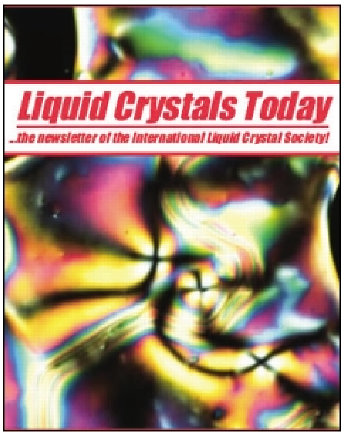


Liquid Crystals Today
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713681230

Photoalignment of Liquid Crystal Materials: Physics and Application

Yuri Reznikov[a]
[a] Institute of Physics of the National Academy of Science, Kyiv, Ukraine

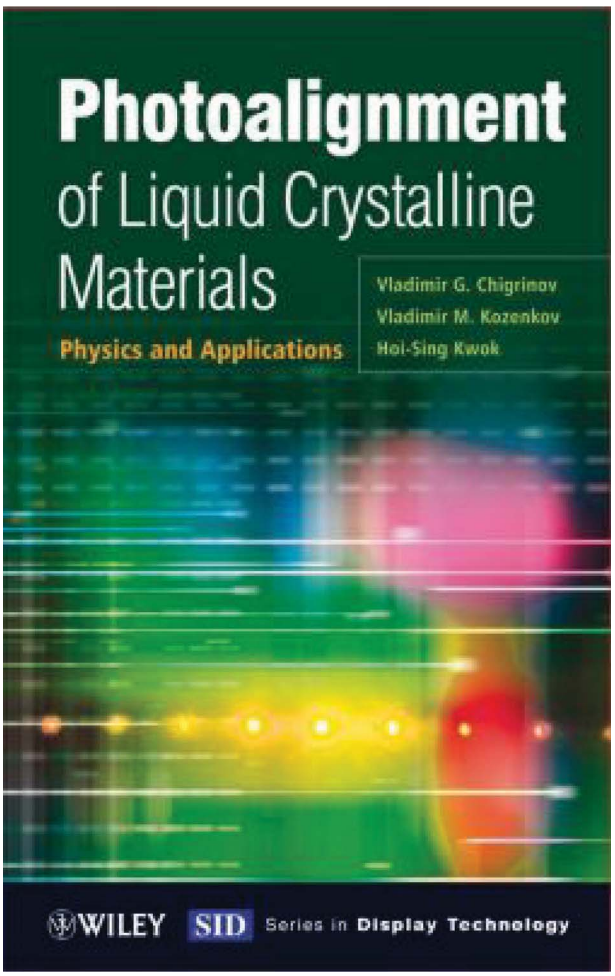
Online publication date: 15 June 2010

To cite this Article Reznikov, Yuri(2010) 'Photoalignment of Liquid Crystal Materials: Physics and Application', Liquid Crystals Today, 19: 1, 31 — 33
To link to this Article: DOI: 10.1080/13583140903396218
URL: http://dx.doi.org/10.1080/13583140903396218

Liquid Crystals Today,
Vol. 19, No. 1, June 2010, 31–33

Book Review

Photoalignment of Liquid Crystal Materials: Physics and Application, by V. Chigrinov, V. Kozenkov and H.S. Kwok, UK, Wiley-SID series, 2008, 248 pp., US$130, ISBN: 978-0-470-06539-6.



Liquid crystals (LCs) display many fascinating phenomena caused by the unique combination of long-range orientational ordering and relatively free movement of their anisotropic molecules in a LC phase. This combination, in conjunction with a weak intermolecular interaction, leads to exceptional sensitivity of the LCs to electric and magnetic fields, and this initiated a booming growth of LC science and the development of a powerful liquid crystal display (LCD) industry in the 1970s to 1980s. Until the end of the 1980s, LC science was basically science of the LC bulk, although by the endeavours of many outstanding scientists (Durant, Kleman, S. Kobayashi, etc) the basis of the surface physics of LCs was established. One of the unique surface phenomena in LCs is their orientation by an anisotropic rigid boundary. Due to long-range orientational interactions, the preferable orientation of a LC (the so-called director) given by the surface extends into the LC bulk on a macroscopic scale. As this takes place, the orientational elasticity 'smoothes out' orientational inhomogeneities that are unavoidably present at the surface. It allows scientists to obtain liquid 'single-crystals' in cells with thicknesses varying from several micrometres to hundreds of micrometres.

