May 18th, 12:00 AM - May 22nd, 12:00 AM

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

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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).
  4. Scattering losses due to nanocrystal aggregation.
- In order to maximize LSC efficiency when paired with a solar cell, our copper indium disulfide/zinc sulfide (CIS/ZnS) NCs must be both extensively researched and further optimized.

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].
- By independently testing each synthetic parameter for the CIS core and the ZnS shell overgrowth, we have increased our NCs.

<table>
<thead>
<tr>
<th>Cu/In (mol)</th>
<th>Zn/Cu (mol)</th>
<th>Shell Growth Solvent</th>
<th>Shell Growth Steps</th>
<th>Mean PLQY</th>
<th>Mean Max Emission (nm)</th>
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</thead>
<tbody>
<tr>
<td>1/1</td>
<td>8/1</td>
<td>1-Octadecene</td>
<td>2</td>
<td>38%</td>
<td>620</td>
</tr>
<tr>
<td>0.75/1</td>
<td>4/1</td>
<td>Paraffin Oil</td>
<td></td>
<td>80%</td>
<td>650</td>
</tr>
</tbody>
</table>

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

Optimizing Polymeric Dispersion Methods
- A sulfur-terminated poly(methyl methacrylate) based ligand has been employed to improve the compatibility of CIS/ZnS NCs in the PMMA matrix of our LSCs. [4]

Polymer Surfactants
- A PMMA-based surfactant (PS) with two alkyl chains has been designed to interdigitate with the surface ligands of the QD. [5]
- Future work will entail characterizing how well the PS dispenses QDs in non-solvents and in PMMA LSCs.

Sources and Acknowledgements

Acknowledgments: Thanks to Bright (Dr. Images), Griffin Rees, Ethics Board, Douglas Bumgarner, Matt Shively, Chris Stiver, Mike Glass.

Figure 1. A cartoon CIS/ZnS absorbance and emission over a schematic solar spectrum displayed over a mock LSC (a.b). Typical loss modes are cartooned for a hypothetical LSC (c).

Figure 2. TEM image of CIS/ZnS Core Shell structure. The average particle size is 3 ± 0.8 nm.

Figure 3. CIS/ZnS particle size analysis from Fig 2.

Figure 4. Normalized absorption (red) and emission (red) spectra of typical CIS/ZnS NCs.

Figure 5. QE, 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.

Figure 6. Sulfur terminated PMMA ligand.

Figure 7. A CIS/ZnS QD cartoon depicting the chemical binding of the polymer ligand and the interdigitation of the polymer surfactant with the QDs native ligands, 1-octadecanethiol.

Figure 8. Two LSCs. Left is constructed without use of the polymer ligand. The right LSC utilizes only polymer-ligand functionalized QDs, improving its dispersion and clarity.

Figure 9. PMMA-based alkyl surfactant.

Figure 10. From left to right: QDs in hexanes atop acetonitrile with PS, QDs in hexanes atop DMSO with PS, QDs in hexane atop DMSO.

Figure 11. A series of UV-illuminated LSCs ranging from 0.1 to 0.6 wFL QDs.

Figure 12. Aperture optical quantum efficiency for a filtered NC LSC.

Figure 13. Typical absorbance and emission of CIS/ZnS.