A Silicone Host for Lumogen Dyes

D A Hardy [1] *, A Kerrouche [1], S C Roaf [2], B S Richards [1]
[1] School of Engineering and Physical Sciences, and [2] School of the Built Environment,
Heriot-Watt University, Edinburgh, EH14 4AS, United Kingdom
*Corresponding author email: dah15@hw.ac.uk

Abstract

Altering the encapsulant colour in photovoltaic (PV) modules is a straightforward way of achieving greater colour range whilst minimising additional cost in PV systems. Lumogen fluorescent, organic dyes offer a way of adding colour to the encapsulant with minimal change in efficiency. The silicone encapsulant material Sylgard 184 is tested as a host material for Lumogen dyes. A method of dissolving various Lumogen dyes in Sylgard is investigated, and limits of solubility are explored. Methods of preparing samples suitable for optical measurements are found. Optical density is measured for a range of dye concentrations. The results indicate that Lumogen dyes can be dissolved successfully within Sylgard 184, giving good optical properties for lower dye concentrations. Initial photoluminescent quantum yield measurements confirm that Lumogen dyes can function effectively within a Sylgard host. This is promising for use of this material combination in the creation of coloured, fluorescent PV encapsulant layers.

Introduction

Altering the colour of PV modules provides a way of adding variety in building-integrated PV, and so increasing the uptake of PV technology, by providing ways of camouflaging PV on a building [1] or by providing a wider PV colour range with which PV can be made an integral part of an architectural design [2]. By dyeing the encapsulant in PV modules, it is possible to add colour with minimal change in module efficiency [3] and at minimal cost, (due to the small quantities of dye being added to the encapsulant, which is an existing, essential PV module component). This is in contrast to other methods of introducing colour, such as altering the antireflection coating thickness on PV cells, which leads to a marked drop in PV efficiency [4].

Reasons for the choice of Sylgard 184

Sylgard 184 is a silicone elastomer, supplied by Dow Corning. It is supplied as a two liquids: part A and B, which are mixed in a 10:1 ratio by weight or volume. Over 48 hours, the mixture cures to form a flexible, adhesive solid. Sylgard 184 is chosen from the range of possible PV encapsulant materials due to its good optical properties [5] [6] and stability [6]. There is a precedent for use of Sylgard [7] [8], which does not require lamination when used as a PV encapsulant, unlike the more commonly used ethylene vinyl acetate (EVA), which is supplied in sheet form. The product is in a liquid form before setting, making it relatively straightforward to add Lumogen dyes.

Reasons for the choice of Lumogen dyes

There is a precedent for using fluorescent, organic dyes out of the available luminescent materials, due to their relative stability [9]. Only a small amount of Lumogen dye is required to obtain strong colouring: for example 0.25mg dye per 10g Sylgard for 20ppm concentration of Lumogen Red dye. When Lumogen dyes are incorporated into a PV encapsulant layer, they have minimal impact on efficiency and can even enhance efficiency in the case of Lumogen violet dye [3].

Experimental Method

Sample preparation method

Lumogen dyes (BASF, Germany) were dissolved in measured amounts of toluene, then added to Sylgard Part A and the mixture heated to 60^{o}C. The toluene was evaporated off before adding Sylgard part B (the curing agent). The sticky Sylgard solution was sandwiched between thin pieces of borosilicate glass in order to make samples suitable for optical testing. To investigate solubility and performance of dye, samples were made in the range of dye concentrations: 20, 100, 200, 500, 1000, 2000 parts per million (ppm).

Sample testing

An optical microscope was used to check for undissolved dye in the samples. A Perkin Elmer Lambda 950 UV-vis-NIR spectrophotometer was used to measure absorbance of the samples. Photoluminescent quantum yield (PLQY) was measured in an Edinburgh Instruments spectrofluorometer using the integrating sphere technique [10].

Experimental Results and Discussion

The solubility of the dyes in Sylgard was assessed by inspecting the samples with an optical microscope at magnifications of 42 and 70 times. The lowest concentration at which dye was visible varied as shown in Table 1. Loss of dye during sample preparation meant that the actual concentration of the dye in the samples was lower than the theoretical value. The actual dye concentrations are also shown in Table 1. These are calculated from Beer's Law, using measured absorbance and sample thickness. In contrast, Lumogen dye in PMMA is fully dissolved at these concentrations [11] [12].

