Environmentally Robust Quantum Dot Downconverters for High Efficiency Solid-State Lighting

Daniel DeRosha†, Abraham Jordan†, Brandon McMurtry†, Ellie Bennett†, Iva Rreza†, Leslie Hamachi†, Peter Chen‡, Joseph Treadway‡, Juanita Kurtin‡, Zhoulei, Zhang§, Emory Chen§, Jonathan Owen†

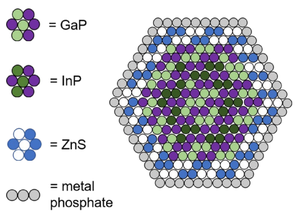
† Department of Chemistry, Columbia University, New York, NY

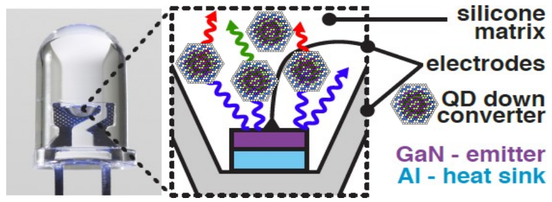
‡ Osram Opto Semiconductors, Inc. Portland, OR

§ Lawrence Berkeley National Lab, Berkely, CA

Overview

Goal: Develop III-V based QD downconverters for high CRI (>90%) and warm (>3000 K) SSL having luminous efficacy of >200 lm/W.





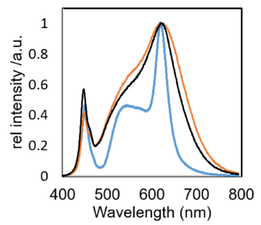
Approach: Synthesize of GaP/InP/GaP spherical quantum wells to reduce strain and avoid dislocation defects, shelled with ZnS and passivated by metal phosphate surface binders to increase long-term stability and performance. This architecture should produce QDs that **1)** absorb strongly at 450 nm **2)** λ_{em} = 625 ± 25 **3)** PLQY > 50% **4)** FWHM < 50 nm.

Effective II-VI QD Downconverters

2018 State of the Art 3000K/CRI90 device efficiencies (lm/W).

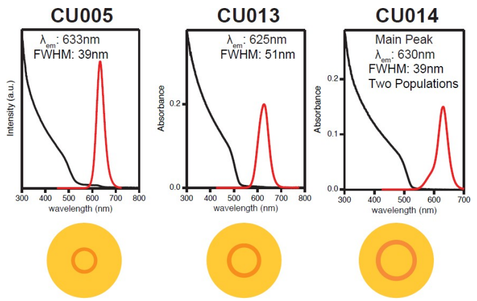
Nichia	Lumileds	Osram
163	163	163

Osram 600 ppm Cd 203 lm/W

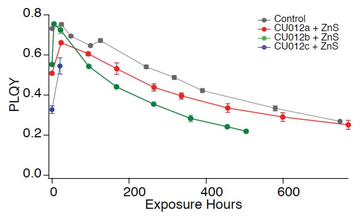


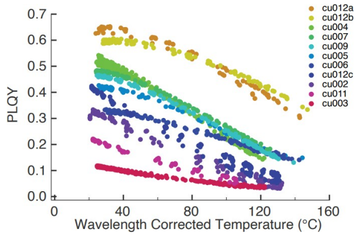
Commercial, no QD.
Commercial 90 ppm Cd.
Osram 600 ppm Cd.

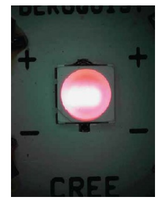
Seed Size Series



Control over II-VI architecture, tuning emission and minimizing reabsorption.

