Fabrication of CuPc/C60 Heterojunction Mediated Broadband Photodetector Using Physical Vapor Deposition

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Introduction

Commercial photodetector technologies are dominated by the use of inorganic semiconductors. However, organic semiconductors offer several advantages over inorganic semiconductors, including greater flexibility, transparency, spectral response tunability, and low-cost manufacturing. Among many organic materials, a heterojunction based on copper phthalocyanine (CuPc)/fullerene (C60) was chosen for investigation. ITO/CuPc/C60/Al photodetector devices were fabricated through physical vapor deposition. Two versions of devices were fabricated. Device 1 had CuPc and C60 thicknesses of 80 nm and 100 nm, respectively. Device 2 had equal thicknesses of 120 nm. Both devices had Al as the top electrode of thicknesses 100 nm.

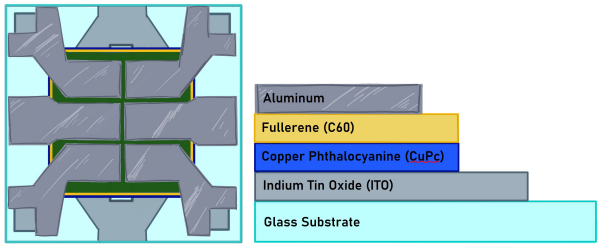
Methods

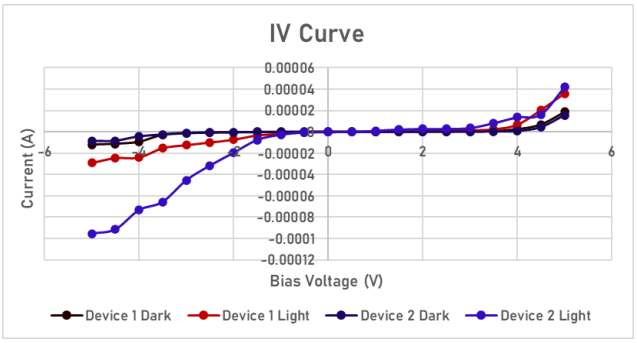
CuPc and C60 were purchased from Luminescence technology corp, and aluminum was purchased from Kurt J Lesker. Devices were fabricated on indium tin-oxide anode patterned substrates. Substrates were cleaned in Jelight model 42 UVO cleaner for 15 minutes, and subsequently submerged in deionized water and placed in a VWR 150D ultrasonic cleaner for 10 minutes. Before deposition, masks were designed for metal deposition. Masks were created on AutoCAD 2024 and patterns were cut from a Polyethylene Naphthalate (PEN) sheet using a VersaLaser VSL2.30.

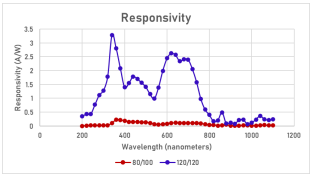
For deposition, substrates were fitted to masks and placed on the ceiling of the Angstrom systems deposition chamber. Materials were loaded on tungsten boats and placed inside the deposition chamber. Deposition always followed the order: CuPc, C60, then Aluminum. For the organic materials CuPc and C60, the deposition was operated on manual, with power within the range of 19-21.5% and 20-23%, respectively. For the Aluminum deposition, the machine was operated on automatic using the given recipe.

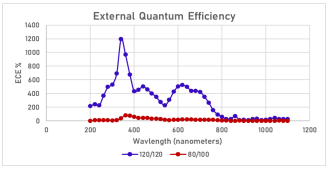
The devices were tested using an Agilent E3631A voltmeter and a Keithley 6485 picoammeter. The devices were biased in increments of 0.5 V in the range of -5 and 5 V. Current of the devices were measured at each bias under full spectrum white light, broadband red fiber optic, and 360 nm monochromatic light. The current over the spectrum between 200 - 1100 nm was measured using a Stanford Research Systems SR830 Lock-In Amplifier. The power over the spectrum was measured using a Thorlabs PM100USB power and energy meter.

Results









The spectral photoresponsivity, external quantum efficiency (EQE), and detectivity were calculated from the measurements. The peak photoresponsivity of device 1 was 0.22 A/W at 340 nm. The peak for device 2 was 3.28 A/W at 340 nm. The highest EQE for device 1 81.8% at 340 nm. The highest EQE for device 2 was 1199% at 340 nm. The highest detectivity for device 1 was 2.87E13 at 340 nm. Device 2 had a peak detectivity at 4.45E13 at 340 nm.

Conclusions

Both devices were most responsive at 340 nm within the high ultraviolet range. Device 2 exceedingly outperformed device 1, which could have been due to device 2's greater thickness, which allowed for a larger depletion region for electron excitations. However, the photoresponse in both devices were feeble than those of high-end commercial silicon photodetectors. Performance of these devices could be improved by exploring more variations in thickness and further optimizing the fabrication process.

References

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