ENGINEERING TRIPOS PART IIB

Tuesday 22 April 2008 9.00 to 10.30

Module 4B17

PHOTONICS OF MOLECULAR MATERIALS

*Answer not more than **three** questions*

All questions carry the same number of marks

*The **approximate** number of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments.

STATIONERY REQUIREMENTS
Single-sided script paper
Graph Paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculators allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1. (a) Describe the splay, twist and bend director deformations in a nematic liquid crystal. In such a material the surface alignment may be planar or homeotropic. Explain the differences between these two forms of alignment and describe how a Freedericksz transition may be used to determine the splay elastic constant k_{11} of a nematic liquid crystal. [40%]

(b) Explain the principles of operation of a twisted nematic device and discuss briefly why the surface alignment is of paramount importance in a display device. [30%]

(c) At room temperature a planar aligned nematic liquid crystal of dielectric anisotropy, $\Delta\varepsilon$ (equal to 6), has a threshold voltage, V_{th}, of 2V. With a voltage V applied, where $V > V_{th}$ the nematic director realigns to a different equilibrium direction which, on removal of the voltage, relaxes back to the original planar alignment in a time of 10 ms. If the electrode spacing is 10 μm calculate both the splay elastic constant and the viscosity coefficient of the nematic liquid crystal. [30%]

Note: The permittivity of free space $\varepsilon_o = 8.54 \times 10^{-12}$ Fm^{-1}

2. (a) A smectic side chain liquid crystal polymer (SCLCP) is to be used for electro-optic data storage. Describe the molecular features of such a polymer and discuss how these features influence the SCLCP's transition temperatures. [40%]

(b) Describe how (i) light scattering and (ii) clear optical textures may be produced by applying electric fields to such SCLCP materials. [30%]

(c) A 500 mW laser emitting at 410 nm is to be used in pulsed mode to write linear tracks 10 μm long and 10 μm wide in a 5 μm thick dyed SCLCP film at speeds of 2 ms^{-1}. Assuming all of the laser energy is absorbed,

(i) calculate the required duration of the laser pulse,
(ii) estimate the local temperature increase produced in the track, and
(iii) sketch the absorption curve for the dyed SCLCP. [30%]

You may assume that the dyed SCLCP has a density of 100 kg m^{-3} and a specific heat of 50×10^3 J kg^{-1} K^{-1}.

3. (a) Describe the molecular arrangement typical of a chiral nematic (cholesteric) liquid crystal. If such a material is aligned by surface forces to give a planar texture, discuss the properties of light reflected from it. In your description differentiate between the effects found when light is incident normally and obliquely. [40%]

(b) Explain the physical features of such materials that make them suitable for use in thermometry devices. Why is the first or second order nature of a chiral nematic to smectic phase transition important for such devices? [30%]

(c) White light is normally incident on a chiral nematic material which has a mean refractive index of 1.5, a helix pitch of 433 nm and a birefringence of 0.15. Calculate the peak wavelength, and the bandwidth for light reflected normally.

A chiral nematic material with the same mean refractive index and helix pitch is used as an optical filter. Calculate the birefringence of this material if the optical filter has a bandwidth of 13 nm. Describe the construction of such a filter used in reflection mode. [30%]

4. (a) Explain why, in the absence of external forces, a chiral smectic C phase is not normally ferroelectric. [20%]

(b) Describe the principles of operation of a surface stabilised ferroelectric electro-optic device based on birefringence effects. [40%]

(c) In order to improve the brightness of a ferroelectric device the birefringence mode of operation may be replaced by the dye-guest-host (DGH) effect. Explain how this (DGH) effect might be used to construct a light emissive display. In your explanation discuss the parameters that affect the performance of the latter device. [40%]

5. (a) Describe the operation of a polariser-free electro-optic polymer dispersed liquid crystal display (PDLC) suitable for use in a slow update video projector. Discuss how the optical switching properties might be optimised. [40%]

(b) Describe how a chiral nematic film may be used to construct a photonic band gap based microscopic laser system. Discuss the operating principles of such a laser, assuming it is driven by nanosecond light pulses at a wavelength of 530 nm, and describe the main features of the output light in terms of the liquid crystalline properties. What properties of the output light would you measure to ensure that you were observing a lasing effect rather than some other form of light emission? Describe one method by which you could tune the wavelength output of the laser and give typical data. [60%]

END OF PAPER