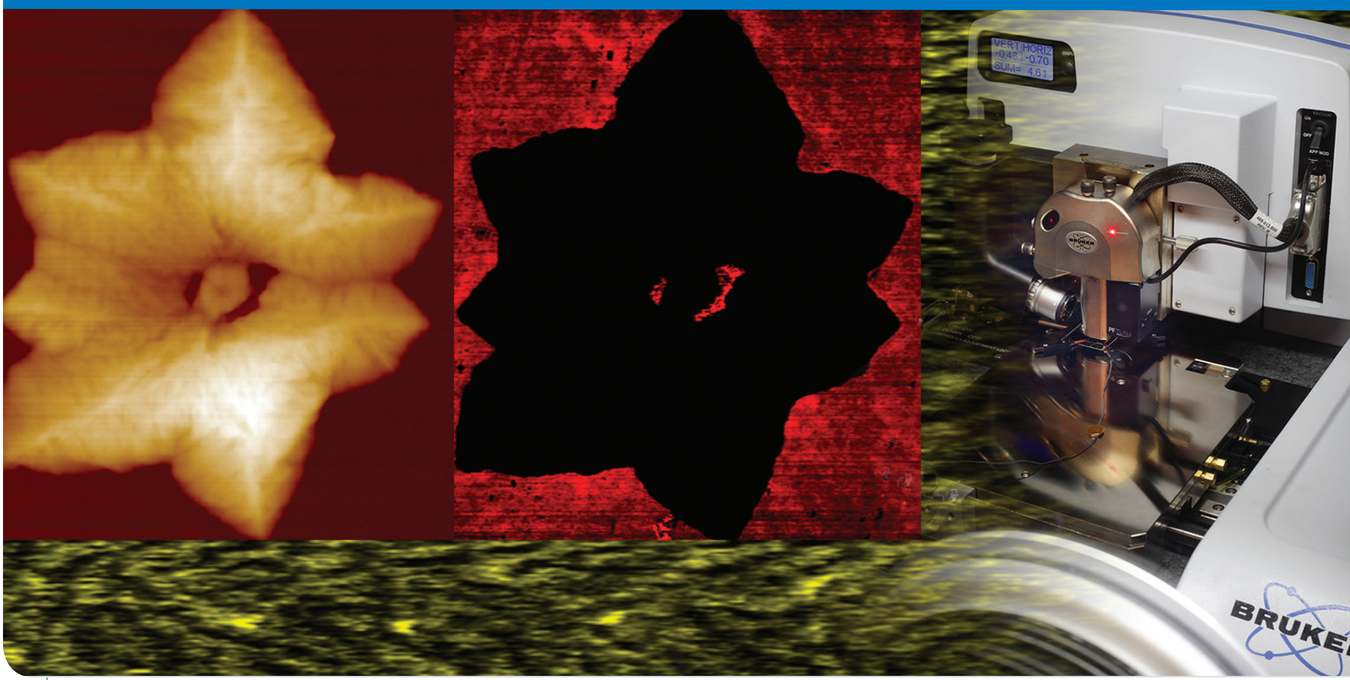


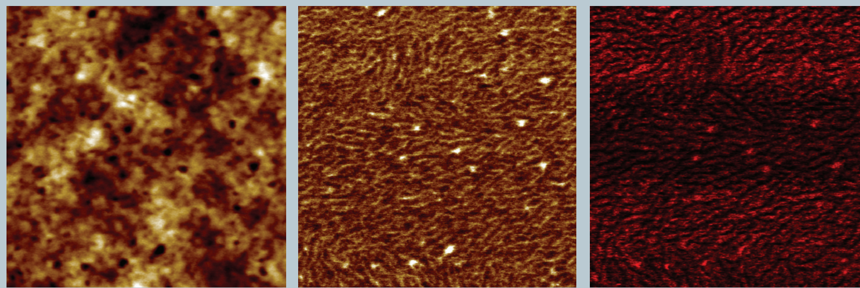
Photoconductive Atomic Force Microscopy

Quantitative, High-Resolution OPV Characterization

Bruker's Photoconductive Module for the Dimension Icon® Atomic Force Microscope (AFM) enables quantitative nanoscale electrical characterization of organic photovoltaics (OPVs) at the highest resolution. In addition, the module provides compatibility with both industry-standard Newport solar simulators for uniform sample illumination and Bruker's turnkey 1ppm environmental control accessory. Building upon proprietary PeakForce TUNA™ nanoelectrical characterization and the Icon's industry-best AFM performance, this photoconductive atomic force microscopy (pcAFM) solution provides the highest resolution, most reliable photoconductivity mapping available for soft, fragile samples such as OPV materials.

