Polymers for Lightwave and Integrated Optics: Technology and Applications (Optical Engineering Series/32)

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This volume deals with the emergence of novel optical polymers for use in the growing fields of photonics and related technologies. It summarizes a wide range of information on linear and second- and third-order nonlinear optical polymers for communications devices. Materials synthesis, characterization, and device design and fabrication are all surveyed. Many articles are cross-disciplinary reviews of current technology, with extensive references. This is an excellent overview for readers at all levels of background.

Chapter 1 (Kaino) is an excellent description of the physics involved in light propagation through polymer optical fibers (POFs). A great deal of practical information is summarized in text and tabular form concerning the fabrication and characterization of POFs, particularly PMMA fibers. Loss in fibers caused by scattering and absorption is considered. A short applications overview is also given, with less detail than is discussed in Chapter 2 (Theis et al.), which considers specific device applications for POFs in the data communications and sensors fields with data obtained in the mid-1980s. Power budgeting for different types of networks and a variety of optical couplers are discussed, along with the practical bandwidth considerations for making commercial system parameters. Multimode fiber optic sensors are also briefly discussed.

Chapter 3 (Koike) returns to materials properties and considers the relatively new class of graded index (GRIN) polymers. A brief, but comprehensive, overview of the mathematics of GRIN optics is given, followed by a good outline of materials processing issues (including diffusion and monomer reactivity) involved in the manufacture and application of these materials. The treatment of these applications by considering the structure/property relationships and the evaluation of different polymer processing methods makes this chapter particularly interesting. Chapter 4 (Franke) covers the photopolymerization and multistep processing of poly(methyl methacrylate) for lithographic applications. The effect of processing modifications on the optical behavior of volume phase holograms is discussed in detail, with several in-depth profiles illustrated for a variety of processing conditions. Photolocking and ion implantation methods for preparing lightguides are also considered.

The next series of chapters cover specific device applications and new polymers that might be commercially useful. Chapter 5 (Monroe and Smothers), covering photopolymers for holography and waveguide applications, summarizes several papers specific to the DuPont group's results. Chapter 6 (Kawatsuki and Uetsuki) discusses transmission, reflection, and waveguide microoptical grating elements. Novel polysilynes, linear polymers having all-silicon backbones, are considered in Chapter 7 (Weidman et al.). Synthesis and characterization of selected materials are provided, along with an evaluation of the bleaching properties and photolithographic methods for fabricating waveguides from promising polyalkylsilynes. Another interesting polymeric waveguiding substrate is polyimides, which is summarized by Franke in Chapter 8 including advantages of polyimide lightguides and specific structures examined by several groups. Fabrication of multilayered structures is considered, along with the characterization of environmental factors such as moisture affecting optical performance.

The sections by Booth (Chapter 9) and Hartman (Chapter 10) deal with polymers for linear integrated optics applications. Polymer lightwave fabrication technology is outlined, with etching techniques and polymerization-induced internal diffusion waveguide formation described. Although most of this information appears elsewhere, a large number of photographs and figures make this a useful summary. Optical interconnectability, functionality, and waveguide evaluation are covered. The chapter by Hartman is written from the viewpoint of a computer hardware designer interested in using optical interconnections and other devices, and makes particularly interesting, straightforward reading for the more materials-oriented reader. Figures and photographs here are also very helpful.

The second part of the text considers nonlinear optical (NLO) polymers and their applications in lightwave technologies. Many of the articles in this part represent reviews of earlier work with more background and detail than previously available. The first of these articles by Norwood et al. from Hoechst Celanese discusses their progress in developing passive materials for waveguides and fiber optics and in polymers for second- and third-order NLO applications. The basic requirements and device concepts are discussed, and a limited materials comparison is made. Multifunctional materials, the newest buzzword describing polymers having many useful properties "engineered" into the structure, are briefly discussed. The article by Singer is a nice summary of previous work on molecular processes in poled polymers for second-order nonlinear optics and contains some new information on anomalous dispersion-phase matching in specific polymers. The relationship between the molecular optical nonlinearity and the bulk material susceptibility is described very well.

The article by Pantelis and Hill concerning guest-host systems for second-order NLO applications has a good historical perspective and a broad base of references on the development of a variety of doped materials, and compares these systems to the functionalized materials they have developed at British Telecom. Important processing issues including poling methods and aging phenomena studied by many groups are discussed. The article by van der Vorst et al. from Akzo is also an excellent review, with a detailed description of side-chain functionalized polymers for second-order NLO applications. The outline of the calculation of order parameters following poling is helpful. This paper concentrates on the electro-optic (EO) effect and test devices, unlike earlier papers that emphasize second harmonic generation.

Holland continues with the device theme, examining fabrication, characterization, and device design for EO thin films. The following paper by Lytel et al. describes electrooptic polymer device integration for electronic systems. This chapter summarizes and tabulates a variety of device applications in terms of detailed materials requirements and limitations, and is written from both a materials and electronic systems point of view. Specific applications of NLO polymer as etalons and free space interconnects are described by Kowel and Eldering.

The next several chapters consider third-order NLO effects. Although there is significant overlap in these articles, all are well organized and referenced. Helfin and Garito provide an overview of the history, theoretical formalisms, and mechanisms of microscopic third-order NLO behavior. Characterization and measurements are also discussed. The chapter by Kobayashi is also a detailed summary which considers four wave mixing theory and experiments. Experiments to measure EO coefficients in doped polymers and ultrafast optics are also outlined. This theme is continued in the article by Kajzar et al., detailed with almost 200 references and extensive tables, considering processing and characterization of third-order NLO polymers. The chapter by Kaino and Kurihara discusses specific third-order NLO π-conjugated polymers, such as poly(arylene vinylenes), polythiophenes, and dye-attached and doped polymers. Thakur considers the specific case of polydiacetylene waveguides for all-optical phase modulation waveguides.

The final two chapters are concerned with holographic applications: an article on holographic memory using organic storage media by Driemeier and Lechner and one on persistent spectral hole burning by Itoh and Tani. This type of information, which is rarely considered in other NLO polymer-based books, makes an interesting and thought-provoking addition. The first article describes requirements for optical storage media, principles of holographic storage, and current and future materials and requirements. The second chapter by Itoh and Tani considers spectral hole burning, which can be used to implement frequency-multiplexed optical storage.

The general reader familiar with polymers but not necessarily with optics and who wants to get a good overview of the field will enjoy this book. In addition, sufficient detail and depth make it useful to more knowledgeable readers.

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