Dye	Lowest theoretical concentration (ppm) at which undissolved dye is visible	Actual concentration (ppm) from measured absorbance spectra peaks
Red 300	200	160
Orange 240	500	108
Yellow 170	200	97
Yellow 083	500	266
Violet 570	500	266

Table 1: The lowest concentration at which dye is not fully absorbed

Optical Density

The absorbance of the Sylgard samples was compared with data for Lumogen dyes dissolved in PMMA [10] to verify that absorption peaks were similar (Figures 1 and 2). Results generally show good correlation in absorbance peaks, with red and orange dyes giving the closest match. The yellow dyes exhibit a shift of spectral peaks to longer wavelengths, whilst the violet dye demonstrates a slight shift to a shorter wavelength.

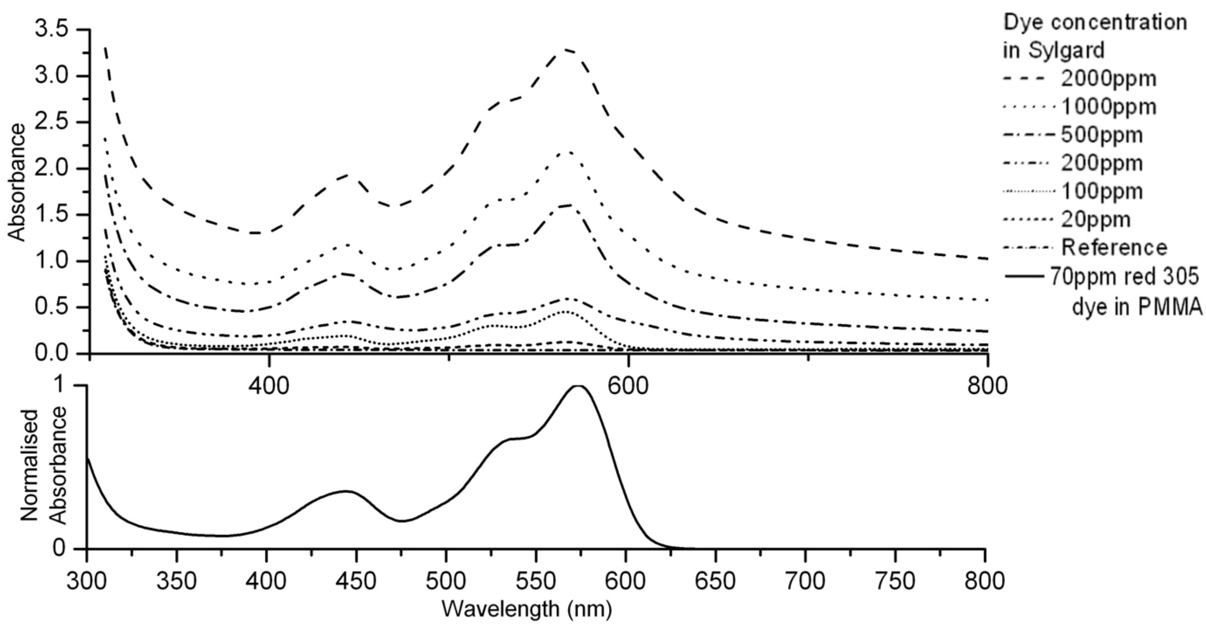

Figure 1: Absorbance Spectra for Lumogen Red 300 dye in Sylgard and Lumogen red 305 dye in PMMA hosts