The Complete Solution for pcAFM

- Highest resolution conductivity imaging with PeakForce TUNA
- Correlated quantitative nanomechanical property mapping with PeakForce QNM®
- Turnkey OPV environmental control with 1ppm glovebox package



Topography (left), adhesion (middle), and photocurrent (right) of P3HT-PCBM. Image size 1µm. The photocurrent is seen to be localized in fibrils formed by P3HT. Data courtesy of Noham Sebaihi (CIRMAP – UMONS, Belgium).

OPV Research Challenges

Nanoscale structure and properties are at the heart of bulk heterojunction OPVs and their efficiency optimization. Microphase separation at the nanoscale affects OPV external quantum efficiency (EQE) through mechanisms such as exciton losses (e.g., when the path to a phase boundary is longer than ~10nm), recombination losses at phase boundaries, and collection losses when insufficient mobility or lack of continuous conductive paths prevent charges from reaching the electrode. Since atomic force microscopy can investigate nanoscale topography, phase separation, and electrical properties of device structures, it would seem to be an ideal technique for pinpointing EQE limiting mechanisms.

However, conventional AFMs have had limited success in OPV research. Typically, AFM conductivity mapping is based on contact mode, which involves lateral forces and leads to sample damage and tip contamination. The result is low spatial resolution and artifacts that mask desired information. While TappingMode™ can achieve higher spatial resolution, it does not allow conductivity mapping nor does it provide unambiguous nanomechanical (and thus chemical) information. Adding to the challenge is the chemical fragility of OPVs, necessitating 1ppm-level control of oxygen and water when working in situ with unsealed devices. Finally, photocurrent interrogation requires controlled sample illumination.

Bruker's Breakthrough Technology Solution

Bruker's exclusive PeakForce TUNA mode solves these limitations by providing the highest spatial resolution on fragile organic and polymer samples with direct, precise force control at the pA level and complete elimination of lateral forces. Similarly, proprietary PeakForce QNM enables simultaneous, directly correlated quantitative nanomechanical information for unambiguous identification of the microphase nanostructure. The Photoconductive AFM module makes these capabilities, along with turnkey 1ppm environmental control compatible with the industry-leading Dimension Icon platform. It is also compatible with industry-standard Newport solar simulators to enable even, backside sample illumination produced across the scan area, allowing PeakForce TUNA conductivity mapping while illuminating with achievable intensities equivalent to several 100 suns.

OPV Nanoelectrical Characterization Case Study

The data on page one shows topography and photocurrent under short-circuit condition of a well-studied system, poly (3-hexylthiophene) (P3HT) donor and [6,6]-phenyl-C61 butyric acid methyl ester (PCBM) acceptor. The mixture was annealed at high temperature leading to the formation of micron-sized crystals. The data clearly shows photocurrent only in the flat (non-crystalline) areas, consistent with the hypothesis that a pure PCBM crystal was formed, while the rest of the surface is still covered with photoconductive, nanostructured P3HT/PCBM mixture.

To understand the mechanism of photocurrent generation in the P3HT/PCBM mixture, a much higher resolution study is needed (see 1µm images on this page). Where the topography only shows nanometer-scale roughness, the concurrently acquired adhesion image immediately reveals the presence of a nanoscale fibrillar structure, where fibrils surround more compact domains. The correlated current map resolves the photocurrent at the same 10nm level as the adhesion image and shows photocurrent to be present only at the location of the fibrils.

Combining the high-resolution data with the large image on the previous page unravels the physical picture. P3HT forms fibrils surrounding nanoscale PCBM crystallites. The photocurrent is dominated by hole-hopping in the P3HT domains. Only the combination of PeakForce TUNA with the new Dimension Icon Photoconductive AFM module could generate the high-resolution, artifact-free data that serves as direct evidence for this dominant conductivity mechanism.

Cover images

Topography (left) and photocurrent (right) images of P3HT-PCBM under short circuit conditions. Image size 10µm. Data courtesy of Noham Sebaihi (CIRMAP – UMONS, Belgium).

Bruker Nano Surfaces Division

Santa Barbara, CA • USA
Phone +1.805.967.1400/800.873.9750
productinfo@bruker-nano.com

www.bruker-axs.com