

DEPARTMENTS

BOOK REVIEWS

Optical and Spectroscopic Properties of Glass

Gan Fuxi, 283 pages, illus., index, references. ISBN 0-387-54071-7. Springer-Verlag New York, Inc., 44 Hartz Way, Secaucus, NJ 07096-2491 (1992) \$198 hardbound.

Reviewed by W. A. Reed, AT&T Bell Laboratories, 600 Mountain Ave., Murray Hill, NJ 07974.

In the introduction of this book, the author states, "To obtain the available information and experimental results of optical and spectroscopic properties of new glasses, one must read a large number of papers appearing in journals of widely different interests. Therefore, the main effort has been directed towards a compilation of all experimental informations in the above mention field in a book." Toward this end, he has taken on the formidable task of trying to condense a large number of topics on the optical properties of glass into a book of a modest 283 pages. In 10 chapters this book covers glass structure, light scattering, Eigen absorption, refractive-dispersion properties, nonlinear optical properties, ESR spectroscopic properties of transition elements, optical spectroscopic properties of transition elements, laser properties of transition elements, optical and spectroscopic properties of semiconductor microcrystallites, and magneto-optical and optical recording properties of glass thin films. The selection of topics is excellent and one starts the book with great anticipation. Unfortunately, the author has failed to achieve his goal.

The coverage of the material is, in general, superficial. For example, in the chapter on light scattering, the subject of elastic scattering is never treated in a general formulation that is then shown to reduce to either Rayleigh or Mie scattering depending on the assumption that the wavelength is either much greater or much smaller than the size of the scattering sites. Similar examples could be given for the

other chapters. Thus, a reader interested in learning more about any of the subjects is forced to go to the literature. This would be fine if the references were complete and up to date. However, the references listed at the end of each chapter are largely either to the author's own work or to work that is not current. For example, in the chapters on light scattering, optical spectroscopic properties of transition elements, and laser properties of transition elements, the date of the latest reference in each chapter is 1988. In the chapter on optical recording, 15 out of 30 references are to the author's own work with the date of the latest paper by another author being 1987. These are all active and exciting fields of research and one expects a book that purports to be a source of references to be more current. This lack of current references is not due to a delay in publishing and is clearly an omission by the author, since other chapters contain references to his own work dated as late as 1991.

Two subjects that are completely absent from this book are the optical properties of glass fibers and fiber amplifiers/lasers. I would have expected that some mention of these topics would be included, at least as natural extensions of the discussions of bulk glass properties if not as separate topics. Another problem is that many figures and tables are not referenced, which I assume means that the data are taken from the author's own work, but which also leaves the reader no opportunity to examine the source papers. In summary, this book has little to offer that cannot be found in other better written texts, and it is too pricey at \$198.

Liquid Crystals, Applications and Uses

Birendra Bahadur, Ed., three volumes, 1476 pages, illus., index, bibliography. ISBN 981-02-0110-9, 981-02-0111-7, 981-02-0403-5.

World Scientific Publishing Co., 1060 Main Street, River Edge, NJ 07661 (1990, 1991, 1992) \$109, \$80, \$74 hardbound.

Reviewed by Philip J. Bos, Tektronix Inc., Display Research Laboratory, P.O. Box 500, Beaverton, OR 97077.

Liquid Crystals, Applications and Uses, edited by Dr. Birendra Bahadur, is a three volume set of books that covers the diverse applications of liquid crystals. It is a monumental work, with 1476 pages in 26 chapters written by 33 authors.

The books are an encyclopedia of the applications of the liquid crystalline phases of matter that also include several chapters describing what a liquid crystal material is and how its basic physical properties can be understood and controlled. They give the reader a sense of the breadth of the interesting uses of this phase of matter. I found that the books could be skimmed to get a well-rounded introduction to the applications of liquid crystals. If considered at a slower rate, they provide the in-depth descriptions and data necessary for the reader to get a full understanding of the topics covered.

The authors for the subjects covered are of the best in their field. They were selected from many areas and allow the fields covered in the books to be seen from several viewpoints. I found that rather than giving the books a disjointed feel, the different viewpoints make the books more well rounded and easier for a novice reader to appreciate.

Chapters 1 through 4 provide a basic understanding of liquid crystals. Demus opens with an introduction to the general types of liquid crystalline materials and how they are classified. This chapter allows the reader to understand the diversity of the phases of matter that are grouped under the general classification of liquid crystals and to understand how they are different in terms of the shapes and arrangements of the constituent molecules. Madhusudana goes a step deeper

by elucidating the molecular theories of the liquid crystalline phases. Models that predict the molecular ordering found in the various liquid crystal (LC) phases based on the physical intermolecular interactions are presented in detail. The molecular theories are built upon by Coates, who gives a wealth of empirical data on how the details of molecular structure affect the existence of the LC phases. Focusing next on molecular structures that yield the most commonly exploited nematic LC phases of matter, Pohl shows how modifications to the molecular structure affect the bulk physical properties of the nematic phases. Detailed empirical results are given.

