Improvement of Luminescent Solar Concentrators Using Vertically Aligned Dye

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Abstract
Luminescent solar concentrators (LSCs) incorporating a dye doped thin film coating can be used as a wave-guide to absorb and redirect light to coupled solar cells. Coatings including dyes dispersed in a liquid crystalline host can be used to direct absorbed light preferentially to the edges of a concentrator for collection by solar cells. The goal of this project is to demonstrate that a liquid crystalline host (UCL-018) can improve the efficiency of the solar concentrator and to design an LSC based on this technology. To prepare the device, we spin coat a liquid crystal/dye mixture on plain glass. The film coating is measured to be approximately 600μm in thickness. The LSCs are coupled to solar cells using an optical gel to allow internally reflected light to pass through the glass substrate.

Background
Luminescent Solar Concentrators (LSCs) use a dye doped thin film coating on a plain glass substrate and act as a wave guide to absorb and redirect sunlight using total internal reflection (TIR). LSCs are becoming popular because of their inexpensive nature and the fact that mechanical tracking is unnecessary for their performance. Theoretical predictions for conventional waveguides using randomly aligned luminescent dyes have an efficiency of approximately 75%.

- The use of a liquid crystalline (LC) polymer host creates a scaffold to help vertically align luminescent dyes in the mixture.
- The LC molecules align vertically with a clean glass substrate.
- Then rod-shaped dye molecules align with the liquid crystal mesogens.
- Previous efficiencies of up to 81% have been documented for this sort of alignment.

Experimental Methods
Preparing the vertically aligned LSC: A luminescent thin film coating is spin coated onto a plain glass substrate. The thin film is made from a mixture containing 1) a dye (coumarin 6) and 2) liquid crystal polymer (UCL-018) in toluene solution. Once spin coated, the LSC undergoes a 24hr UV curing process to allow cross linking of the polymer.

Preparing the horizontally aligned LSC: A plain glass substrate is first spin coated with 1% polyvinyl alcohol (PVA) aqueous solution and allowed to dry. The coating is then rubbed 4-5 times on velvet to give an orientation. The same dye doped liquid crystal mixture is then spin coated onto the glass substrate.

We use birefringence to confirm liquid crystal alignment, LSC samples are placed under a polarizing microscope to check this effect. When aligned horizontally: When the microscope stage is rotated, the image goes from light to dark through each 45° rotation. Horizontally aligned molecules are birefringent with a transmitted intensity dependent on molecular angle w.r.t. polarizer direction.

To confirm vertical alignment: A vertically aligned LC is not birefringent. No light should pass through the concentrator; it should appear dark no matter regardless of rotational orientation.

Coupling LSCs to Solar Cells: The LSC is coupled to the solar cell using optical gel, which has an index of refraction close to that of glass. This allows the TIR taking place in the LSC to pass from the glass to the solar cell.

Experimental Methods / Testing

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<tr>
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<th>Plain Glass</th>
<th>Horizontal Alignment</th>
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</thead>
<tbody>
<tr>
<td>Gain</td>
<td>3.39%</td>
<td>7.56%</td>
<td>7.81%</td>
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After subtracting the gain of the plain glass substrate from the vertical and horizontal LSC gain, gains of 3.99% for the horizontally aligned LSC film and 4.42% for the vertically aligned LSC film are given.

Results

Future Work
We would like to show a larger gain for the vertically aligned LSC. To improve the LSC further, we might try adding more dye to the thin film coating mixture, or experimenting with different LC Polymer materials.

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