Preface

With the rapid advance of integrated optics, the importance of optical waveguides, which are the fundamental elements of optical integrated circuits, has been widely recognized. For example, the further success of broadband communications in optical networking, metro/access communications, and computing will rely on advances in optical interconnects, optical components, such as splitters, combiners, multiplexers and demultiplexers, optical switches/modulators, tunable filters, variable optical attenuators, amplifiers, and integrated optical circuits that are based on optical waveguides. The most widespread optical waveguide has been the optical fiber, which provides the huge bandwidth required to carry all of the information between tele-/datacommunication centers. After having moved from long haul backbones to metropolitan area networks and local area networks, integrated waveguides are and will become increasingly more important for rack-to-rack, board-to-board, chip-to-chip, and component-to-component within a single chip or on-chip interconnect.

Integrated optics presents a potentially low cost and higher performance alternative to electronics in optical communication systems. A dramatic scaling down in feature sizes has mainly driven semiconductor productivity and performance increases at exponential rates in the past decades, as smaller devices on lager wafers led to larger yield, lower cost, and faster circuits. However, with approach of Giga-scale integration, the scaling-down in sizes has almost reached a physical limitation due to its negative impact on the resistance and inductance of metal interconnects with current copper-trace base technology. As a result, electronic interconnects have become the primary limit on high speed/high frequency circuits, causing significant propagation delays for clock signals, overheating, information latency, and electromagnetic interference. The optical interconnect is therefore an increasingly attractive alternative, which can provide much greater bandwidth, lower power consumption, decreased interconnect delays, resistance to electromagnetic interference, and reduced crosstalk. Optical interconnects in which light can be generated, guided, modulated, amplified, and detected need to be integrated with standard electronic circuits to combine information processing capabilities of electronics with data handling of photonics. However to be widely adopted, these covering technologies must provide significant performance breakthrough with a cost-effective engineering. In other words, an optical interconnect could replace an electrical interconnect when it has higher performance at lower cost and strong manufacturability in high volume. This can be done through integrated optics with optimal waveguide materials selection, and improved component design and integration.

Integrated waveguide optics now represents a truly multidisciplinary field of science and engineering, which encompasses not only a rather broad range of research topics but also a diverse variety of well-rooted industrial applications. As the technology of waveguide optical devices and systems has matured, it has penetrated a number of markets by providing performance-competitive integrated optic and fiber-optic device solutions. This growth, in turn, requires new developments in modeling, further advances in material science, and innovations in integration platforms. In addition, the processing and fabrication of these new devices must be optimized in conjunction with the development of accurate and precise characterization and new testing techniques. In response to these critical needs, there have been many investigations and revolutionary advances in optical waveguide materials and fabrication technologies for integrated optics that promise integrated and cost-effective optical interconnect solutions. As a result, a great many papers, articles, and presentations have been published on the development of advanced materials for optical waveguides. However, few comprehensive discussions devoted to the buildup of a fundamental system from optical waveguide materials have been available to students, scientists, and engineers.

To meet this need, this book aims to introduce in a comprehensive manner advanced materials and fabrication technologies, characterization methodology, design and simulation guidelines, and perspectives on likely future trends and challenges in integrated optical waveguides for information technology and data communications. Chapter 1 provides an outline of waveguiding theory, evolution of optical interconnects, waveguide component and integration technology, waveguide materials and fabrication techniques, and component simulation and design guideline. Chapter 2 gives an extensive review of assessment techniques and characterization methodology for advanced optical waveguide materials and components. Chapter 3 provides an overview of the state of the art of optoelectronic devices integrated with optical waveguides, including light sources, modulations, detectors, receivers, optical pathways, switches, and their integration technology. Chapters 4–11 are an in-depth introduction to the diverse and increasing number of advanced optical waveguide materials and fabrication techniques, including optical fibers, semiconductors, electro-optic materials, glasses, silicon-on-insulator technology, polymers, hollow waveguides, and metamaterials. Finally, Chapter 12 presents a perspective on anticipated future trends in advanced materials for integrated optical waveguides and their applications.

It is a great pleasure to acknowledge the help and support I have received from my colleagues who have contributed to my understanding of optical waveguides and integrated optics. I would like to express my sincere gratitude to Dr. David Packer, the series editors, and all other editing staff at Springer who helped to give the text its final polish.

Schaumburg, IL, USA Xingcun Colin Tong

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