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Plasmonic photoinjection spectroscopy: Unraveling charge carrier injection directly in organic electronic devices

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Current injection and extraction at a metal-organic semiconductor interface is central to the operation of all organic (opto)electronic devices, strongly influencing the efficiency and performance of organic light emitting diodes, photovoltaics, and thin film transistors. Efforts to date have developed various working models aimed at describing injection in organic semiconductors, however, a broadly applicable, comprehensive understanding at the level needed for continued development and commercialization of these devices remains to be developed. To a large extent, the difficulty in reaching this goal has been intertwined with a lack of techniques capable of comprehensively characterizing the interface energetics and bulk electronic transport properties *directly* in an operating device.

Here, we exploit resonant coupling to the surface plasmon polariton (SPP) mode(s) of a metal contact to extend the method of internal photoemission[1-4] and use it to investigate the injection process in various small molecule organic semiconductor devices. By measuring the injected current on and off resonance as a function of wavelength and external bias for sub-gap, near-infrared excitation, we determine the electron and hole injection barriers directly in the devices of interest. As compared to conventional internal photoemission under free-space illumination, resonant coupling to an SPP mode affords three important advantages in application to organic semiconductors: an order of magnitude improvement in sensitivity, unambiguous differentiation between photoinjected current and spurious trap-state photoconductivity, and the capability to measure bulk time-of-flight mobility directly in sub-100 nm thick devices.

This talk will focus on the development and application of this method to several commonly used small molecule and polymeric semiconductors, including tris(8-hydroxyquinoline) aluminum (Alq_3), N,N'-diphenyl-N,N'-bis(1-naphthyl) -1,1'biphenyl-4,4" diamine (NPD), and poly(9,9-di-*n*-octylfluorene-*alt*-benzothiadiazole) [F8BT] in conjunction with Ag, Au, and Al contacts. Additionaly, we explore the effects of interface layer additions such as the use of LiF with an Al contact, and we discus whether the coherent nature of SPP quanta lead to differences in photoemission as compared to excitation of incoherent hot carriers. By measuring both the interface energetics and bulk transport properties of a single device in the *same* experiment, we are able to rigorously test injection models applied to the current-voltage characteristics with the aim of progressing toward a better understanding of charge carrier injection and extraction in organic electronic devices.

References

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