THICK FILMS OF HITCI:PMMA AS LUMINESCENT SOLAR CONCENTRATOR FOR PHOTOVOLTAICS WINDOWS

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ABSTRACT. We have investigated the potential use of HITCI molecules in PMMA for use as a luminescent solar concentrator (LSC) in a photovoltaic (PV) window, where the LSC layer is used to direct the infrared solar radiation towards silicon solar cells located inside the window's frame. On small sample with various HITCI concentrations, Stokes shift in the range of 70nm to 80nm have been measured. The LSC layer as an IR waveguide shows a decay length of 12.9mm^{-1}. Implementation on a real size window (20cm x 20cm) shows only marginal improvement compared to a similar window without any LSC layer.

Keywords: Building Integrated PV (BIPV), Luminescent Solar Concentrator (LSC), Infrared Waveguide

1 MOTIVATION

A very promising way to design a photovoltaic window is to use a thick film of a material tailored to diffuse IR light and to guide it towards PV [1] usually located inside the window's frame. In that way, the visible transparency of the window is fully guaranteed, and the efficiency of the window can potentially reach more than 5% [2] if the entire solar spectrum >600nm is sent towards c-Si solar cells.

Nevertheless, the concept is usually tested on very small areas, typically only a few square centimeters. The issue of the efficiency for larger windows, and the strategies for enhancing the efficiencies through an efficient IR waveguide [3], is seldom addressed. We have chosen the HITCI [4] molecule as the IR diffuser, following the original research of Ref [1], for which HITCI was one of the molecule investigated.

2 FABRICATION OF SAMPLES AND WINDOWS

2.1 LSC samples

HITCI molecules were first dissolved in dichloromethane (CH_2Cl_2), producing a greenish-blue solution.

The mixture was then poured in a homemade silicon mold and dried either at room temperature or at 50°C in a closed oven during 12 hours.

Small samples (5mm x 5mm x 1mm) at various HITC concentration have been prepared as shown in Figure 1.

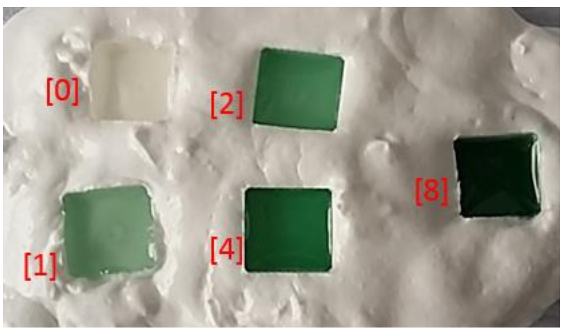


Figure 1: small LSC samples at various relative HITCI concentration (from 0 which is only PMMA, to 8) in their silicone mould

Similar preparation was used for 27mm x 7mm x 0.5mm sample used in the optical caracterisation described in § 3.

The absorbsion spectra for the various cententration are shown in Figure 2. We found a pic absorption at 738nm at low concentration with a reduction of 0.5nm each time the concentration is doubled.

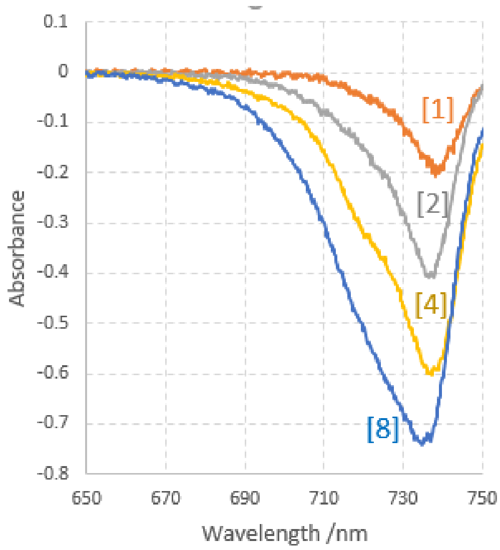


Figure 2: Absorption spectra of HITCI@PMMA for the various relative concentration

The emission spectra at 730nm excitation for the various concentration ratio are shown in Figure 3.

