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Characterization of indium tin oxide surfaces and interfaces using low intensity x-ray photoemission spectroscopy

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Ultraviolet photoemission spectroscopic (UPS) and x-ray photoemission spectroscopic (XPS) characterizations of indium tin oxide (ITO) surfaces prepared in ambient environment significantly lower the work function of the ITO surface. This artifact complicates the investigation of ITO surfaces and interfaces using XPS and UPS. The presented results demonstrate that, while the exposure of the sample surface to standard UPS UV sources results in a reduction of the work function within a second or less, XPS measurements show a more gradual work function change over the course of hundreds of seconds. This allowed the design of a measurement protocol based on low intensity x-ray photoelectron spectroscopy work function measurements, which do not cause significant work function changes during the exposure time needed for characterization. Applying this technique, the orbital lineup between the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital of the semiconducting polymer poly(3-hexylthiophene) (P3HT) and the valence and conduction bands of ITO were determined. The results indicate that it is appropriate to describe the ITO/P3HT junction as semiconductor heterojunction, and that hole injection most likely occurs between ITO conduction band minimum and P3HT HOMO.