Since the first works of O. Lehmann (1906), C. Mauguin (1911) and P. Chatelian (1943), the anisotropy of the aligning surfaces was achieved by mechanical rubbing. Firstly, the experimentalists simply rubbed the glass substrate with a piece of paper or leather. This method required an exclusive cleaning of the glass, was not particularly reliable and could not be applied in mass production. The rubbing technique became much more simple and durable when James Fergason[1] proposed to cover a glass substrate with a rubbed polymer layer. It is agreed now that there are two main mechanisms of LC alignment on a rubbed polymer surface. The first mechanism is a change of the topography of the polymer surface, namely producing an anisotropic micro-relief on the surface, and the second is an ordering of polymer fragments during the rubbing process.

The rubbing of polymers turned out to be a very convenient technique and it is now widely used both in small scientific labs as well as large LCD factories. At the present time, the technology of latest generation LCD production also involves a rubbing technique in order to provide homogeneous alignment of nematic LCs over large (32–40") screens. Enormously expensive rubbing machines of several metres width provide precise pressure and accurate motion of the rubbing roll over the glass substrate in this case.

Despite apparent achievements of the rubbing technology, it has some serious drawbacks which became obvious from the first steps of its applications, and these appeared to be crucial for the production of

[1]Information about the first application of a rubbed polymer layer (PVA) for LC alignment was courteously granted to me by J. Castellano.

last-generation LCDs and miniature LC telecommunication devices. These drawbacks follow from the contact type of the rubbing technology. Movement of the rotating rubbing roll over the polymer surface leads to the accumulation of static charges and the generation of fine dust particles that can diminish the fundamental characteristics of the device and are dangerous for its operation. For instance, accumulation of static electricity may destroy transistors or diodes driving the LCD. The application of the rubbing technology for large diagonal LCDs faces additional difficulties due to the problems of the precise control of the rubbing characteristics over huge substrate areas. Other problems may arise when rubbing is used in miniature telecommunication devices where there is the need to align LCs in the thin gaps of the light waveguides.

The idea to align LCs by light was born independently and almost simultaneously at the beginning of the 1990s in the USA (Gibbons *et al.*), Russia (Chigrinov, Kozenkov *et al.*) and Ukraine (Reshetnyak, Reznikov *et al.*). The idea was based on the application of an effect of light-induced anisotropy in the solid state (the Weigert effect, 1919) to produce an anisotropy axis on a polymer surface by the use of polarised light. Shortly before that, Ichimura *et al.* (Japan) proposed to change the alignment of a LC in a cell by non-polarised light irradiation of a photosensitive aligning surface modified with an azobenzene monolayer. The advantages of the new contactless technology were evident. In contrast to the rubbing technique, neither excess charge nor dust end up on the substrates. Photoalignment technology promised effective control of basic anchoring parameters: easy orientation axis, pretilt angle and anchoring energy. Photoalignment can become a powerful tool to control the orientation in the LC bulk by means of light-induced changes of the anchoring on the boundary surfaces. Moreover, photoalignment techniques promise new advanced applications of LCs for optical processing and storage where the rubbing technique cannot be applied due to the complex geometry of the LC units. Therefore, studies of photoaligning effects, synthesis of photoaligning materials and development of different photoalignment technologies for mass production have became one of the hottest topics of applied LCs science since the invention of photoalignment.

Since photoalignment was discovered, more than 500 papers have been published, several companies now produce photoaligning materials and the photoalignment process has gained popularity in LC labs. Therefore, the publishing of the first book on this topic in the Wiley-SID series by V. Chigrinov, V. Kozenkov and H.S. Kwok (*Photoalignment of Liquid Crystal Materials: Physics and Application,* 2008, UK*)* is very timely. As some of the pioneers in the field, the authors set themselves the task of delivering to a wide LC community the main principles, physical origins and the application of the photoaligning technique, and they coped well with this task.

The book begins with a very short (in my opinion, a little too short, only 2 pages) introduction, in which the authors briefly refer to the basic publications of the topic (probably by mistake the authors forgot to refer to the priority paper of the Kiev group, published in the *Ukrainian Physical Journal* in 1991), list possible benefits of the photoalignment technique and formulate the principal aims of the book. In my opinion, it would benefit the book if the authors had included in the introduction at least a short review of the physical principles of anchoring of LCs on aligning surfaces and set the place of photoalignment technology among other alignment techniques. A brief description of the main principles and definitions of the surface physics of LCs would be very useful for scientists and students who are not familiar with the book's topic.

The following text is divided into five chapters that cover two principal areas: the physical principles of photoalignment technology (chapters 2 and 3) and application of photoalignment (chapters 4–6). In addition, at the end of the book, abstracts of the US patents related to photoalignment technology are listed.

