Towards Holographic Data Storage: Polymer Dispersed Liquid Crystals and Its Applications

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1. Introduction

Context

“The scaling laws are not favourable to flash...It looks like manufacturers are already in that age of diminished gains”

- Tom Lee, co-founder of Matrix Semiconductors

The race is on to find a successor to flash memory – the predominant form of non-volatile RAM used in the majority of consumer electronic devices. Microholographic data storage techniques have shown promise in this area, however, there are still issues in terms of practicality. Polymer dispersed liquid crystal (PDLC) materials can potentially make this technology practical and commercially feasible through its application both as a storage medium and also as a solid-state beam steering device for optical addressing.

Polymer Dispersed Liquid Crystals Theory

PDLC materials have micron sized domains of liquid crystals (LC) dispersed throughout a polymer matrix. The alignment and dispersion of these liquid crystals are random. However, LC have positive dielectric anisotropy and the optical properties of the material can be significantly altered with an external electric field.

2. Process Development

The Materials

The Polymer:
- Norland Optical Adhesive 65 (NOA 65).
- UV cured.
- Refractive Index = 1.524

The Liquid Crystals:
- 4’-Pentyl-4-biphenylcarbonitrile (5CB) (Nematic).
- Extraordinary refractive Index = 1.74
- Ordinary Refractive Index = 1.53

Matched indices → high transparency in the ‘on’ state.

The Process

- Based on photo-induced phase separation.
- 5CB and NOA 65 solution are mutually soluble and forms a single phase when mixed together.
- Curing with UV causes phase separation. 5CB precipitates out of solution and becomes encapsulated by solidifying polymer matrix.

1. Dissolve 60% wt./vol. of 5CB in NOA 65.
2. Distribute a few drops of the solution on to ITO coated glass slides with the ITO coated side touching the solution.
3. Cure using UV until NOA 65 film as set.

3. Process Verification

Polarisation microscopy of PDLC film with LC washed away using carbon tetrachloride. Dark cavities suggest of encapsulation of LC.

Application of electric field highlights the random refractive index distribution in the ‘off’ state (scattering) and the uniform distribution in the ‘on’ state (non-scattering).

4. To Be Continued...

Solid-state Beam Steering Device

- Successor to flash memory needs to be a solid-state solution.
- Current holographic data storage techniques use mechanical parts to address stored data.
- Holographic PDLC (H-PDLC) materials have periodically dispersed LC domains.
- Created using laser interferometry.
- H-PDLC can be used make tunable photonic crystals.
- Tunable photonic crystals can be used to make tunable superprisms which have large dispersion properties.

Conclusion

- Successfully synthesised PDLC films using NOA 65 and 5CB.
- Outlined process to synthesis PDLC films.
- Demonstrated the electro-optic properties of PDLC films.
- Revealed the microscopic structure of PDLC films.
- Paved the way for future, application specific, research.

Holographic Data Storage Medium

- Photorefractive (PR) effect creates internal electric fields which alters the material’s refractive index.
- Microholograms can be written into PR materials as an index grating.
- Modulation of index is poor in most PR materials – leads to stability issues.
- PDLC materials can increase the modulation due to the alignment of the LC domains caused by the internal electric fields from the PR effect.