The main theme of the book, applications of LCs, is introduced with a focus on the main application of LCs: display devices.

Important factors in actually building a LC device are considered by two authors. Uchida provides an overview of the theories concerning alignment of LCs on a surface, methods of preparing surfaces, how the resulting alignment can be measured, and how the resultant alignment can affect the alignment of the LC material. Morozumi then continues the discussion of alignment and outlines the construction steps used to produce LC devices.

Display applications of nematic LCs are considered in a number of chapters by experts in the respective areas. The areas covered are: dynamic scattering mode LCDs, twisted nematic (TN) and supertwisted nematic (STN), polymer dispersed LCDs, active matrix LCDs, projection devices, and other types of LCDs. This section is opened by a detailed chapter by Bahadur on display parameters and requirements. It begins with an interesting description of the human visual system and progresses into a section on how perception of color is quantified. The remainder of the chapter discusses the measurable parameters related to LCDs such as contrast, switching speed, defects, etc. For each parameter, measurement methods, examples of failure modes, and insights into the underlying factors affecting these parameters is provided.

The first specific display application area covered is the first display application for which LCs were used historically. Dynamic scattering devices are devices that exploit the interesting turbulent flow that results when a LC that tends to dielectrically align perpendicular to an applied electric field is mixed with ions that travel parallel to an electric field and tend to align the LC by their motion. The competition of the ion flow induced alignment and the dielectric alignment produces the turbulent flow patterns that are fully explained in this chapter. The scattering of light by the flow patterns is also covered, as is its optimization by controlling device

construction parameters. Furthermore, the relation of these parameters to observable display parameters such as viewing angle, contrast, and switching speed is made clear. Although not currently exploited, dynamic scattering devices have many interesting properties, and Bahadur does an excellent job in explaining them.

The most significant application of LCs, TN and STN display devices, is covered by the world-recognized authorities on these types of devices: Scheffer and Nehring. For many readers this chapter will be the highlight of the book, because it provides easily readable descriptions of the basic issues related to these ubiquitous devices. First, a simple explanation of the TN device is given, followed by results of detailed calculations that enable a user of TN devices to understand the design and optimization trade-offs. The problems of viewing angle and the limitations related to high pixel count matrix displays are quantified. Scheffer then proceeds to describe his own invention, the STN device, which has become the world-standard flat panel device. Using computer simulation results, the differences in design and operation of the numerous variations of these types of matrix-addressed flat panel displays (STN, OMI, DSTN, FSTN, etc.) are made clear.

Another major display application of LCs is dichroic displays. In these devices, elongated dye molecules are dissolved into and aligned by a LC host. In his chapter on this subject, Bahadur provides a definitive review of these devices. The structure of several dyes is considered and its effect on cell brightness, contrast, and life is made clear through theoretical and experimental observations. The wide variety of particular devices that use dissolved dyes are then described in detail. In each case, the performance of the devices is analyzed in quantities relevant to display devices, and the underlying physics of the performance characteristics are made clear.

A relatively new type of display device that has received a great deal of recent interest, polymer dispersed LCDs, is reviewed by Doane, the inventor of these devices. These interesting devices have small droplets of LC dispersed in a solid "swiss cheese" type of material. The application of an electric field can cause these devices to go from a light scattering condition to a transparent condition. Doane describes the physics of these devices, how to make them, how to optimize their performance, and how they perform in several applications.

The main approach toward achieving flat panel television has been to make a matrix array of individual pixels where each pixel is turned on or off by its own controlling transistor. The performance limitations, status, and future trends for this type of display are out-

lined by Luo in his chapter on active matrix LC devices.

Light valve and projection mode LCDs are covered by Schields and Bleha, who also cover many approaches to making a display device for which individual pixels are addressable. Included are a device for which a light image is focused on a photoconductor to control the voltage dropped across a LC layer and a device for which an electron beam is used to write a charge pattern on one surface of a LC cell to produce the same control effect. In both of those devices, the spatially modulated electric field causes an image to be formed by the LCD. These and other image generation methods are discussed in relation to projection devices with detailed descriptions of the projection optics and resulting performance.

Concluding the chapters on display devices that use nematic LC materials is an eclectic discussion by one of the most senior LC experts in Japan, Kobayashi, and one of his former star graduate students, Mochizuki. This chapter fills in some of the gaps left by the previous chapters by considering tunable birefringence mode devices, fast switching nematic devices, and several types of bistable LC devices. One of the most interesting of these devices is the cholesteric-nematic phase change device that Mochizuki has pushed to very high performance. He describes the operation of his 1000-line color projection display that has intrinsic memory. Also discussed in this chapter are the recent developments in super-homeotropic displays and methods of viewing angle improvement.

Chiral nematic materials are those where the orientation of the nematic LC is described by a twisted structure. If this twist is on the order of the wavelength of light, the structure acts as a Bragg reflector for one sense of circularly polarized light. One application, as described by Sage in Chap. 20, is thermometers, because the tightness of the twist and thus the wavelength of the Bragg reflection can be made highly temperature dependent. Another application is in the decorative arts (remember mood rings?). This application is discussed by Makow in Chap. 21, where experimental observations on the optical effects that can be observed with these materials are provided.

Leaving display applications of LCs, applications related to the nonlinear optical response of LCs are discussed by Palffy-Muhoray in Chap. 18. This chapter has easy-to-read general explanations and rigorous derivations of the origins of optical nonlinearity in LCs. The organization of this chapter together with the author's clear desire to help the reader understand a complicated topic makes the chapter interesting and educational.

Up to this point the applications chapters have dealt with the most well known of the liquid crystalline phases, the thermotropic nematic phase, where the long axes of the molecules tend to thermally fluctuate about a particular axis called the director. This orientational order is common to all of the liquid crystalline phases, but a distinguishing factor is the degree of translational ordering of the molecules. In the nematic phase there is no translational order, but in the smectic A (SmA) phase the molecules tend to form layers with the director axis perpendicular to the plane of the layers. Coates, in his chapter on SmA LCDs, clearly describes this phase of matter and several applications. He covers the most common display applications that make use of the stable but reversible disruption of the smectic layers that can be accomplished through the application of heat and electric fields. He also fully covers and explains one of the more recent applications in the area of fast switching (less than 1 μ s) light modulators.

Another interesting liquid crystalline phase results if the molecules are layered as in the case of the SmA phase but with the director tipped with respect to the plane of the layers. In this smectic C (SmC) phase the director is free to rotate about the layer normal. If the molecules of the SmC phase are chiral, the thermal fluctuations of the molecules do not cause complete averaging out of any macroscopic dipole moments, as occurs in the less-ordered liquid crystalline phases discussed so far. This chiral SmC phase is described by Dijon in his chapter on ferroelectric LCDs. The display device invented by Clark, called the surface stabilized ferroelectric LC (SSFLC) device, is described and investigations aimed at optimizing the device for display applications are clearly presented. In addition to display applications, SSFLC devices have been found to be important as SLMs for optical computing. The chapter in this field by the pioneers of the use of SSFLC SLMs, Clark and Johnson, is particularly interesting. It describes how these new devices can be used in the areas of optical image correlation and processing, optical phase conjugation, and optical neural networks.

Thermotropic LCs of both the nematic and SmC variety have been used as monomers in the synthesis of macromolecules. The varieties and applications of these macromolecules are described in a chapter entitled "Liquid Crystal Polymers" by Finkelmann, Meier, and Scheuermann. An interesting example application of these materials is described in the area of optical storage media. In this case, low molecular weight LC molecules are hung on a polymer "backbone" to form a so-called side-chain LC polymer. This material, which can

form a flexible media, can be locally heated by a laser to change the "frozen" orientation of the LC molecules. Thus, the flexible media can have optically readable information written onto it with a scanning laser. Details of the materials, operation, and limitations of these types of devices are presented along with several other applications.

The diversity of potential applications of LCs is made more evident by three chapters that describe the use of LCs as a medium for spectroscopic studies (Chap. 25 by Khetrapal), for chromatography (Chap. 26 by Witkiewicz), and for chemical reactions (Chap. 27 by Leigh). Each of these chapters is a complete study in their respective areas. Chapter 25 also includes methods and results of magnetic resonance and optical spectroscopic studies of LCs.

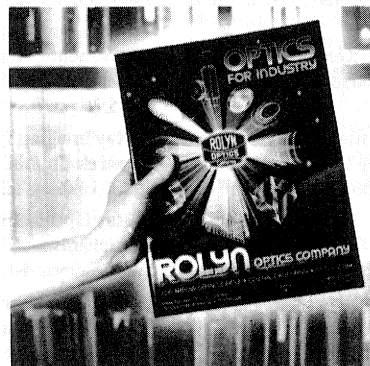
While the applications presented in the chapters discussed so far are numerous, they are only for the branch of liquid crystalline materials called thermotropic LCs. Materials in this class pass from one phase of matter to another (for example, from the nematic to SmA) as the temperature is changed. The other branch of liquid crystalline materials is called lyotropic LCs. These materials are

elongated molecules in solution, and the phase transitions associated with them are controlled by the solvent concentration. Applications of lyotropic LCs are discussed in two chapters: "Lyotropic Mesophases in Non-living Systems" by Friberg covers applications including emulsions, foams, and lubricants; and "Lyotropic Mesophases in Biological Systems" by Chapman covers the application of lyotropic LCs by living systems.

Because many areas are discussed in these books, it may be asked: Is anything missing? In my opinion, there is not much that has been left out, except that additional chapters on the continuum theory and optics of LCs would have been beneficial. These additions would have helped to bridge the gap between discussions on molecular theories of LCs and physical properties of LCs and LC devices.

Overall, Bahadur has done an excellent job in bringing together some of the best people working in the area of applications of LCs. The quality of the individual contributions is very high, and in many cases I think they may be considered definitive reviews of the application areas they consider.

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