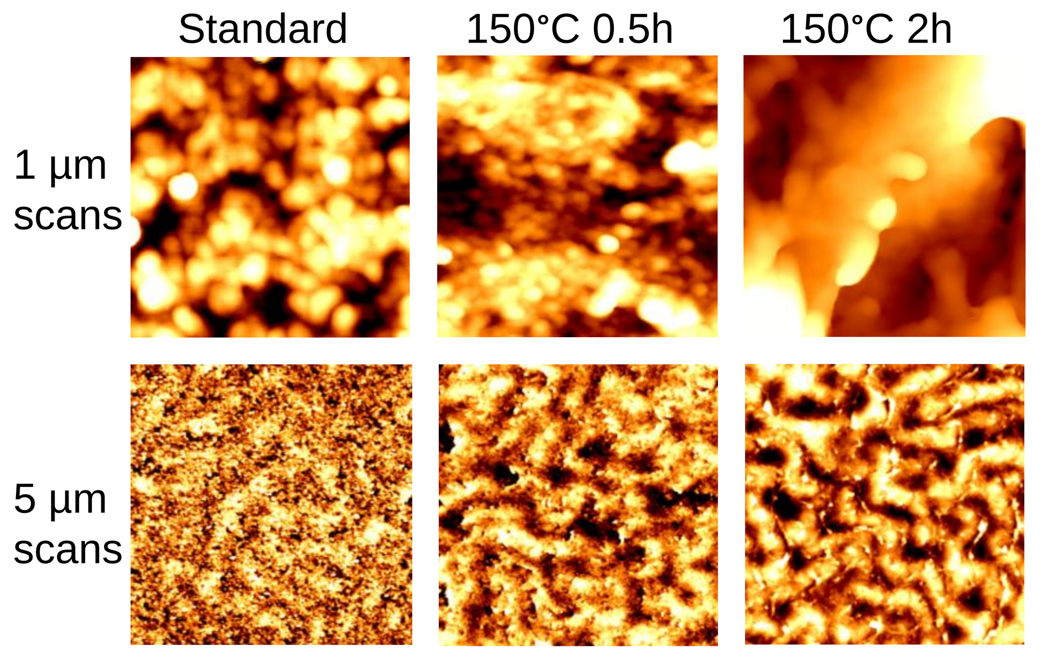












	Standard	150°C 0.5h	150°C 2h
R_a	4.0 nm	7.0 nm	41.5 nm
R_q	5.1 nm	9.0 nm	54.9 nm

5 micron AFM scans reveal the effects of annealing. The rougher morphology corresponds to higher cohesion fracture energy.

Note: All devices were cured at 90°C for 1h prior to subsequent anneals

Acknowledgements

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