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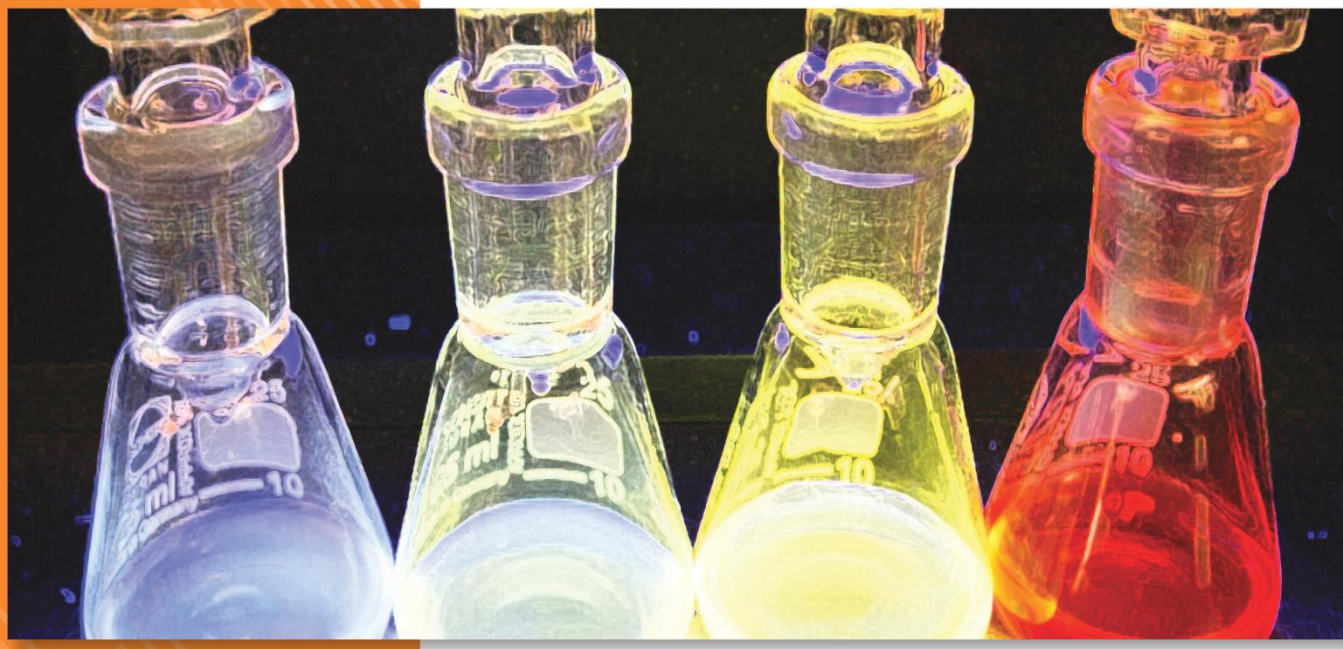

Mapping the Energetic Landscape of Solution-Processed Organic Photovoltaic Devices

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The field of organic photovoltaics (PV) is experiencing a renaissance with remarkable advances in power conversion efficiencies recently reported for both single and double junction devices. Despite these major breakthroughs many aspects of device physics of organic PVs, in particular those with low energy offsets, remain unknown. One of the most common aspects of the device, routinely used for device physics interpretation is the energy level diagram (energetic landscape) of the solar cell, with such diagrams being ubiquitous in literature, appearing in almost every publication. Despite the importance of energy level diagrams in determining the elementary processes taking place in the device (e.g. charge generation, transport and extraction), accurately determining these diagrams is extremely challenging, especially for solution-processed systems. Most commonly, these diagrams are constructed by combining energy values for the individual components as obtained by different methods, resulting in a large scatter of reported values even for the same material systems. In addition, this approach neglects to account for interfacial effects such as formation of dipoles or band bending.

In this talk, I will present a new method that can directly measure the vertical energetic landscape of solution-processed organic photovoltaic systems. Our methodology is based on UPS depth profiling, made possible by the use of a gas-cluster ion beam that allows essentially damage-free sputtering of organic materials. First, we demonstrate the efficacy of our technique for both bi-layer and bulk heterojunction layers of a model PV system and establish its ability to accurately probe interfacial effects such as dipoles and band bending. Next, we apply our method to the study of a range of high performance material systems with either fullerene or non-fullerene acceptors and demonstrate an excellent agreement between the measured photovoltaic gaps, the CT state energies and corresponding open-circuit voltages of the devices. Finally, I will present three examples in which we apply UPS depth profiling to study vertical stratification in sequentially deposited organic solar cells, effects of degradation in polymer and small molecule based-devices and the energetic alignment in ternary blends consisting of fullerene and non-fullerene acceptors.

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Campus Freudenberg
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