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Scanning Nearfield Optical Microscopy of Polymeric Solar Cell Materials

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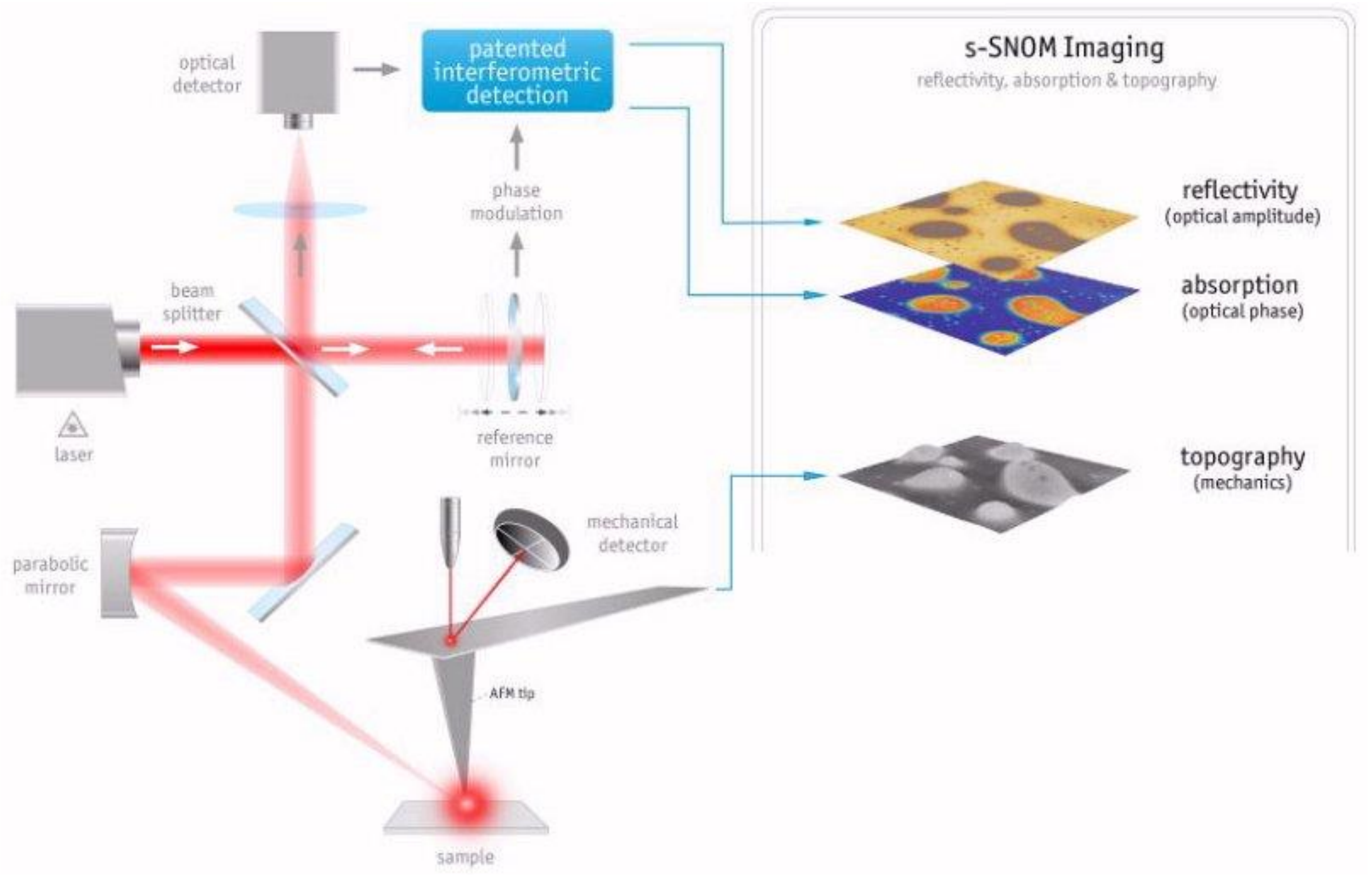
Summary