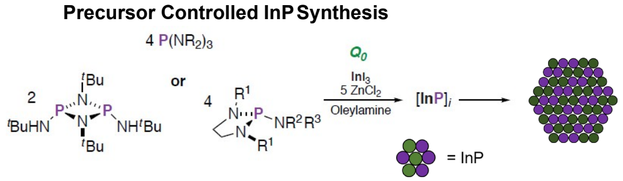




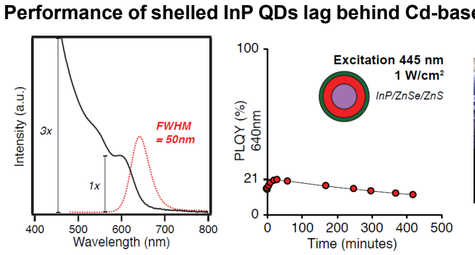


New Syntheses of III-V QDs

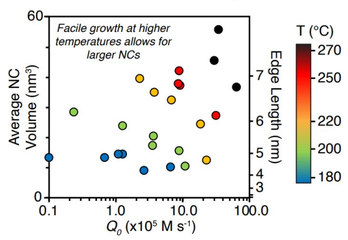
Precursor Controlled InP Synthesis



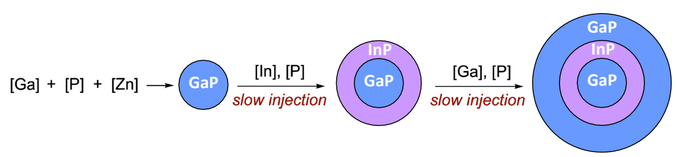
Performance of shelled InP QDs lag behind Cd-based QDs



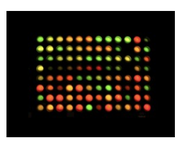
Rate dictates size at high T



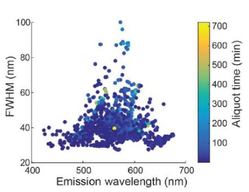
Target: GaP/InP/GaP structure with $A_{450\ nm}$ and $PLQY_{625\ nm}$ from thin InP

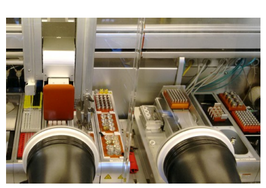


Direction: High-throughput screening of synthesis conditions for heterostructue InGaP alloys using HERMAN (High-throughput Experimentation Robot for Multiplexed Automation Nanocrystal synthesis).

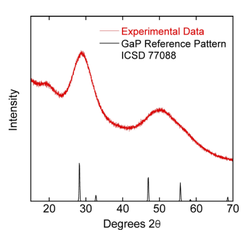


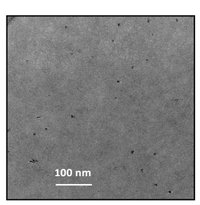
Photoluminescence of QDs in 96 Well Plate





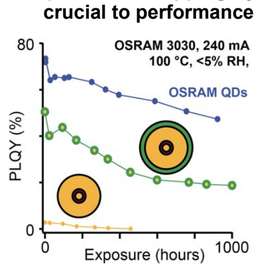
PXRD and TEM of small crystalline GaP nanocrystals

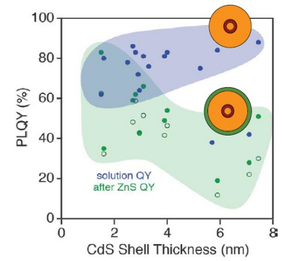




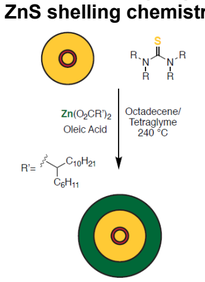
Barrier Layer Development

Deposition of capping layer crucial to performance

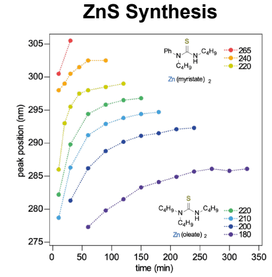




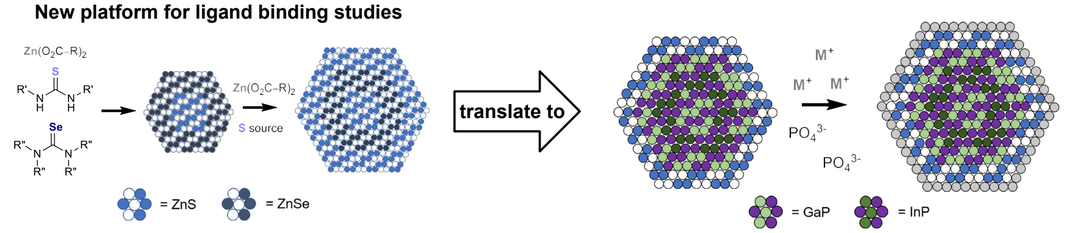
Direction: Develop superior ZnS shelling chemistry



Thiourea Controlled ZnS Synthesis



New platform for ligand binding studies



Acknowledgements

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy