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Introduction

This book was conceived as a continuation of the series devoted to the physics and applications of liquid crystal devices [1–14]. The physical and electrooptical properties of liquid crystals (LCs) were reviewed in books written by de Gennes [1], Chandrasekhar [2], de Jeu [3], Bahadur [4], and others [5–14]. The encyclopedia of LCs collects articles on basic physical and chemical principles of LCs, as well as their application strategies in displays, thermography, and some other fields [7]. Electrooptical effects and their applications in LC devices were also discussed in books written by Blinov and Chigrinov [6, 8], Wu [11, 13], and Khoo [14]. LC optics and LC displays (LCDs) were discussed in books written by Yeh [9], Lueder [10], and Boer [12].

A deeper understanding of the basic physics of liquid crystals, including their chemical nature, macroscopic properties, and electrooptical effects, will be a considerable help to acquaint with the already existing and new liquid crystal devices. This book is oriented more toward the reader who not only like to be deeply engaged in the theory or basic physics but also is interested in applications.

This book presents the original description of rheological viscous and elastic properties of liquid crystals and shows the importance of these properties for practical applications in display and nondisplay technologies. In general, liquid crystals show quite complicated rheological behavior described in terms of a number of specific anisotropic elastic and viscous coefficients. Even in the simplest case of incompressible nematic liquid crystals, three elasticity curvature coefficients (Frank's modules) and five independent viscous-like parameters (Leslie coefficients) have to be introduced to make a proper hydrodynamic description of a number of electrooptical effects mostly used in applications. Additional viscous and elastic parameters are needed to describe extremely complicated surface dynamics of liquid crystals interacting with solids. In some specific applications, compressibility of liquid crystals is important, so additional parameters such as anisotropic bulk viscosity coefficients have to be taken into account.

The book will consider the physical nature of anisotropic viscoelasticity of liquid crystalline media, experimental methods for determination of elastic and viscous parameters important for practical applications, main directions for an optimization of existing liquid crystal displays, and physical backgrounds for the application of liquid crystals. Special attention will be paid to the properties and surface dynamics of liquid crystals described in terms of additional viscoelastic parameters such as

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anchoring strength, surface viscosity, and "gliding" viscosity. We will consider some theoretical models useful for understanding the complicated phenomena in the vicinity of liquid crystal–solid boundary, including extremely slow motion (gliding) of an easy axis, which defines a boundary orientation of LCs. The experimental methods and technique for the determination of viscous and elastic parameters of liquid crystals will also be described. We will emphasize the most suitable and reliable methods of viscosity measurements applied for studying newly synthesized liquid crystal materials of a restricted amount. Special parts of the book will be devoted to the display and photonics applications of liquid crystals where rheological properties play a key role. We will present physical backgrounds for the application of liquid crystals as sensors of mechanical perturbations (the sensors of pressure, acceleration, inclination, vibrations, etc.). Most of them are based on the intrinsic connection between shear flows and orientation of nematic liquid crystals. We will consider different types of shear flows of liquid crystals and will present linear hydrodynamic models adopted for a description of such devices. The role of viscous and elastic parameters for the optimization of the parameters of LC sensors will be analyzed in detail. We will also consider nonlinear phenomena in shear flows of liquid crystals essential for practical applications. The possibility of detecting and visualization of high-frequency acoustic fields via liquid crystals will also be discussed.

The problems of studying surface dynamics and determination of viscoelastic parameters responsible for fast and slow orientational motions will be highlighted. The aim of this book is to present the ways of optimization of liquid crystal displays by a proper choice of viscoelastic characteristics. We will focus on new types of displays where surface anchoring and surface dynamics play a key role.

We will pay special attention to describe in detail the original results obtained by the authors. For example, we will discuss the advantages of new experimental methods for shear viscosity measurements, the problem of optimization of viscoelastic properties for modern display applications, the physical backgrounds of liquid crystal sensors, the usage of ultrasound in rheological investigations, and applications of liquid crystals.

After the "Introduction," which is the first chapter of this book, we will come to Chapter 2, which is devoted to basic physical properties of LCs, such as structure and symmetry of LCs, phase transitions, and mixture preparations. Dielectric, optical, and viscoelastic properties of LCs are reviewed in this chapter, taking into account their relationship with the molecular structure and mixture content. Chapter 2 also considers the surface phenomena and cell preparations, strong and weak anchoring conditions, and the behavior of liquid crystals in magnetic and electric fields.

Chapter 3 describes anisotropic LC flows. Very complicated rheological behavior in Couette and Poiseuille LC shear flows results in a number of linear and nonlinear phenomena that have no analogues in isotropic liquids.

The optical response of LC channel at low frequencies strongly depends on LC layer thickness and boundary conditions and can be effectively controlled via electric fields, which is a key factor for LC sensor applications. Both steady LC flow regimes and flow instabilities will be considered in this chapter as key factors for LC applications as sensors and microfluid detection.

Ultrasonic methods and techniques especially developed for the characterization of LC elastic and viscous parameters are listed in Chapter 4. In particular, we have shown that such an important LC parameter as rotational viscosity coefficient can be easily extracted from LC ultrasonic data in experiments with rotating magnetic fields. We have also discussed ultrasonic methods as a unique tool for studying critical dynamics of liquid crystals at phase transitions of different types, including strongly confined systems.

Chapter 5 includes a review of experimental methods of determination of viscoelastic parameters of liquid crystals. This chapter also summarizes a very complicated behavior of LCs in near-surface layers in terms of a restricted number of parameters such as an easy axis, a surface director, an anchoring strength, and a surface viscosity. Contrary to the case of viscoelastic properties in bulk samples, these parameters reflect the interaction between LC and solid substrate. A photo-alignment technique is shown to be very effective for surface patterning with well-defined anchoring properties, which is of great practical importance. Various experimental techniques used for measuring anchoring strength such as field-off and field-on techniques are studied in detail. Near-surface layers of liquid crystals with a specific surface dynamics, such as bulk, surface, and gliding switching, are also studied.

Chapter 6 is devoted to optimal rheological properties of liquid crystals for applications in displays and photonics. We provide a general insight into various electrooptical modes in LCs with the purpose of explaining (i) the basic characteristics of the effects and their dependence on LC physical parameters and (ii) correlation of the LC rheological properties (elastic and viscosity constants, dielectric and optical anisotropy, type of LC alignment, and surface energy) with the application requirements. We consider in this chapter both active matrix (AM) and passive matrix (PM) LCD applications. Low power consumption LCD with memory effects is also highlighted. Finally, we will pay a special attention to a new trend of LC development in photonics: passive optical elements for fiber optical communication systems (DWDM components).

Extremely high sensitivity of nematic layers to the action of steady and low-frequency flows induced by a pressure gradient, which is very attractive for sensor applications, is considered in Chapter 7. The stabilizing electric fields are shown to be very effective for the optimization of technical characteristics (threshold sensitivity, dynamic range, and operating times) of LC sensors. A number of pressure gradient LC sensors (differential pressure sensors, sensors of acceleration, vibrations, inclination, and liquid and gas flows) are proposed. We have shown that LC sensors are most effective for registration of steady or low-frequency mechanical perturbations, as well as for registration, visualization, and mapping of ultrasonic fields.

The principal aims of the book are:

- to describe the practically important rheological properties of liquid crystals and preparation of liquid crystal cells most important for applications;
- to summarize the basic methods of the experimental determination of LC basic rheological parameters such as elastic and viscosity coefficients;

- to enlist LC surface interactions in terms of bulk, surface, and gliding switching as well as measurement methods for such important LC surface parameters as polar and azimuthal anchoring energy, surface, and gliding viscosity;
- to show how to control the liquid crystal behavior in electric and magnetic fields by varying its macroscopic rheological physical parameters and cell geometry;
- to compare various liquid crystal applications in displays and photonics dependent on LC rheological parameters and cell geometry;
- to present the original results of the authors in LC flow dynamics, acoustical LC phenomena, ultrasonic techniques, and LC sensors.

The book is intended for a wide range of engineers, scientists, and managers who are willing to understand the physical backgrounds of LC usage in modern display industry and nondisplay applications of liquid crystals as sensors of mechanical perturbations and as active optical elements, such as modulators, shutters, switchers, and so on. The book would be useful for students and university researchers, who specialize in the condensed matter physics and LC device development.

To the best of our knowledge, there are no books, and only a few reviews and book chapters devoted to some of the problems under considerations are available; so, we believe that our book would be of considerable interest to a relatively wider audience.

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