

Optical Biosensor Based on Integrated Interferometer Using Polymeric Waveguides

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ABSTRACT

Design, simulation, and preliminary experimental studies of an integrated optical micro-biosensor, which is based on a Mach-Zehnder interferometer for biochemical samples, are presented. The biosensor consists of SU-8 polymer waveguides integrated on silicon substrate and is based on the evanescent interaction of light with an immobilized bio-sample on a waveguide. The interferometer comprises of two branches: a reference and a sensing waveguide. The latter of which is in direct contact with a bio-sensitive layer and can bind biological specimens. This layer serves as cladding for the sensing waveguide. Changing the specimen causes a variation of the refractive index of the cladding layer, which can be observed through the phase shift between light of both interferometer branches.

Consequently, changes of the interference maxima and minima of the output signal can be detected and analyzed with a CCD or a simple integrated photodiode. The refractive index of the specimen is sensitive to density, sample composition and layer thickness of the cladding. The effective refractive index is also strongly dependent on the light polarization showing differences in response for TE and TM waves.

Finite domain computation for SU-8 waveguides was carried out for TE and TM at a wavelength of $\lambda = 630$ nm. The interferometric configuration was analyzed using the FDTD method and further filtering and signal computing provided quantitative results, which can be used for the final design of the interferometer. In addition, optical waveguides with a thickness of 1 μm and width 5 μm - 15 μm were defined. The refractive index was around 1.59 and depends on exposure time and thermal processing.

Keywords: bio sensor, polymer waveguides, SU-8, interferometer

1. Introduction

Biosensors are important devices for the determination of the mechanisms and kinetics of biological events.

Optical integrated biosensors are monolith devices capable of fast, precise and accurate measurement of presence, identity, and quantity of molecules, enzymes, proteins etc. It basically consists of a source, a sensing area and a detector. There are many techniques used to detect bio samples properties: luminescence, interference, Surface Plasmon Resonance (SPR). It depends on how bio layer manifests itself during the interaction with light field. The SPR method for the detection of thin biological films outputs a single value comprising two parameters describing the biological layer: its thickness and refractive index.

This work describes a high accuracy interferometric sensitive method for measuring the parameters for a polymeric SU8 waveguide sensor: thickness and refractive index. Furthermore the refractive index study gives information also on bio layer composition.

We chose the interferometric method of measurement. It is based on an integrated micro-interferometer: a Mach-Zehnder(MZ), an Y splitter or

double layered waveguide with far field interference. The main idea is to obtain cheap miniaturized sensors that can be integrated with the light source and field detector with a high working accuracy.

2. Structure and working principle

Our first interest was to determine more precisely the interaction between the wave front and the bio specimens. This results mainly from the main modes and propagation principles of light through the waveguide. Evanescent wave sensing is based on surface plasmon resonance (SPR) phenomena at the frontier between the waveguide and the bio layer [1,2]. The waveguide top surface must be biological „active“. During bio interactions: DNA hybridization [3], formation of enzyme layers, cells binding [4] etc., the spectrum of the SPR is altered. Bio interaction also changes the effective refractive index and absorbance coefficient of the layer at a certain frequency. Our main interest is focused in DNA genome and enzyme detection. The basic theoretical and preliminary tested structure of the sensor has the construction and cross section profile presented in figure 1. As it can be seen a polymer (typically PMMA or other) with a lower refractive index

Optical Biosensor Based On Hollow Integrated Waveguides

Aaron R. Hawkins, Holger Schmidt



Optical Biosensor Based On Hollow Integrated Waveguides:

Optochemical Nanosensors Andrea Cusano, Francisco J. Arregui, Michele Giordano, Antonello Cutolo, 2016-04-19 This book provides an overview of the state of the art in optical and chemical nanosensors for industrial environmental diagnostic security and medical applications It summarizes the various types and developments in optical and chemical sensor technology and then explains how the integration of optical chemical sensors and nanomaterials creates new opportunities The text also reviews optochemical sensors starting from the basics in optoelectronics and concluding with the principles of operation at the basis of optochemical devices The authors offer insight into future trends in this growing field and present a range of applications in the fields of medicine security and bioterrorism

Optical Guided-wave Chemical and Biosensors II Mohammed Zourob, Akhlesh Lakhtakia, 2010-03-10 For the first time distinguished scientists from key institutions worldwide provide a comprehensive approach to optical sensing techniques employing the phenomenon of guided wave propagation for chemical and biosensors This includes both state of the art fundamentals and innovative applications of these techniques The authors present a deep analysis of their particular subjects in a way to address the needs of novice researchers such as graduate students and post doctoral scholars as well as of established researchers seeking new avenues Researchers and practitioners who need a solid foundation or reference will find this work invaluable This second of two volumes covers the incorporation of periodic structures in waveguides to exploit the Bragg phenomenon optical fiber sensors hollow waveguides and micro resonators as well as a review of the tremendous expansion of terahertz technology for sensing applications

