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Uniform Dispersion of Nanoparticles in PMMA Waveguides for Luminescent Solar Concentrators

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Uniform Dispersion of Nanoparticles in PMMA Waveguides for Luminescent Solar Concentrators

Daniel J Korus, Kayla Koch, Meredith Boxx, Justin Doyle, Maya Noesen, Kendal Dragotto, Dr. David Patrick, Dr. David Rider, Western Washington University.

Background
- Luminescent solar concentrators (LSCs) are a promising solution to rising global energy demands. [1]
- Before LSCs can be commercially viable, four key loss mechanisms must be addressed to ensure their efficiency: [2]
  1. Insufficient Solar Absorption.
  2. Non-Unity Photo Luminescent Quantum Yield (PLQY)
  3. Compounding Self-Absorption and Escape Cone Losses
  4. Scattering Losses due to Nanocrystal Aggregation
- Copper Indium Disulfide/Zinc Sulfide (CIS/ZnS) Nanocrystals (NCs) go a long way towards addressing loss mechanisms 1-3: [3]
  - Broad band solar absorption
  - Potential for high PLQY
  - Large effective Stokes shift
- With increasing QD loadings, CIS/ZnS NCs aggregate in Poly(Methyl Methacrylate) (PMMA). Consequently, inconsistencies in the refractive index of the LSC matrix dramatically increases optical losses due to light scattering.
- Our work focuses on resolving such optical losses in order to achieve higher and commercially viable LSC efficiencies.

Optimization of Quantum Dot Synthesis
- Our Copper Indium Disulfide/Zinc Sulfide Quantum Dots are synthesized by a solvothermal “heat-up” method adapted from Klimov et. al. [3]
- In order to maximize LSC efficiency when paired with a solar cell, integrated luminesphores must have near unity PLQY as well as an exceptionally red emission profile.
- By independently testing each synthetic parameter for the CIS core synthesis and the ZnS shell overgrowth, we have increased our NCs Klimov et. al. Optimized

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CIS/ZnS</th>
<th>Optimized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu/s (m)</td>
<td>1:1</td>
<td>1:3</td>
</tr>
<tr>
<td>Zn/Cu (mol)</td>
<td>8:1</td>
<td>4:1</td>
</tr>
<tr>
<td>Shell Growth Solvent</td>
<td>1-Octadecene</td>
<td>Paraffin Oil</td>
</tr>
<tr>
<td>Shell Growth Steps</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Mean PLQY</td>
<td>36%</td>
<td>80%</td>
</tr>
<tr>
<td>Mean Max Emission (nm)</td>
<td>650</td>
<td>754</td>
</tr>
</tbody>
</table>

Table 1. Differences between a synthetic regime adopted from the work of Klimov et. al. and Patrick groups optimized synthetic recipe.

Results
- Typical Absorbance and Emission of CIS/ZnS
- Aperture Optical Quantum Efficiency for a Filtered NC LSC
- Typical Absorbance and Emission of CIS/ZnS
- The ratio of photons absorbed by an LSC to the photons delivered to its edge, plotted against illumination distance from the excitation beam to the aperture of an integration sphere.

Polymeric Surfactants
- A PMMA-based surfactant (PS) with two alkyl chains has been designed to interdigitate with the surface ligands of the QD. [5]
- The Polymer Surfactant has been shown to stabilize CIS/ZnS QDs in orthogonal solvent pairings.
- Future work will entail characterization of how well the PS disperses QDs in non-solvents and in PMMA LSCs.

Polymeric Dispersion Methods
- A sulfur-terminated Poly(Methyl Methacrylate) based ligand has been employed to increase the compatibility of CIS/ZnS QDs in the PMMA matrix of our LSCs. [4]
- A steric inhibitor (“Linker”) has been exploited to prevent the auto-formation of a thiolactone ring, keeping the terminal thiol chemically available to bind to the QD.
- Recent NMR and TGA experiments corroborate that the total polymer ligand exchange is about a 35% replacement for the native ligand DDT.
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- Future work will entail characterization of how well the PS disperses QDs in non-solvents and in PMMA LSCs.

Sources and Acknowledgements
5. The Polymer Surfactant has been shown to stabilize CIS/ZnS QDs in orthogonal solvent pairings.