This project combines vibrational spectroscopy with a scanning near-field optical microscope that employs a sharp tip for an approximate spatial resolution within in the 20-nanometer range. The nanoscale structure is the key to understanding the functionality and deterioration mechanisms of a polymer. Whether or not the polymer components are blended with another, contaminated, or have any kind of previous deterioration can be probed with a scanning near field optical microscope (SNOM). This microscope can access below the diffraction limit by scattering light off a very sharp tip that is approximately 20nm in width. These interactions allow the tip to trace the physical structure of the sample while simultaneously using the scattered light to give chemical information. The infrared wavelength can be tuned to absorption bands of any polymer. In this poster, we focus on polymers related to solar energy: commercial silicone solar cells as well as organic solar cell components currently being researched, poly(3-hexylthophene) (P3HT) and Phenyl-C61-butyric acid methyl ester (PCBM).

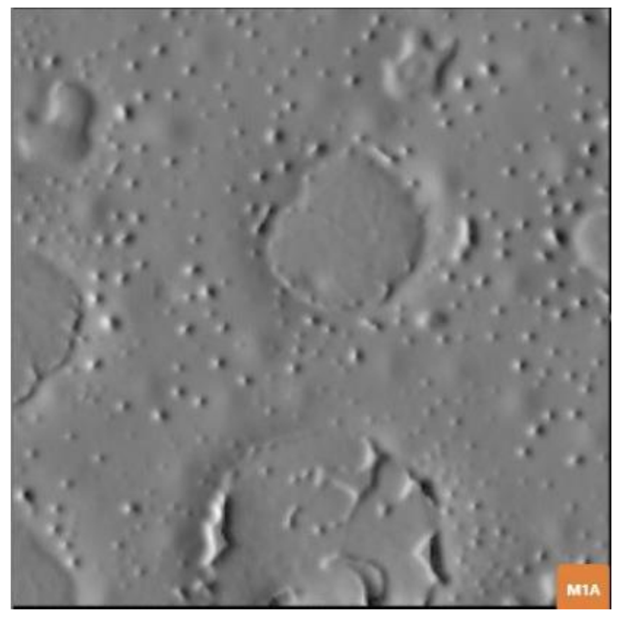
Imaging the Nanoscale



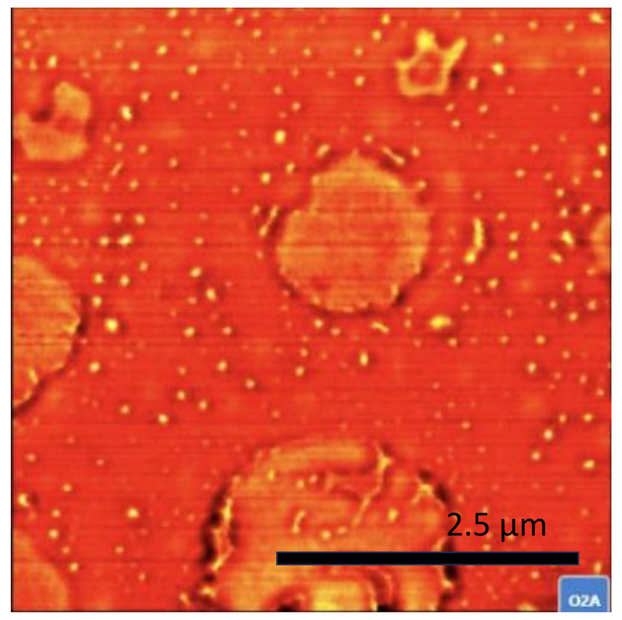
Nearfield optical microscope set up (NeaSpec)

Various molecules vibrate at specific frequencies, providing a 'fingerprint' to detect specific chemicals. However, a key limitation of conventional light spectroscopy is the diffraction limit. The solution is that there is a very sharp tip that is much closer than the wavelength of the light to the sample (nearfield). This tip will scatter light directly off the laser, exciting the sample and allowing spatial resolution on the nanometer scale past the diffraction limit [1, 2]. This scanning probe instrument allows for both nearfield optical and atomic force nanoscopic imaging (yielding morphology) at the same time. P3HT and PCBM [3] were in thin film form. The topography is the mechanical image, which is the differences in z-height measured by the AFM tip. The optical amplitude shows the reflectance of the sample, while the optical phase shows the absorbance. The optical images reveal vibrational fingerprints in the infrared spectral region.

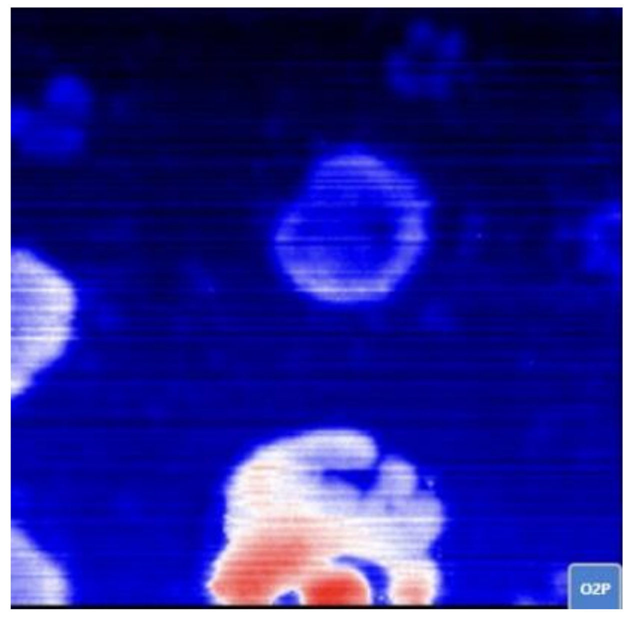
P3HT Organic Solar Cell Component



Topography (z-height)



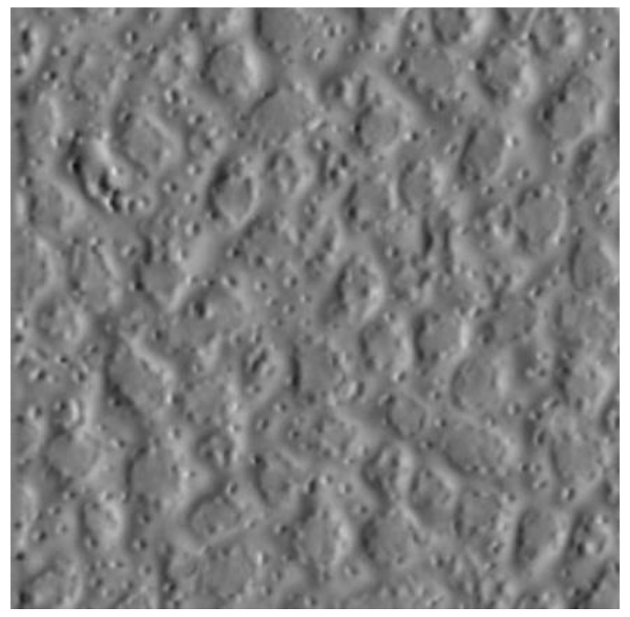
Reflectivity (Optical Amplitude)



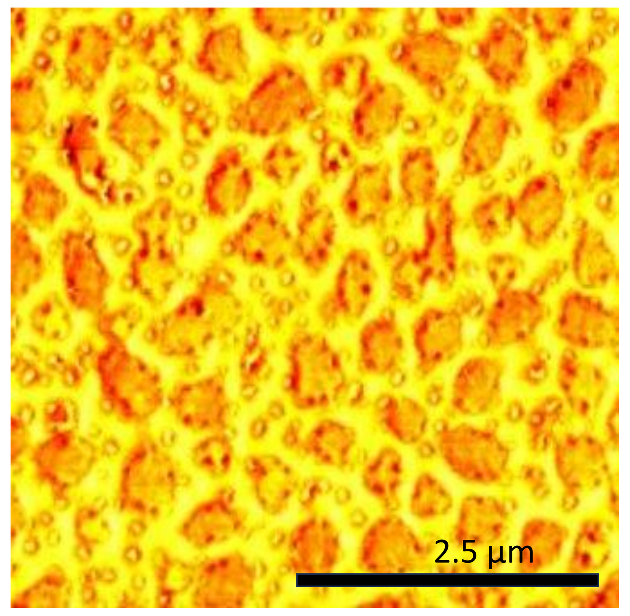
Absorbance (Optical Phase)

Laser Frequency is tuned to 1425 cm^{-1} with a scan area of 5 µm x 5 µm. These maps reveal physical, optical reflectivity, and optical absorbance characteristics. The round deposits of P3HT clearly show spatial differences between the morphological and chemical distributions.