Planar Waveguide Optical Sensors Aradhana Dutta, Bidyut Deka, Partha Pratim Sahu, 2016-08-30 This book concentrates on the design and development of integrated optic waveguide sensors using silicon based materials The implementation of such system as a tool for detecting adulteration in petroleum based products as well as its use for detection of glucose level in diabetes are highlighted The first chapters are dedicated to the development of the theoretical model while the final chapters are focused on the different applications of such sensors It gives the readers the full background in the field of sensors reasons for using silicon oxynitride as a potential waveguide material as well as its fabrication processes and possible uses

Optofluidics 2015 Shih-Kang Fan, Da-Jeng Yao, Yi-Chung Tung, 2018-07-04 This book is a printed edition of the Special Issue Optofluidics 2015 that was published in Micromachines

Progress in Optical Fibers Research Zhijian Guo, 2007 This book presents new and important research on optical fibres An optical fibre is a glass or plastic fibre designed to guide light along its length by confining as much light as possible in a propagating form In fibres with large core diameter the confinement is based on total internal reflection In smaller diameter core fibres widely used for most communication links longer than 200 meters the confinement relies on establishing a waveguide Fibre optics is the overlap of applied science and engineering concerned with such optical fibres Optical fibres are widely used in fibre optic communication which permits transmission over longer distances and at higher data rates than other forms of wired and

wireless communications They are also used to form sensors and in a variety of other applications The term optical fibre covers a range of different designs including graded index optical fibres step index optical fibres birefringent polarisation maintaining fibres and more recently photonic crystal fibres with the design and the wavelength of the light propagating in the fiber dictating whether or not it will be multi mode optical fibre or single mode optical fibre Because of the mechanical properties of the more common glass optical fibres special methods of splicing fibres and of connecting them to other equipment are needed Manufacture of optical fibres is based on partially melting a chemically doped preform and pulling the flowing material on a draw tower Fibers are built into different kinds of cables depending on how they will be used

On-Chip Photonics Alina Karabchevsky,Amol Choudhary,2024-08-13 On Chip Photonics Principles Technology and Applications reviews advances in integrated photonic devices and their demonstrated applications including ultrafast high power lasers on a chip mid infrared and overtone spectroscopies all optical processing on a chip logic gates on a chip and cryptography on a chip The summaries in the book s chapters facilitate an understanding of the field and enable the application of optical waveguides in a variety of optical systems The ultimate goal of this work is aimed at accelerating the transition of on chip photonics from academia to the industry Each chapter where appropriate provides an overview of the computational tools fabrication methods and suggestions for the realization of on chip photonic devices Introduces advanced concepts of passive and active on chip photonic components Discusses emerging applications of on chip photonics quantum technologies computing and more Reviews materials computational tools and suggestions for the realization of on chip photonic devices **Integrated Hollow Core Waveguide Devices for Optical Sensing Applications** Dongliang Yin,2006

Advanced Materials for Integrated Optical Waveguides Xingcun Colin Tong Ph.D,2013-10-17 This book provides a comprehensive introduction to integrated optical waveguides for information technology and data communications Integrated coverage ranges from advanced materials fabrication and characterization techniques to guidelines for design and simulation A concluding chapter offers perspectives on likely future trends and challenges The dramatic scaling down of feature sizes has driven exponential improvements in semiconductor productivity and performance in the past several decades However with the potential of gigascale integration size reduction is approaching a physical limitation due to the negative impact on resistance and inductance of metal interconnects with current copper trace based technology Integrated optics provides a potentially lower cost higher performance alternative to electronics in optical communication systems Optical interconnects in which light can be generated guided modulated amplified and detected can provide greater bandwidth lower power consumption decreased interconnect delays resistance to electromagnetic interference and reduced crosstalk when integrated into standard electronic circuits Integrated waveguide optics represents a truly multidisciplinary field of science and engineering with continued growth requiring new developments in modeling further advances in materials 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 testing methods. Students and professionals in materials science and engineering will find *Advanced Materials for Integrated Optical Waveguides* to be an invaluable reference for meeting these research and development goals. *Electromagnetic Propagation and Waveguides in Photonics and Microwave Engineering* Patrick Steglich, 2020-10-21. Optical and microwave waveguides have attracted much research interest in both science and industry. The number of potential applications for their use is growing rapidly. This book examines recent advances in the broad field of waveguide technology. It covers current progress and latest breakthroughs in emergent applications in photonics and microwave engineering. The book includes ten contributions on recent developments in waveguide technologies including theory, simulation, and fabrication of novel waveguide concepts as well as reviews on recent advances.