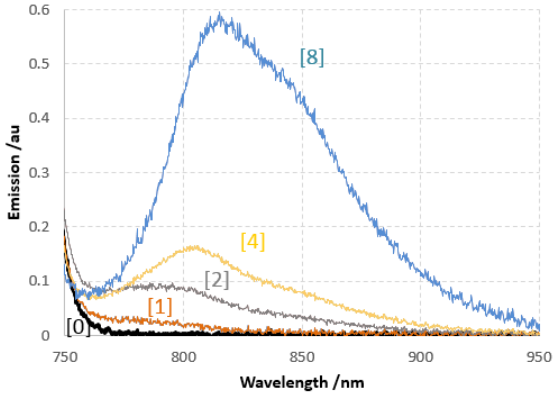
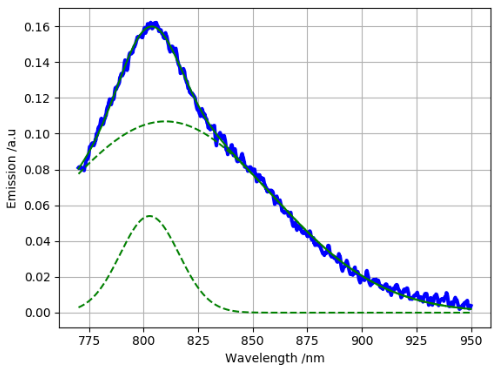
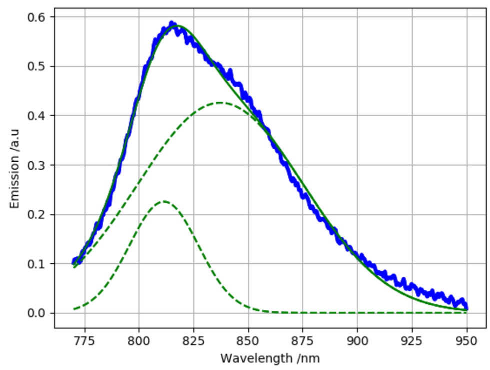


Figure 3: Emission spectra @730nm excitation for the various concentration ratio of HITCI molecules

As can be seen in Figure 3, the Stokes shifts are concentration dependent. The deconvolution of the emission spectra for the concentrations *[4]* and *[8]* are shown in **Figure *4*** a) and b) respectively. We found emission peaks at 802.7 nm and 806.7 nm for concentration *[4]*, and 811.5 nm and 828.5nm for concentration *[8]*.



(a)



(b)

Figure 4 : Decovolution of the emission spectra @730nm emxcitation for a) concentration *[4]* and b) concentration *[8]*

Stokes shifts are then in the range of 70 to 80nm, much larger than the 20nm reported in Ref [1].

2.2 Windows fabrication

The LSC layer for the 20cm x 20cm window has been done with the help of the home-made Dr blade system shown in Figure 5.

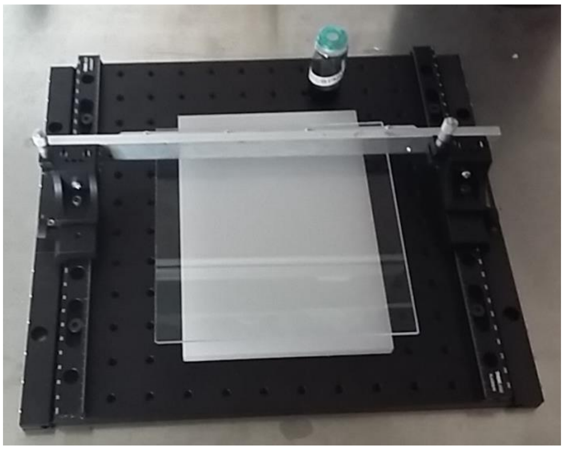


Figure 5: Picture of the manual DrBlade setup for the LSC deposition on 18cm x 18cm PMMA plate

As the homogeneity of the thickness of the dried LSC layer is critical, in Figure 6 is shown an example of the height profile (KLA Tencor Profilometer D-120) on a ¼ mm thick LSC over a distance of 5.5 cm.