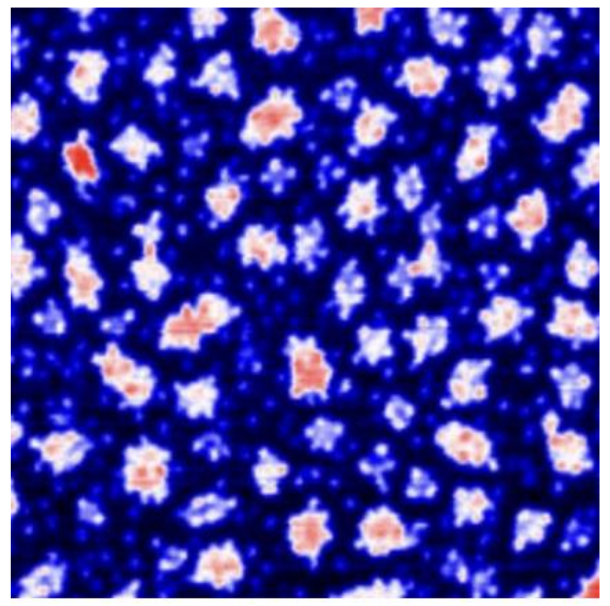
PCBM Organic Solar Cell Component



Topography (z-height)



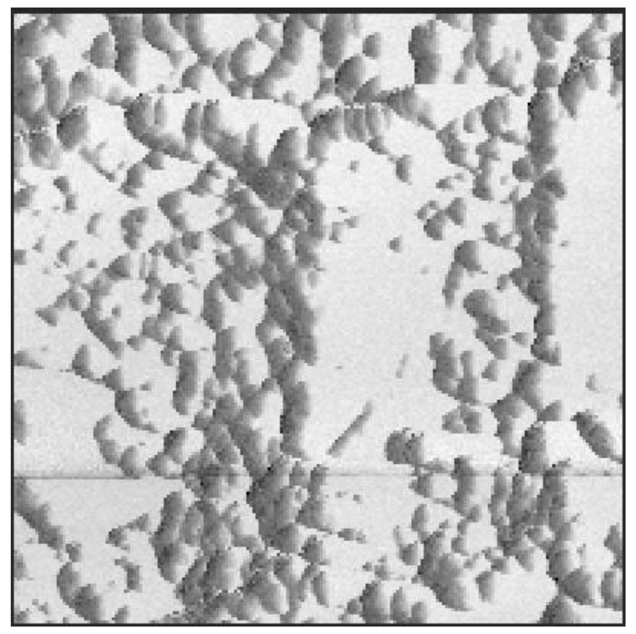
Reflectivity (Optical Amplitude)



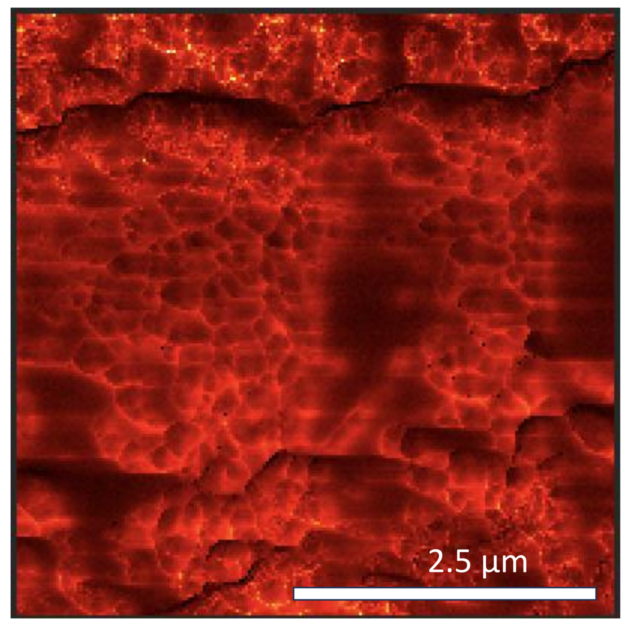
Absorption (Optical Phase)

Laser Frequency is tuned to 1250 cm^{-1} with a scan area of 5 µm x 5 µm. The map resolves sub-micron features, such as aggregates and their spatial distributions.