Plasmonic Optical Fiber Biosensors Christophe Caucheteur, Médéric Loyez, 2023-04-30. This book provides a thorough vision of the current trends in plasmonic optical fiber biochemical sensing. It gathers the most recent technological information and shows the maturity reached by the different subsequent technologies. Demonstrating roadmaps for the design process and implementation of plasmonic optical fiber biochemical sensors, the book bridges the gap between theory and application. With this philosophy, understanding key physical properties is of paramount importance for the efficient design of sensing platforms that will meet target specifications. You will learn about the role of the fiber configuration and the functional coating on the properties of the resulting optrodes. You will also get an encompassing overview on all optical fiber configurations used for plasmonic sensing, thus far, especially on the progress made over the last decade and rendering the technology compatible for use in real conditions. The book presents both fundamental aspects and advanced applications while focusing on recent and emerging fields of research such as the use of tilted fiber Bragg gratings, the integration of sensors in situ, the use of smart interrogation techniques, and much more. This is a unique reference for both beginners and experts in optical fiber-based sensors, especially for industrial engineers working in biophotonics and biochemical sensing, as it presents state-of-the-art design procedures and sensing features. The book's theoretical background combined with recent advances of plasmonic-based optical fiber technologies also make it highly beneficial for all researchers, academics, and students specialized or interested in this flourishing and promising discipline.

Computational Photonic Sensors Mohamed Farhat O. Hameed, Salah Obayya, 2018-06-13. This book provides a comprehensive overview of the photonic sensing field by covering plasmonics, photonic crystal, and SOI techniques from theory to real sensing applications. A literature review of ultra-sensitive photonic sensors, including their design and application in industry, makes this a self-contained and comprehensive resource for different types of sensors with high value to the biosensor sector in particular. The book is organized into four parts. Part I covers the basic theory of wave propagation, basic principles of sensing, surface plasmon resonance, and silicon photonics. Part II details the computational modeling techniques for the analysis and prediction of photonic sensors. Part III and Part IV cover

the various mechanisms and light matter interaction scenarios behind the design of photonic sensors including photonic crystal fiber sensors and SOI sensors This book is appropriate for academics and researchers specializing in photonic sensors graduate students in the early and intermediate stages working in the areas of photonics sensors biophysics and biomedical engineering and to biomedical environmental and chemical engineers

Microneedles for Drug and Vaccine Delivery and Patient Monitoring Ryan F. Donnelly, Thakur Raghu Raj Singh, Eneko Larrañeta, Maeliosa T.C. McCrudden, 2018-08-20 Provides comprehensive coverage of microneedles for delivering and monitoring patient drugs and vaccines Microneedles are an incredibly active research area and have the potential to revolutionize the way many medicines and vaccines are delivered This comprehensive research book covers the major aspects relating to the use of microneedle arrays in enhanced delivery applications Beginning with a history of the field and the various methods employed to produce microneedles from different materials Microneedles for Drug and Vaccine Delivery and Patient Monitoring discusses the penetration of the stratum corneum by microneedles and the importance of application method and force and microneedle geometry height shape inter needle spacing Transdermal and intradermal delivery research using microneedles is comprehensively and critically reviewed focusing on the outcomes of in vivo animal and human studies The book describes the important topics of safety and patient acceptability studies carried out to date It also covers in detail the growing area for microneedle use in the monitoring of interstitial fluid contents Finally it reviews translational and regulatory developments in the microneedles field and describes the work ongoing in industry The only book currently available on microneedles Filled with tables graphs and black and white images photographs micrographs Authored by four experts in pharmaceuticals Microneedles for Drug and Vaccine Delivery and Patient Monitoring is an ideal source for researchers in industry and academia working on drug delivery and transdermal delivery in particular as well as for advanced students in pharmacy and pharmaceutical sciences

Advances in Fibers, Optical Sensors, Optical Communications and Networks Varun Raghunathan, Tapajyoti Das Gupta, Seabrata Mukherjee, 2024-11-21 This book presents the proceedings of the Biennial Photonics Conference Photonics 2023 held at IISc Bengaluru on 5-8 July 2023 It covers topics across multiple areas of photonics including established areas like optical communication and networks quantum optics non linear and ultrafast photonics nanophotonics biophotonics and bioimaging photonic integrated circuits fibers and sensors optical materials and fabrication techniques optical metrology and instrumentation optofluidics laser applications optoelectronics The book also covers emerging areas in photonics such as THz photonics structured Light 2D materials optomechanics topological photonics and AI ML in photonics The book will be useful for researchers and professionals interested in the broad field of photonics