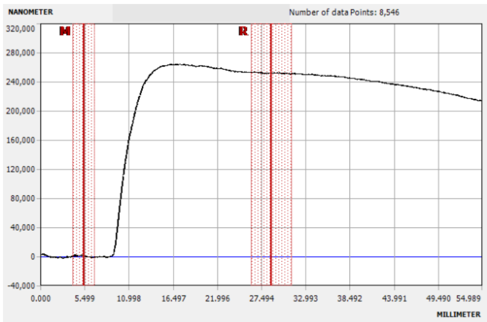


Figure 6: Heigh profile of a ¼ mm thick LSC guzide over 5.5 cm.

The 20cm x20cm window has been built from an aluminum frame, is shown in Figure 7. The transparent plate in the middle is the PMMA plate with the LSC layer, and the c-Si cells are visible inside the window frame

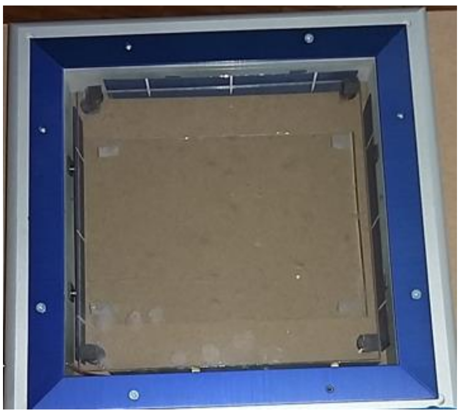


Figure 7: Picture of the prototype 20cm x 20cm LSC photovoltaic window.

3 PERFORMANCE AS AN OPTICAL WAVEGUIDE

3.1 Optical setup

We want to caracterise both the ability of the LSC layer to guide the light over the distance, and the abiility of the layer too couple the solar light.

The optical setup to caracterise the LSC layer as an IR waveguide is shown in Figure 8. It allows for the 2 measurement above mentionned.

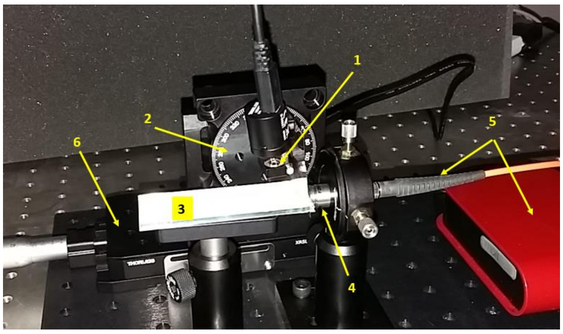


Figure 8: Setup for the optical caracterisation of the 25mm x 7mm LSC layers. 1)Mounted LED 2)Rotation stage 3) Sample with optical blanks 4)VIS-NIR collimator 5)Fiber and Spectrophotometer 6) Translation stage

3.2 Optical results

The EQE (a.u.) as a function of the distance detector is shown in Figure *9*. The exponential fit (solid line) shows a decay length of 12.9 nm^{-1}. Such a strong decay is not encouraging if we want to make usable building windows, but perhaps not redhibitory as the Stokes shift is large (see Ref(1)).

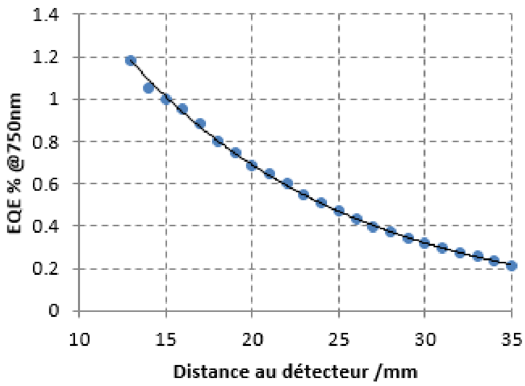


Figure 9: EQE (a.u.) as a function of the detector distance from the source

The EQE as a function of the incident sangle is shown in Figure 10. The coupling change near 40° corresponds to the critical angle.