The second chapter is devoted to the basic mechanisms of photoalignment, i.e. to the effects of light-induced anisotropy in aligning materials. The authors distinguish and describe the mechanisms connected with trans-cis isomerisation in dye-containing polymers and dye films, topochemical crosslinking in side-chain polymers and photo-deimidisation of polyimides. The authors very clearly explain the physical origin of these mechanisms and this chapter is easy to read. At the same time, it is surprising how little is said about the mechanisms of reversible cis-trans isomerisation of azo-containing polymers, the cross-linking mechanism and deimidisation of polyimides, compared to the detailed description of the pure reorientation of azo-dye molecules. One can understand the wish of the authors to provide the readers with the excellent work on this topic from their own group, but it would be reasonable to keep a balance by paying some attention to the other mechanisms. For instance, it would be useful if the description of the theory of photo-induced deimidisation of polyimides proposed by Johnson *et al.* (1994) were mentioned together with the diffusion model of Chigrinov *et al*. (2004). It would also be reasonable to include in the list of mechanisms of photoalignment the mechanisms of bulk mediated photoalignment (Voloshchenko *et al.* 1994), to which a series of papers in *Physics Reviews* were devoted.

Although the third chapter of the book is entitled 'LC-surface interaction in a photoalignment cell', it is mainly devoted to the measurement and control of the basic anchoring parameters (pretilt angle and anchoring energy) and the relative characterisation of the photoaligning materials. The authors present clear descriptions of peculiarities of the oblique alignment on photoaligning surfaces and methods of pretilt generation. Special attention is paid to materials that provide control over a wide range of the pretilt and the anchoring energy. A separate sub-chapter is devoted to the stability of photoaligning materials. The authors concentrate on the experimental data for azo-dye photoaligning materials underlining their perfect stability for ultraviolet and infrared irradiation and good voltage holding ratio. At the same time, it would be reasonable to give the corresponding data for other photoaligning materials. It would also be useful to give some information about image sticking effects, which in fact still prevent the application of photoalignment materials in mass production. The authors briefly describe the methods of the quality characterisation of photoaligning materials. At the end of the chapter the authors present a table summarising the characteristics of different photoaligning materials and make the conclusion that the reorientation of azo-dye molecules is the most suitable mechanism of LC photoalignment. Unfortunately, the qualitative character of the data presented in the table and the lack of information relevant to real applications (alignment quality parameter, voltage holding ratio, sticking parameter, etc, thermo-stability and light-stability) do not allow the reader to draw any determined conclusion.

The fourth chapter of the book is entitled as the book itself, 'Photoalignment of LCs' and it is devoted to the application of photoalignment to different multi-domain LCD modes (vertical alignment and twist modes), the demonstration of the possibility of producing an aligning relief grating and the use of photoalignment technology for alignment on plastic substrates. The authors show that some of the LC photoalignment can be rewritable. Unfortunately, the authors refer exclusively to their own papers on the topic. Besides photoalignment of nematics, the photoalignment of ferroelectric and discotic LCs as well as lyotropic LCs are described in this chapter. At the end, the authors describe very interesting applications of the photoalignment technology for the orientation of LCs in modern optical elements – photonic crystal fibres, glass micro-tubes and optical micro-resonators. The production of such elements is practically impossible using traditional rubbing techniques and clearly demonstrates the potential of the photoalignment techniques.

The fifth chapter is devoted to the application of photoalignment materials in optical elements. In addition to optical elements, described at the end of the fourth chapter, the authors show successful application of the photoalignment technology in the production of patterned polarisers, retardation films, diffraction gratings and Fresnel lenses. The unique capability of the photoalignment technique to obtain different types of alignment on the same substrate, for instance, to alternate vertical and planar alignment, allows the proposal of a number of new types of LCDs. In the sixth chapter the authors describe some of these new devices. Special attention is paid to the application of photoalignment for producing high-quality gray-scale ferroelectric LCDs.

The seventh chapter is entitled 'US patents related to photoalignment of liquid crystals' and occupies about 30% of the book volume. It contains a huge table of the patent classification, the abstracts of 150 patents and very condensed comments. The authors count this chapter as a bibliographical review but it is actually a patent database and inclusion of this database in the book is perplexing.

Overall, although the book has some shortcomings, and in parts represents a compilation rather than a generalised text, I believe that the reader will obtain beneficial information on the various aspects of the physics and applications of the photoalignment of LCs and the techniques involved.

Yuri Reznikov
Institute of Physics of the National Academy of Science
Prospect Nauky 46
Kyiv 252022
Ukraine