Improvement of Luminescent Solar Concentrators Using Vertically Aligned Dye

Melissa N Ricketts, Andrea Rodarte, Lun Jiang, Roland Winston, Linda S. Hirst
School of Natural Sciences and School of Engineering, University of California Merced

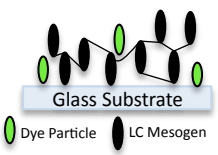
Abstract

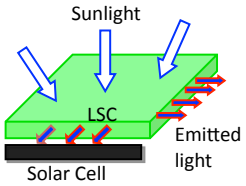
Luminescent solar concentrators (LSCs) incorporating a dye doped thin film coating can be used as a wave-guide to absorb and redirect light to coupled solar cells. Coatings including dyes dispersed in a liquid crystalline host can be used to direct absorbed light preferentially to the edges of a concentrator 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 scaffolding 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.





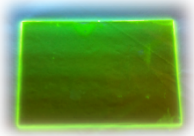
Motivation/Goals

We would like to show that using a liquid crystal polymer to vertically align the dye molecules can improve the efficiency of LSCs. Here we test LSCs using both vertically and horizontally aligned LC coatings. We expect that the vertically aligned LSCs will have a larger gain than the horizontal LSCs. Once this has been tested, we would like to further improve the efficiency of vertically aligned LSCs.

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.

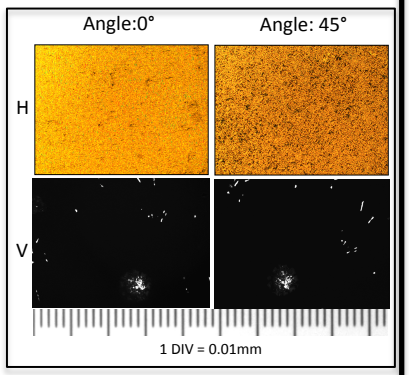


The LSC

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.

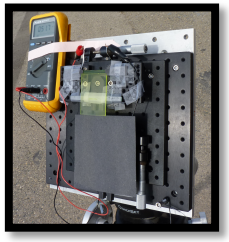


Coupling LSCs to Solar Cells:
The LSC is coupled to the solar cell using optical gel, which has an index of refraction close to that of glass. This allows the TIR taking place in the LSC to pass from the glass to the solar cell.

Leads are connected to the solar cell to allow for a voltmeter connection

Experimental Methods / Testing

To test the LSC, leads are connected to the solar cell and attached to a voltmeter. To measure the gain, a reading is taken when the LSC is fully exposed, as well as when it is covered to only expose the part of the LSC overlapping solar cell. Dividing the two results gives the overall gain. The gain for a plain glass substrate is also tested. This gain is subtracted from the gain of the LSC leaving the overall gain to be that of the thin film.



Results

	Plain Glass	Horizontal Alignment	Vertical Alignment
Gain	3.39%	7.56%	7.81%

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.

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.

Acknowledgements: We would like to thank Abengoa Solar for generous financial support and the UC Solar team.

Mulder, C.L. *et al.* Dye alignment in luminescent solar concentrators: I. Vertical alignment for improved waveguide coupling. (Optics Express 2010)