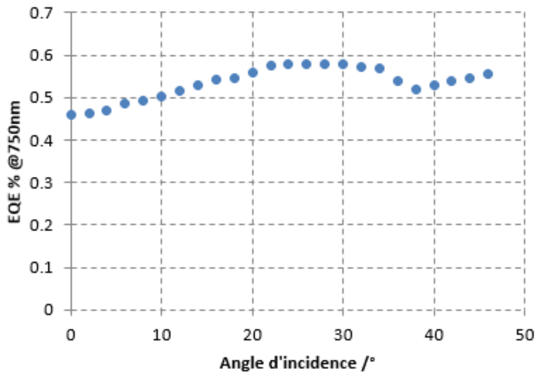


Figure 10: EQE as a function of the angle

4 PERFORMANCE of the LSC PV window

Figure 11 is a picture of the first LSC prototype window used for the outdoor (real conditions) tests. It allows for gas exchange inside the double glazed window, in order to investigate degradation issues. As seen in the picture, four silicon cells connected in series are fastened inside the frame. Also in between the two glasses is located the 18cm x 15 cm (in this prototype) LSC layer.

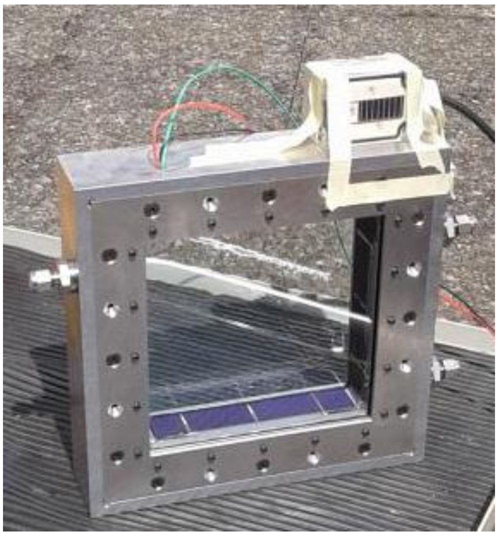


Figure 11: First prototype of the LSC window.

I-V curves, during a sunny day in Geneva, Switzerland, for various window inclination relative to solar irradiation are shown in Figure ***12***. It is fair to say at this point that the improvement of the efficiency due to the LSC material does not exceed 0.3 %. Most of the collected photons by the PV silicon cells are then directly collected form the unaffected solar beams.

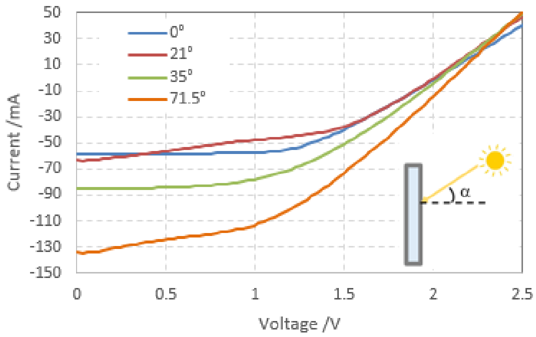


Figure 12: Outdoor IV curves of the window as a function of the sun orientatation

Along the same line, the I-V curves during the day as a function of the time are shown in **Figure *13***. The window is in the vertical position. Again, the results are fully explained by the shadowing effect of the frame, showing the little effect of the LSC material, at least for this frame and illumination geometry.

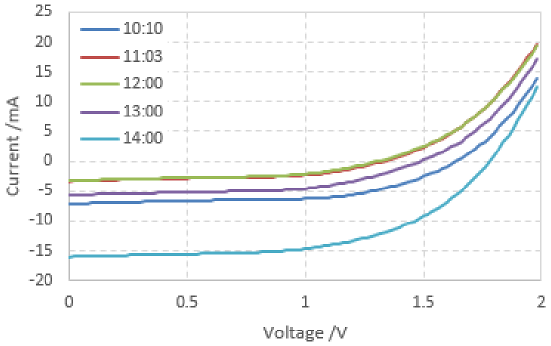


Figure 13: Outdoor IV curves of the window as a function of the day time

As a conclusion, although the large Stockes shift we measured could be seen as very promising at first, the LSC layers based on HITCI we produced were not satisfactory in terms on IR waveguide and therefore insufficient for being implemented in the photovoltaic window.

References

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