Integrated Ring Resonators Dominik Gerhard Rabus, Cinzia Sada, 2020-12-04 The optical filter is resonator based The required passband shape of ring resonator filters can be custom designed by the use of configurations of various

ring coupled resonators This book describes the current state of the art on these devices It provides an in depth knowledge of the simulation fabrication and characterization of ring resonators for use as example filters lasers sensors

Handbook of Optofluidics Aaron R. Hawkins,Holger Schmidt,2010-03-19 Optofluidics is an emerging field that involves the use of fluids to modify optical properties and the use of optical devices to detect flowing media Ultimately its value is highly dependent on the successful integration of photonic integrated circuits with microfluidic or nanofluidic systems Handbook of Optofluidics provides a snapshot of the s

Integrated Optics: Devices, Materials, and Technologies ,2005 **Portable Biosensing of Food Toxicants and Environmental Pollutants** Dimitrios P. Nikolelis,Theodoros Varzakas,Arzum Erdem,Georgia-Paraskevi Nikoleli,2013-10-21 Biosensors are poised to make a large impact in environmental food and biomedical applications as they clearly offer advantages over standard analytical methods including minimal sample preparation and handling real time detection rapid detection of analytes and the ability to be used by non skilled personnel Covering numerous applications of biosensors used in food and the environment Portable Biosensing of Food Toxicants and Environmental Pollutants presents basic knowledge on biosensor technology at a postgraduate level and explores the latest advances in chemical sensor technology for researchers By providing useful state of the art information on recent developments in biosensing devices the book offers both newcomers and experts a roadmap to this technology In the book distinguished researchers from around the world show how portable and handheld nanosensors such as dynamic DNA and protein arrays enable rapid and accurate detection of environmental pollutants and pathogens The book first introduces the basic principles of biosensing for newcomers to the technology It then explains how the integration of a receptor can provide analytically useful information It also describes trends in biosensing and examines how a small sized device can have portability for the in situ determination of toxicants The book concludes with several examples illustrating how to determine toxicants in food and environmental samples

Practical Applications of Microresonators in Optics and Photonics Andrey B. Matsko,2018-09-03 Assembling an international team of experts this book reports on the progress in the rapidly growing field of monolithic micro and nanoresonators The book opens with a chapter on photonic crystal based resonators nanocavities It goes on to describe resonators in which the closed trajectories of light are supported by any variety of total internal reflection in curved and polygonal transparent dielectric structures The book also covers distributed feedback microresonators for slow light controllable dispersion and enhanced nonlinearity A portion of coverage is dedicated to the unique properties of resonators which are extremely efficient tools when conducting multiple applications

Photonic Crystals Alessandro Massaro,2012-03-30 The second volume of the book concerns the characterization approach of photonic crystals photonic crystal lasers photonic crystal waveguides and plasmonics including the introduction of innovative systems and materials Photonic crystal materials promises to enable all optical computer circuits and could also be used to make ultra low power light sources Researchers have studied lasers from microscopic cavities in photonic crystals that act as reflectors

to intensify the collisions between photons and atoms that lead to lasing but these lasers have been optically pumped meaning they are driven by other lasers Moreover the physical principles behind the phenomenon of slow light in photonic crystal waveguides as well as their practical limitations are discussed This includes the nature of slow light propagation its bandwidth limitation coupling of modes and particular kind terminating photonic crystals with metal surfaces allowing to propagate in surface plasmon polariton waves The goal of the second volume is to provide an overview about the listed issues

Chemical Sensors and Biosensors Florinel-Gabriel Banica, 2012-08-15 Key features include Self assessment questions and exercises Chapters start with essential principles then go on to address more advanced topics More than 1300 references to direct the reader to key literature and further reading Highly illustrated with 450 figures including chemical structures and reactions functioning principles constructive details and response characteristics Chemical sensors are self contained analytical devices that provide real time information on chemical composition A chemical sensor integrates two distinct functions recognition and transduction Such devices are widely used for a variety of applications including clinical analysis environment monitoring and monitoring of industrial processes This text provides an up to date survey of chemical sensor science and technology with a good balance between classical aspects and contemporary trends Topics covered include Structure and properties of recognition materials and reagents including synthetic biological and biomimetic materials microorganisms and whole cells Physicochemical basis of various transduction methods electrical thermal electrochemical optical mechanical and acoustic wave based Auxiliary materials used e g synthetic and natural polymers inorganic materials semiconductors carbon and metallic materials properties and applications of advanced materials particularly nanomaterials in the production of chemical sensors and biosensors Advanced manufacturing methods Sensors obtained by combining particular transduction and recognition methods Mathematical modeling of chemical sensor processes Suitable as a textbook for graduate and final year undergraduate students and also for researchers in chemistry biology physics physiology pharmacology and electronic engineering this book is valuable to anyone interested in the field of chemical sensors and biosensors

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