3D Printed Optoelectronics: Silicon Nanocrystal LEDs & Polymer Photodiodes

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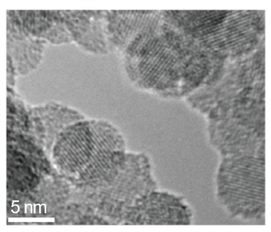
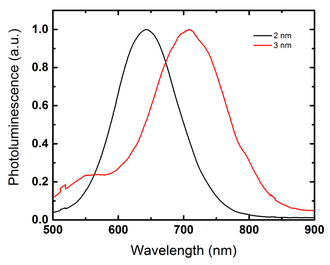
Introduction

- ✓ Application of 3D printing to optoelectronic devices that are conventionally fabricated by semiconductor technology renders high flexibility in device design and material selection
- ✓ Performance of the 3D printed optoelectronics can be optimized by ink development and uniformity control of the printed patterns
- ✓ Multifunctional devices can be fully 3D printed with basic optoelectronic elements onto freeform surfaces

Active Materials

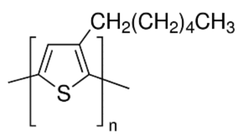
- ✓ The non-toxic silicon nano crystal (SiNC) with high electroluminescence efficiency was printed as the emissive layer of light emitting diodes (LEDs)



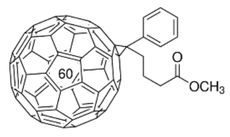


(*SiNCs were provided by the Kortshagen Group in Mechanical Department of UMN)

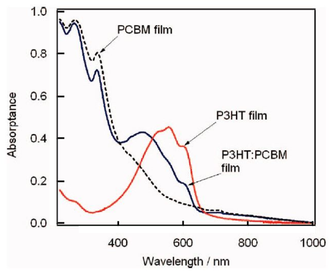
- ✓ P3HT:PCBM, which has been intensively studied for high-efficiency organic solar cells, is printed as the active layer of PD



P3HT

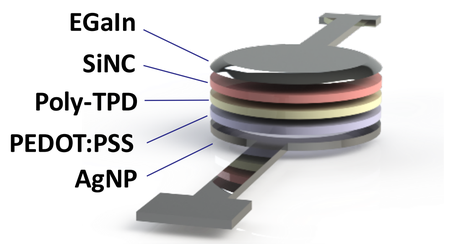


PCBM

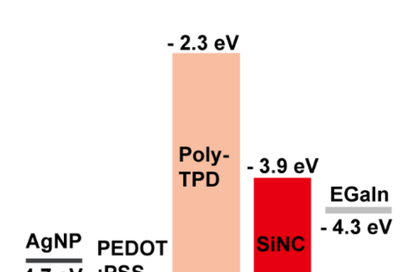


Structure Design

- ✓ Layer-by-layer structure is adopted for both LEDs and PDs
- ✓ Silver nano particle (AgNP) was printed as the bottom interconnects and Eutectic Gallium-Indium (EGaIn) was printed as the top electrode

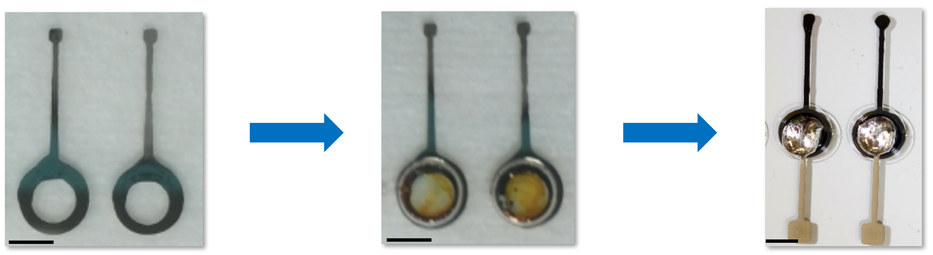


- ✓ Barriers to charge carrier transport were minimized by matching energy levels of adjacent layers
- ✓ For SiNC-LED, the large bandgap of poly-TPD increases the efficiency and purity of emission



Device Fabrication

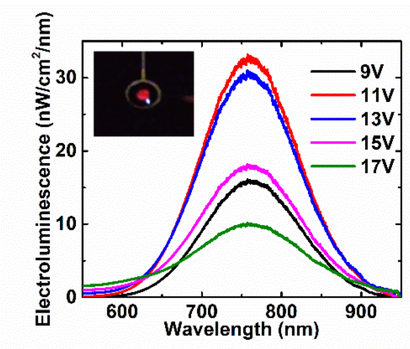
- ✓ Devices were printed using a customized 3D printer that consists of motion control modules, ink dispensing modules as well as real-time imaging modules
- ✓ Printing parameters including dispensing pressure, feeding speed, ink viscosity and surface tension, printing distance and curing conditions were optimized to increase the device yield and performance

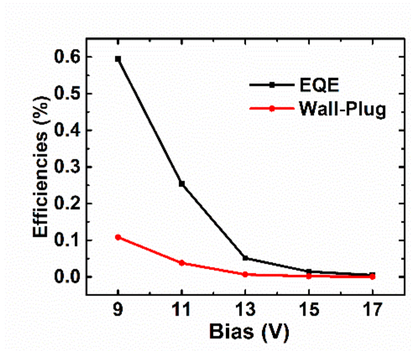


(Scale bars: 3 mm)

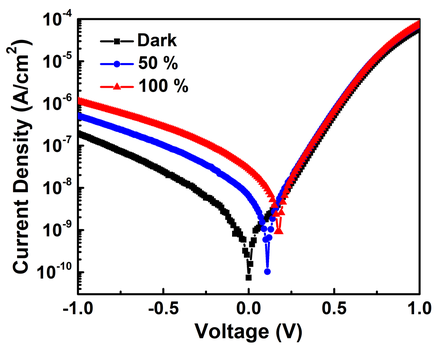
Electrical and Optical Characterization

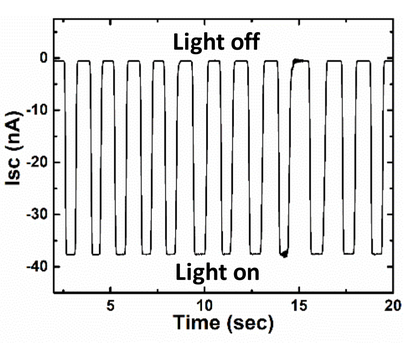
- ✓ High-purity emission at targeted wavelength and high efficiencies were demonstrated by the 3D printed SiNC-LED





- ✓ 3D printed PD demonstrated high sensitivity in light detecting





Summary

Feasible structures and ink formula for 3D printed optoelectronics were explored. Flexible devices with high performance were printed from both nano particles and polymer based active materials. Further optimization for enhanced layer uniformity by fluid mechanics will be conducted

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This work was supported by the National Science Foundation under Award Number **DMR-1420013**