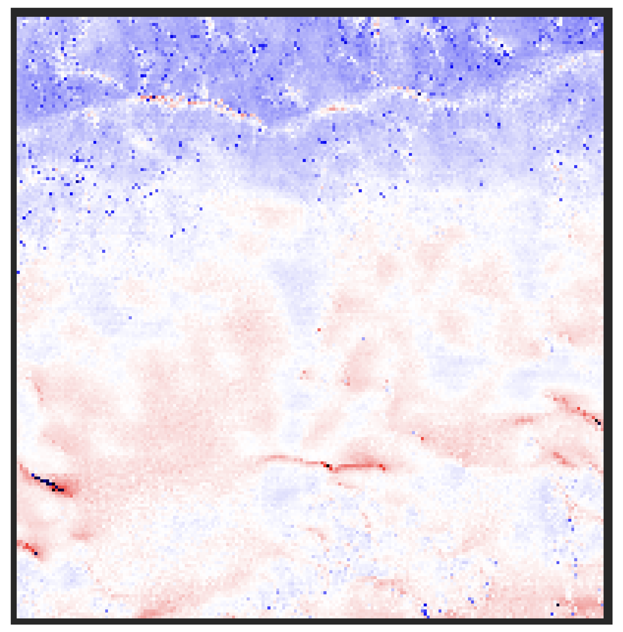
Silicone Solar Cell



Topography (z-height)



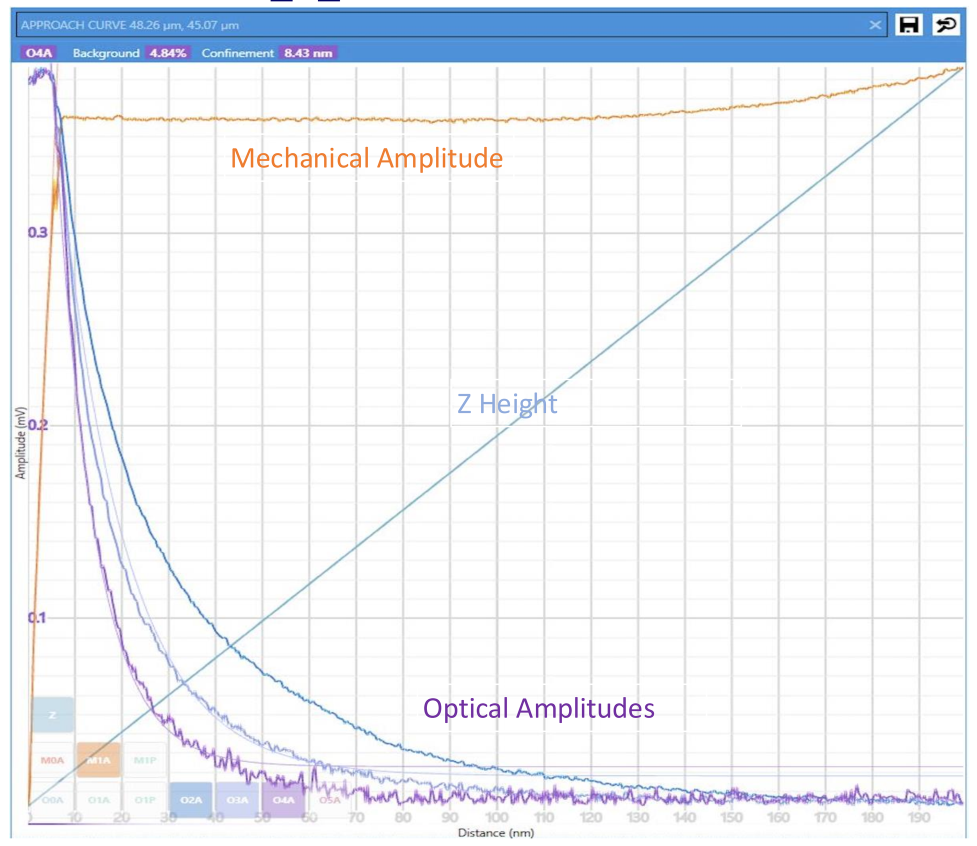
Reflectivity (Optical Amplitude)



