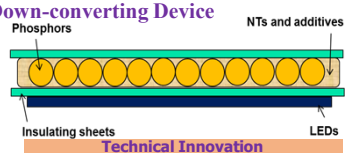
Hybrid Down-Converting Structures for Solid State Lighting

Zhitao Kang[1], Arun Thamban[2], Hisham Menkara[2], Christopher Summers[2]
Georgia Tech Research Institute[1] & PhosphorTech Corporation[2]

Project Objectives

Hybrid Inorganic Down-converting Device



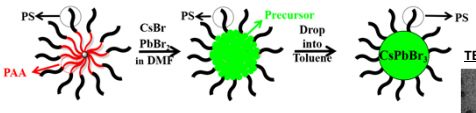
- ❖ **Developed HIDC-NTs structures integrated into phosphor films**
  - ✓ Synthesized and fine-tuned a wide range of nanorod/tetrapod/perovskite materials and 3-dimensional luminescent nanocrystals (3DLNs)
  - ✓ Demonstrated high LER in warm white, high brightness pcLED devices
  - ✓ Built LED devices and lamps using remote & proximate hybrid configurations with high performance.
- ❖ **Coating Process compatible with roll-based manufacturing**

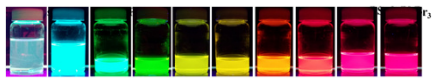
Technical Innovation

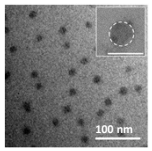
- ➢ 3DLNs & perovskites offer controlled narrow band emission, especially important as red emitting down-converters.
- ➢ 3DLNs offer low self-absorption and high temperature stability compared to standard QDs.
- ➢ Hybrid sheets offer combined advantages of *RadiantFlex*™ and LNs with tunable spectral properties maximizing LER
- ➢ Optical gain and further bandwidth reduction possible due to amplified spontaneous emission (ASE) at high optical fluxes.

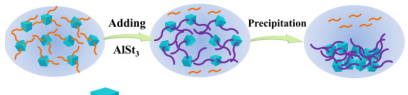
Potential Products and Applications

PS-capped Perovskite NCs

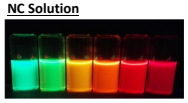




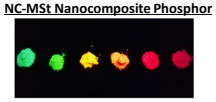


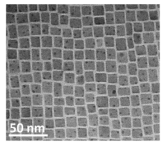


NC Solution

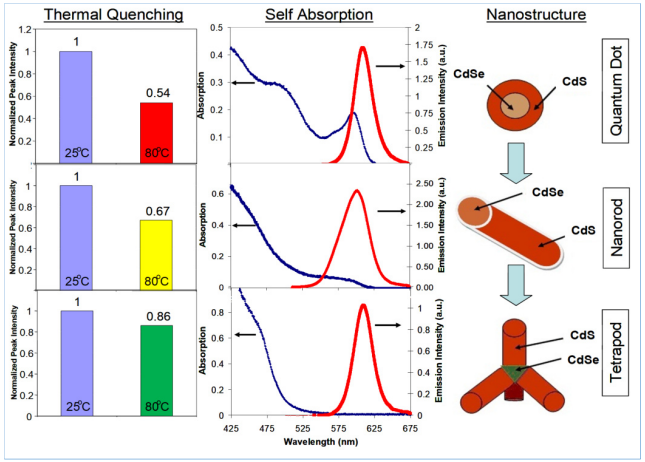


NC-MSt Nanocomposite Phosphor



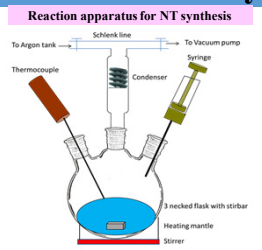


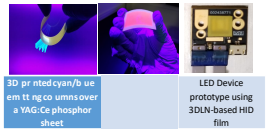
Nano-tetrapod (NT) Technology



CdSe/CdS Tetrapod Nanostructures Exhibit Improved Optical and Thermal Performance Compared to Conventional QDs

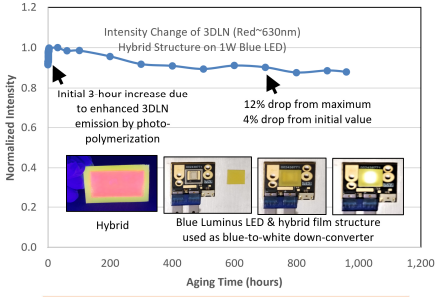
NTs & Hybrid LED Structures

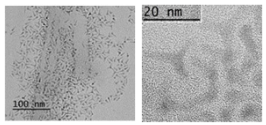


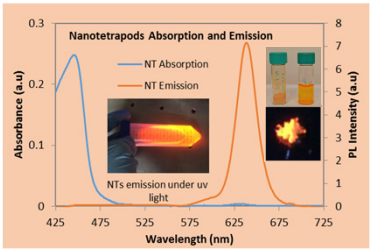


3D printed cyan/blue emitting columns over a YAG:Ce phosphor sheet

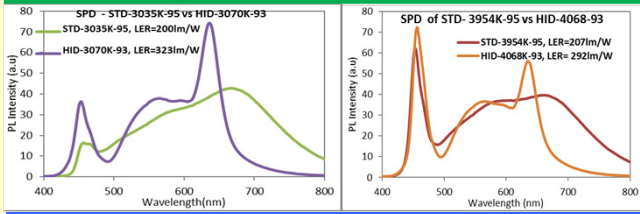
LED Device prototype using 3DLN-based HID film



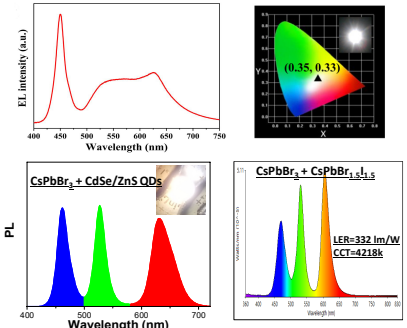




Properties of HIDC-NTs

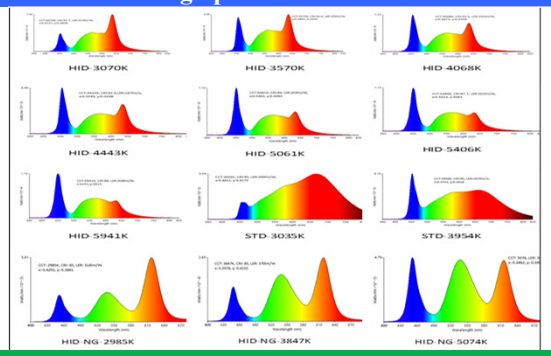


Perovskite LED Strategies : Hybrid Phosphor NCs or All NCs



- YAG:Ce^{3+} / $CsPbBr_{1.5}I_{1.5}$ NCs-MSt nanocomposites were used to fabricate white light LED.
- Proof of principle demonstration for WLED (CRI = 89.9, CCT = 4588K).
- PS-$CsPbBr_3$ NCs and CdSe/ZnS QDs were used to fabricate WLED.
- 116% of NTSC Color Gamut & 163% of sRGB Color Gamut.
- RadiantFlex sheets prepared with perovskite NC-MSt nanocomposites

Tuning Spectral Distribution



Successfully designed and built hybrid structures with high efficiency (~87%), with spectral tunability and narrow bandwidth. Demonstrated perovskite NCs with PLQY up to 81% and green emission bandwidth as narrow as 18 nm

U.S. DOE: Awards# DE-SC0015159 & DE-SC0018611