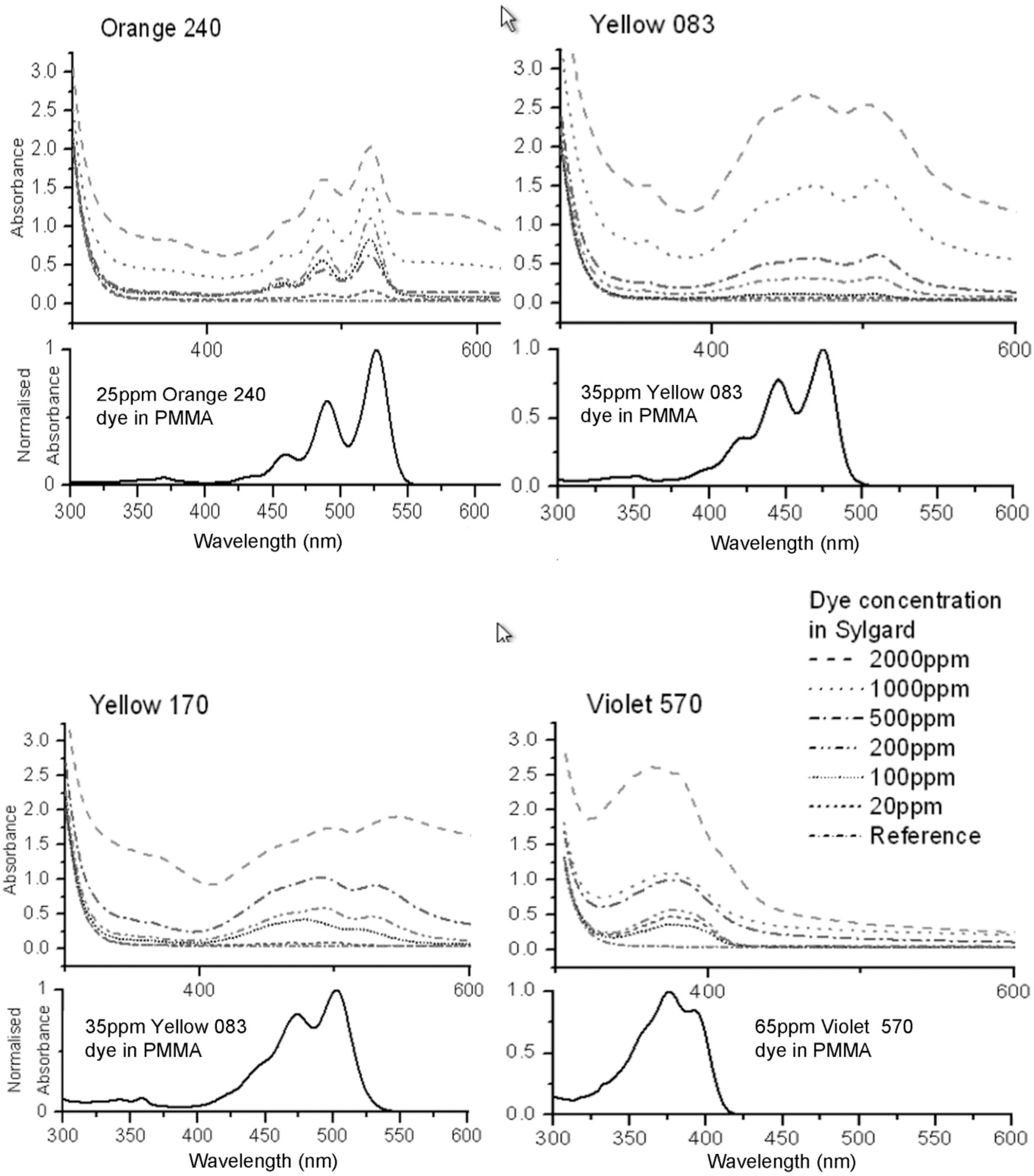

Figure 2:Absorbance Spectra for Lumogen Dyes in Sylgard, compared with Lumogen Dyes in PMMA

<u>Photoluminescent Quantum Yield (PLQY) Measurements</u>

PLQY values were measured for samples with the lowest dye concentration, in order to minimise light re-absorption [11]. Initial results indicate that the dyes are fluorescing within a Sylgard host.

Conclusions

Sylgard 184 can act as a host for Lumogen dyes, but the dyes do not appear to be absorbed into a Sylgard host as well as into a PMMA host. This limits the use to lower concentrations.

Lumogen dyes exhibit similar absorption spectra in Sylgard 184 to those shown in a PMMA host, with the closest correlation for red and orange dyes.

Photoluminescent quantum yield measurements show that Lumogen dyes exhibit fluorescence within a Sylgard host.

Acknowledgement

This research was made possible through funding from the Leverhulme Trust.

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