

Crosslinked reactive mesogens and photo-chemical alignment for organic polarised EL

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Abstract

A doped coumarin based photoalignment polymer is irradiated with polarised UV light and used to macroscopically orient a light-emitting photoreactive mesogen. This is subsequently crosslinked to form an electroluminescent nematic polymer network. The photoluminescence order parameter of the nematic is discussed in terms of the photoalignment conditions.

Keywords: Electroluminescence, Liquid Crystals, Conjugated, LEP, OLED, Chromophore

1. Introduction

Organic light-emitting displays (OLEDs) are a rapidly developing technology with a first application as polarised EL back-lights for LCD illumination. This would simplify manufacture, as well as aid portability and efficiency of low cost, bright, portable displays for mobile comms. Typically EL polarisation ratios ($EL_{||}/EL_{\perp}$) of 30 to 40 are required, but with a clean up polariser, EL ratios of 10 or more are adequate. Uniaxially aligned chromo-phores are required for polarised emission and polarisation ratios of 25:1 have been obtained using liquid crystalline polymers on rubbed alignment layers¹. However, high temperature processing is required and the rubbing process causes scratching and electrostatic charging. Photo-alignment techniques for LCDs are well known^{2,3} but the technology has only recently been applied to OLEDs. We demonstrated polarised EL ratios of 11:1 using polymer networks formed by the UV photopolymerisation of aligned reactive mesogens⁴. A doped photoalignment layer was used to macroscopically align the chromophores. Here, we present the photoalignment process in more detail.

2. Experimental

Figure 1 shows the materials used to obtain polarised emission. The alignment polymer [1], a derivative of 7-hydroxycoumarin, is doped with 4,4',4''-tris(1-naphthyl)-

N-phenyl-amino)-triphenylamine [2] to aid hole injection. Deposition is via conventional spin coating. The alignment layer was exposed to polarised UV radiation from an Argon Ion laser at 300 nm to induce an anisotropy through (2+2) cycloaddition of adjacent coumarin side-chains. The luminescent material [3], deposited by spin-coating onto the exposed alignment layer, forms a nematic phase above 45°C with a clearing point at 106°C. A nematic glass, stable at room temperature for several months, was obtained by slow cooling from 100°C to 80°C and rapid quenching to room temperature. [3] is crosslinked at room temperature by exposure to 100 J cm⁻² of unpolarised UV radiation at 300 nm to induce polymerisation via the diene end-groups forming an insoluble and intractable network. Polarised PL measurements were made using a sheet polariser and a photodiode array (Ocean Optics S2000).

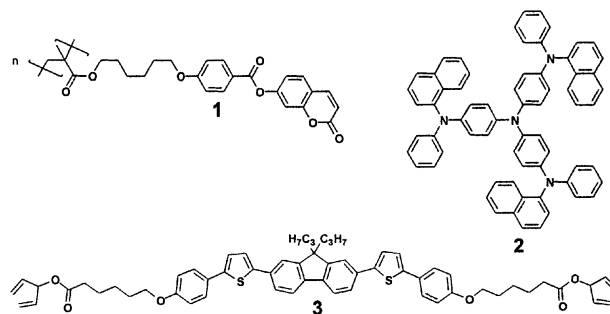


Figure 1. Chemical structures of [1], [2] and [3].

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3. Results

[1] has been used to align LCDs and gives strong anchoring with good thermal and photo-stability⁵. When the incident polarised UV fluence is low, the photo-alignment process involves crosslinking of [1] by (2+2) cycloaddition, as illustrated in figure 2.

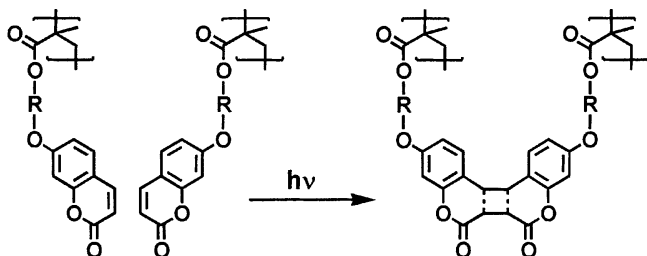


Figure 2. (2+2) cycloaddition for head-to-head coumarin sidechains. Dimerised sidechains have polarization vectors parallel to P .