Absorbance (Optical Phase)

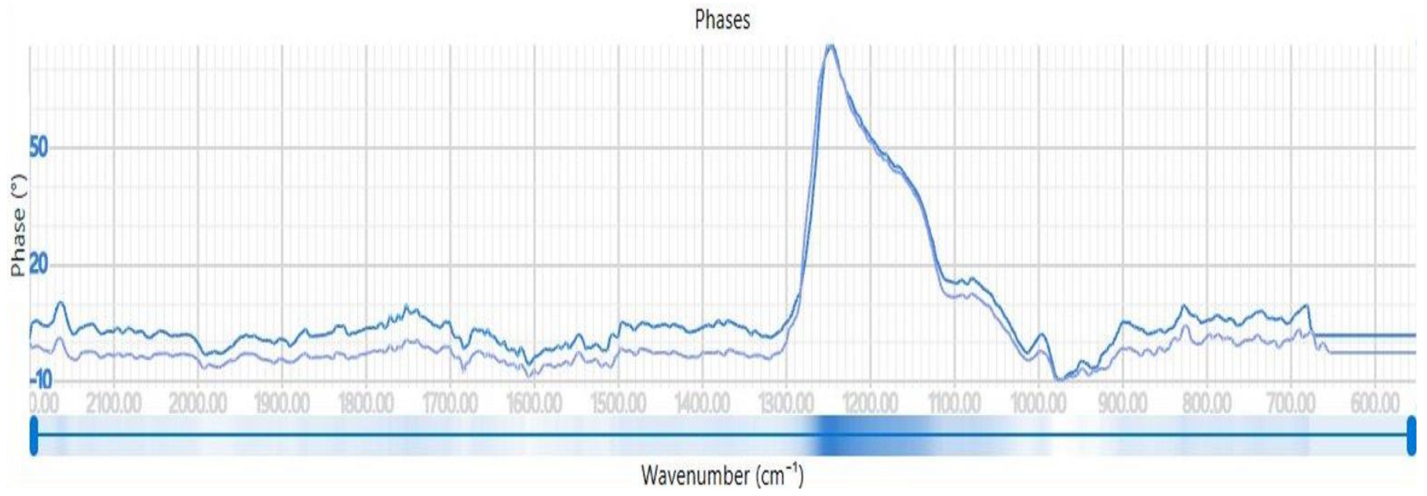
Laser Frequency is tuned to 1250cm^{-1} with a scan area of 5 µm × 5 µm. Due to the solar cell's roughness, there are limitations to the resolution of the images.

Approach Curve



While increasing the z-height linearly, mechanical amplitude will increase linearly, while optical signals will decrease nonlinearly.

SiO_2 IR Point Spectrum



Conclusions

➢Scanning near field optical spectroscopy (SNOM) provides chemically specific images on the nanoscale

➢SNOM show spatial differences between morphological and chemical information among polymeric solar cell materials at ~ 20 nm resolution

➢SNOM reveals spatial distributions of aggregates, and differences between P3HT and PCBM

➢In future work we aim to chemically image the degradation of solar cells

References

[1] B. Noelting, Methods in Modern Biophysics, 2nd ed. Ch. 7, p. 121 Springer (2006).

[2] F. Huth et al., Nano Lett. 12 (2012), 3973–3978. https://doi.org/10.1021/nl301159v

[3] P. R. Berger, M. Kim, J. Ren. Sus. En. 10 (2018) 013508. https://doi.org/10.1063/1.5012992

Acknowledgements

We would like to thank our research advisor, Dr. Alfons Schulte for his mentorship. Thank you to Dr. Mueller-Buschbaum for providing the solar cell material polymer film. Funding for nanoscale instrumentation was provided by NSF MRI#2216239. We appreciate support from the UCF EXCEL URE and SURF programs.