

Photo-induced hole dipoles' mechanism of liquid crystal photoalignment

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Abstract

We explain the observations and show the existence of the new photoalignment mechanism based on photo-induced dipole moments in azo-dye layer. Strong azimuthal anchoring energy $>2 \times 10^{-4} \text{ J/m}^2$ is obtained within $<0.5 \text{ J/cm}^2$ exposure dose.

1. Introduction

Polarized light absorption in photoalignment material layer induces anisotropic long-range interactions that orient liquid crystals [1]. The main known physical mechanisms standing behind anisotropic interaction nature are photo cross-linking and photo destruction of polymers; photo cis-trans isomerization of azo-dyes. The photo isomerization is reduced to photo rotation, when cis-form cannot be registered due to short life-time. Recent study of AtA-2 azo-dye azimuthal anchoring as the function of exposure dose [3] has revealed the presence of unusual strong anchoring energy peak at low exposure doses (Fig.1), which is outside understanding of the known mechanisms.

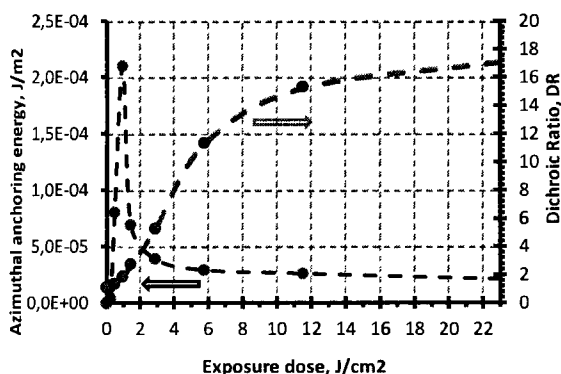


Figure 1: Azimuthal anchoring energy & dichroic ratio of 70 nm ATA-2 dye layer vs. exposure dose

2. Intermolecular bonding

We investigated the AtA-2 azo-dye (Fig.2) in the solid film; and the role of reversible intermolecular bonding between the dye molecules with strong perpendicular dipole moment of $\sim 16\text{D}$.

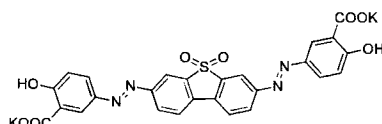


Figure 2: AtA-2 azo-dye structure

The intermolecular bonding of AtA-2 dye is a number of O...K-O coordination bonds that prevent neighbouring molecules from thermal rotation movement in solid film. The bonds energy is the

next: $E_{KT} < E_{bonds} < E_{hv}$. Thus absorbed photon brings enough energy to break the bonding and change orientation of the absorbed molecule.

3 Self-consistency and the mean field

Upon wet deposition of the dye film all dye molecules are consistent to the mean field having the dipole moments of the dyes compensated by the field. Once the solvent is removed, intermolecular bonds lock translation and rotation movement of the dye molecules. Thus the change of orientation of the single molecule having absorbed the photon keeps the local dipole moment of the mean field unchanged – the hole dipole μ_{AL} , while the magnitude of the hole dipole moment equals to the dipole moment of the AtA-2 dye molecule.

4 Alignment layer anchoring energy

In case of the flat surface the anchoring energy W between the alignment layer and the liquid crystal is proportional to the square of dipole moment $(\mu_{LC})^2$ and the order parameter P_{2LC} of liquid crystal, as well as the square of dipole moment $(\mu_{AL})^2$ and the order parameter P_{2AL} of alignment layer [3]: $W \sim (\mu_{LC}\mu_{AL})^2 P_{2LC} P_{2AL}$.

5 Photo-induced hole dipoles

Exposure of AtA-2 layer with linear polarized light induces selective photon absorption by dye molecules primary oriented along the polarization of light. Thus the order parameter of the hole dipoles formed by the mean field at the location of the absorbed molecule of the alignment layer is close to one, $P_{2AL} \sim 1$. At the same time dye molecule is not restricted to change its orientation to any direction, thus the order parameter of dye molecules that underwent single photon absorption is close to zero.

The photo-induction of hole dipoles is the new photoalignment mechanism observed for azo-dye molecules with reversible intermolecular bonding.

6. Acknowledgements

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7. References

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- [3] A. Murauski, *Surface and liquid crystal interlayer interactions: characterizations and applications*, VDM Verlag, 2009.