The crosslinking probability has a $\cos\phi$ dependence where ϕ is the azimuthal angle between the incident polarisation direction P and the polarisation vector of the side-chain. Hence, the dimerised side-chains show an anisotropic distribution with a maximum density parallel to P . In the initial stages of cycloaddition, the unreacted side-chains are mobile and so retain an isotropic distribution⁶. However as the viscosity of the material increases, their depletion becomes anisotropic with a maximum density perpendicular to P . In the device, the insulating photo-alignment material is doped with [2] to promote the transport of holes and so obtain EL. The latter has a tetrahedral pyramidal shape and so inhibits the cycloaddition of [1], a short-range interaction requiring closely-spaced side-chains. Thus, raising the concentration of [2] in [1] is expected to compromise the alignment quality, but to increase the number of holes conducted to the EL layer.

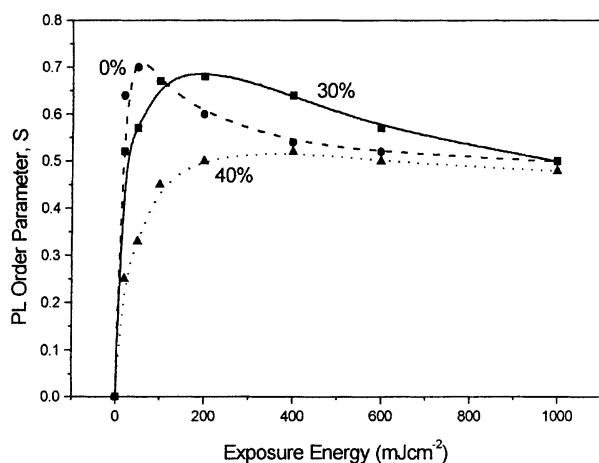


Figure 3. Photoluminescence order parameter of [3] aligned with [1], doped with 0%, 30% and 40% [2].

The PL order parameter, $S = (PL_{||} - PL_{\perp}) / (PL_{||} + 2PL_{\perp})$ of the overlying liquid crystal [3] in its nematic glass phase was measured as a function of the polarised UV fluence incident onto the alignment layer for different dopant concentrations. Other processing parameters were identical for all samples. In all samples, the liquid crystal director aligns parallel to P suggesting that photo-alignment is governed by liquid crystal-dimerised sidechain interactions. Related work suggests that these interactions are steric rather than dispersive⁶. Optimum alignment is obtained with the undoped alignment layer for an incident fluence of 50 mJ cm^{-2} . S decreases for higher fluences due to the increasing anisotropy of the LC-unreacted sidechain interaction, which is maximised with the director oriented perpendicular to P . Figure 3 shows that for a dopant concentration of 40% or higher, there is a detrimental effect on alignment. However, with concentrations up to 30%, the order parameter of emitted light is not severely affected. However higher fluences are required to obtain optimum alignment because of the decreased photo-reaction rate due to dilution with [2]. The order parameter is also unaffected by UV photopolymerisation of [3]. S also depends on the processing conditions of the chromophore. The highest value of S , $=0.77$, was found by cooling at $0.2 \text{ }^{\circ}\text{C min}^{-1}$ from $100 \text{ }^{\circ}\text{C}$ to room temperature.

4. Conclusions

Photoalignment provides an alternative method to align liquid crystal chromophores for polarised EL. It has the advantages of providing thermally and photochemically stable, defect-free, insoluble layers. The order parameter of the chromophore depends on both the UV irradiation conditions of the photoalignment layer and processing of the nematic chromophore.

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