

Towards Quantitative Comparisons of Bulk and Local Optoelectronic Properties of Emerging Solar Cell Materials with Interdigital Electrodes

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Primary CNF Tools: Hamatech Hot Piranha Cleaner, Hamatech developer tool, Class II Resist Spinners, Edge Bead Removal System, ABM Contact Aligner, Hamatech Wafer Processor, Oxford Plasma Etchers (81 and 82), SC4500 Odd-Hour Evaporator, SC4500 Even-Hour Evaporator, Disco Dicing Saw

Abstract:

Gold interdigitated electrodes were fabricated using a simple photolithography procedure. The electrodes were used in space charge-limited current (SCLC) experiments with a thin film of N,N'-Bis(3-methylphenyl)-N, N'-diphenylbenzidine embedded in a polystyrene matrix (TPD:PS). Optimized J–V curve acquisition parameters were determined and will be used in subsequent electric force microscopy (EFM) experiments to compare the bulk charge mobility of the TPD:PS from SCLC to the local charge mobility measured using EFM.

Summary of Research:

Organic photovoltaics (OPVs) and lead halide perovskites (LHPs) are two classes of photovoltaic materials that have attracted significant attention for their application in solar cell devices, with single-junction OPVs reaching 20% power conversion efficiency (PCE) as of 2025 and LHPs reaching 26.15% as of 2024, approaching the Shockley-Queisser limit [1–4]. Despite recent progress, there remain open questions about these materials, specifically the sub-Langevin charge recombination exhibited by OPVs and the generation of light-induced vacancies observed in LHPs [5–6]. Understanding these phenomena requires quantification of the local charge mobility. While novel electric force microscopy (EFM) measurements—a subclass of atomic force microscopy that detects electrostatic forces between a charged cantilever tip and sample—will be used to quantify local electronic properties, an established technique is needed to quantify the bulk charge mobility. Space charge limited current (SCLC) measurements can be used to determine the bulk mobility of a material and can be performed using fabricated gold interdigitated electrodes.

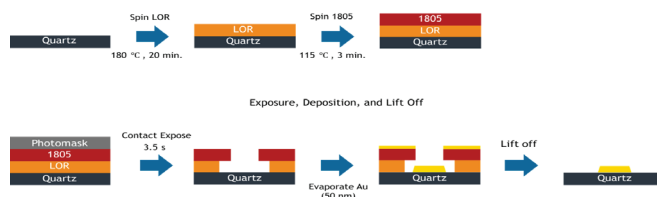


Figure 1: Schematic representation of the fabrication of gold interdigitated electrodes. Specific parameters are provided where possible.

Gold interdigitated electrodes were fabricated using a simple photolithography procedure shown in Figure 1 [7]. Four-inch quartz wafers (Mark Optics) were cleaned using hot piranha solution. The wafers were dehydrated at 180°C for 10 minutes and coated with LOR 1A resist (dynamic dispense at 400 rpm for 4 s, 4000 rpm for 45 s). The layer was soft-baked for 20 minutes at 180°C before S1805 resist was deposited statically (4000 rpm for 60 seconds, 1000rpm/s). The stack was soft-baked at 115°C for 3 minutes, and the edge bead was removed. The coated wafers were contact-exposed (ABM High-Resolution Contact Aligner) with near UV light for 3.5 s, with a corresponding dose range of 41.7 to 53.6 mJ/cm². The wafers were developed using AZ 762 Metal Ion Free developer with single-puddle spray development for 60 seconds (Hamatech). The resulting patterned wafer was descummed using an Oxford 81 Reactive Ion Etcher (50 mW, 30 s) before electrode deposition (5 Å Cr, 500 Å Au, 0.4 Å/s gold deposition rate). Lift-off was performed using 726 Metal Ion Free developer before dicing.

The fabricated electrodes were used in space charge-limited current (SCLC) experiments on the molecularly doped polymer system N,N'-Bis(3-methylphenyl)-N,N'-diphenylbenzidine in polystyrene (hereafter referred to as TPD:PS). This system is known to produce space charge-limited current and has a well-established bulk charge mobility [7–8]. TPD:PS thin films were spun onto

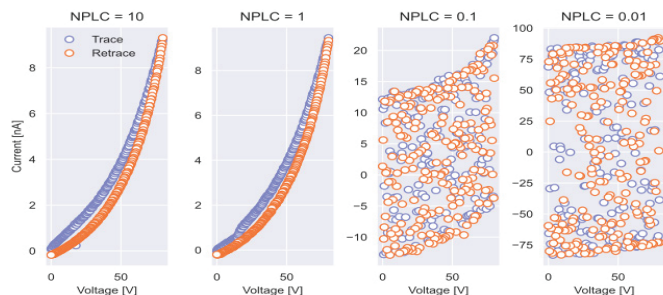


Figure 2: Current–Voltage curves for a *N,N'*-Bis(3-methylphenyl)-*N,N'*-diphenylbenzidine (TPD):polystyrene sample on gold interdigitated electrodes, varying the number of power line cycles (NPLC) used during data acquisition. The electrodes have a 12–micron separation and 1.5–mm length. All scans were taken with a constant voltage delay of 1 second.

interdigitated electrodes with a separation of twelve μm and a digit length of 1.5 mm using the protocol found in reference 7. Samples were loaded into a custom high–vacuum microscope where space charge–limited current measurements were performed using a Keithley 6430 source meter unit. Figures 2 and 3 show current–voltage curves collected as a function of voltage delay and number of power line cycles (NPLC). The optimum conditions were determined to be ten power line cycles and a voltage delay of 5 seconds. These conditions will be used for subsequent EFM experiments in the space charge limit.

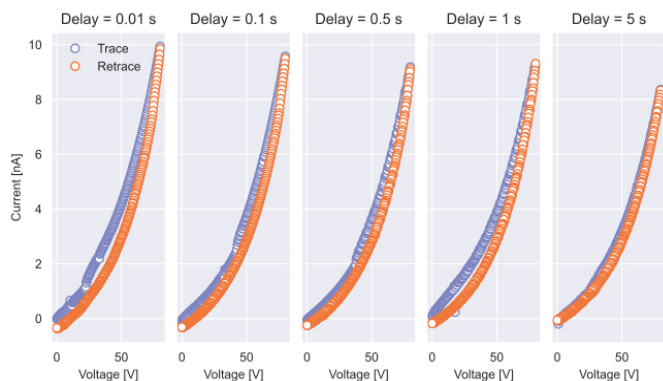


Figure 3: Current–Voltage curves for a *N,N'*-Bis(3-methylphenyl)-*N,N'*-diphenylbenzidine (TPD):polystyrene sample on gold interdigitated electrodes, varying the voltage delay used during data acquisition. The electrodes have a 12–micron separation and 1.5–mm length. All scans were taken with a constant NPLC of 10.

Conclusions and Future Steps:

Gold interdigitated electrodes were fabricated using a simple photolithography procedure. Space charge–limited current experiments on the molecularly doped polymer TPD:PS were performed, and space charge–limited current was directly observed as a non–linearity in the current–voltage curve. Changing the scan speed of the experiment by varying the NPLC and voltage delay revealed the optimal conditions of ten PLC and a five–second voltage delay. These conditions will be used in future experiments to determine the bulk charge mobility of the conductive polymer system, which will be compared to the local charge mobility quantified from novel EFM measurements.

References:

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