Preface

Day by day, the world is witnessing significant advancements in the technologies and strategies used for manufacturing various devices. Even then, there is always an increasing demand for devices which can perform reliably at a faster pace in this era of advanced technologies and instrumentation. In the field of sensing, the need for newer methods and devices that can make life on earth more comfortable and easier is growing. This ever increasing demand, urges the researchers to look for better techniques and instruments in the field of sensing, especially for biochemical analysis.

The invention of optical fibers revolutionised the field of communication in the latter half of the last century. Data transfers at very high bit rates over extended distances were made possible by the use of optical fibers. Lately, optical fiber grating technologies have attracted much attention due to their numerous applications in the field of communication and fiber optic sensor systems. Optical fiber gratings are fabricated by inducing regions of periodically varying refractive indices within the fiber core. Numerous investigations established the sensing capabilities of optical fiber gratings, opening a wide market in the field of sensors. Temperature, strain, refractive index, bending, radiation dose etc. are some of the parameters that could be sensed using optical fiber gratings. Optical fiber grating based sensors are advantageous due to their smaller size, light weight, no electromagnetic interference, remote and distributed sensing capabilities, high sensitivity and large bandwidth operation. Clubbing the diverse sensing capabilities with its merits, fiber gratings are being deployed in numerous fields like structural health monitoring, oil fields, nuclear plants, automobiles, environmental monitoring, biological and food processing laboratories etc.

Monitoring of chemical and biological species is becoming indispensable in many markets including industrial process control, energy production, health care, food industry, environment monitoring and anti-terrorism. Accordingly, chemical and biological sensors which can perform reliably and accurately at a faster pace have attracted extraordinary interest in recent years. The research reports in recent years, clearly establish the potential of fiber optic grating sensors in the field of chemical and biological sensing compared with other sensors which are usually time consuming in operations and require not only high-cost equipment but also well trained personnel.

Towards the end of last century, investigations brought out the higher probability of occurrence of cardiovascular diseases in human beings having increased levels of cholesterol. Since then, researchers started to think loud about developing simpler cholesterol sensing schemes at lower cost and better sensitivities. The focus of this thesis is the design and development of optical fibre grating based sensors, mainly those with surrounding medium refractive index (SRI) sensitivities, for the measurement of cholesterol. Applications of long period gratings (LPGs), fiber Bragg gratings (FBGs) and tilted fiber Bragg gratings (TFBGs) as refractometers to measure the concentration of total cholesterol are presented in this thesis. A biopolymer which has an affinity to cholesterol namely chitosan, is coated as an overlay around the grating region in order to enhance the sensitivity of the sensor heads. Experimental results of the measurement of cholesterol using these gratings, with and without coatings, are also presented in this thesis.

The thesis has been organized into six chapters. Contents of each chapter are briefly described as under:

Chapter 1 presents the general description of various types of optical fiber sensing systems with an orientation to optical fiber grating devices. A brief report on various types of gratings used in the present experimental investigations is included. Photosensitivity in optical fibers and a generalised grating fabrication method is also discussed.

The chapter also provides a short description about cholesterol and the importance of its estimation. A brief summary of the existing detection methods and their demerits are also discussed in this chapter. Chitosan biopolymer with an affinity to cholesterol, used to enhance the sensitivity of the measurements under the present investigations, is also introduced.

An overview of the fundamental theory of fiber optic long period gratings is presented in **Chapter 2**. A review of literature on LPG based sensors is included. This chapter also introduces the sensing capabilities of long period gratings. The basic principle of operation of LPG based sensors is discussed, especially the refractive index sensing. A brief survey on LPG based sensors is also incorporated in this chapter. As a specific application, design and development of an LPG based sensor for the detection and estimation of total cholesterol is also presented in this chapter.

Chapter 3 starts with a survey of sensors based on LPGs with overlay coatings around the grating. A chitosan coated LPG sensor head for cholesterol determination was fabricated by the method of dip coating. The results of the experimental investigations showing a sensitivity enhancement to that of the uncoated LPG sensor head, in the measurement of cholesterol concentration, is also presented.

The operating principle and sensitivity of fiber Bragg gratings to temperature and strain and its inertness to refractive index variations of external medium is covered in **Chapter 4**. A report on sensors based on FBGs and the need for the reduction of cladding diameter in order to induce RI sensitivity is presented. The method of chemical etching using HF, to fabricate thinned FBGs is discussed here. The etched FBG sensor head fabricated was used for the measurement of cholesterol and the results were analysed. To have better sensitivity in cholesterol measurements, a coating of chitosan was deposited over the thinned FBG. This coated sensor head was able to measure cholesterol with enhanced sensitivity, compared to the uncoated FBG sensor.

TFBGs have the advantage of intensity measurements with relatively higher sensitivities rather than wavelength interrogation. **Chapter 5** outlines the theory of operation of tilted FBGs. A survey of TFBG sensors is incorporated in this section. The use of low cost detectors makes the experiments and analysis simpler and easier. This chapter also provides the application of TFBGs with and without chitosan coating, for cholesterol measurement.

Chapter 6 summarizes the findings of the present investigations and discusses the scope for future research possibilities.

This thesis also includes a list of the papers accepted for publication during the course of this research work.

List of Publications

International Journals

[1]. **C Bobby Mathews**, T M Libish, B Kaushalkumar, V Vivek, Radhakrishna Prabhu, and P Radhakrishnan, "*A fiber optic biosensor for the detection of cholesterol levels based on chitosan coated long period grating*", Optoelectronics Letters; Vol.12 (1), pp. 23-26 (2016).

[2]. **C Bobby Mathews**, T M. Libish, J Linesh, P Biswas, S Bandyopadhyay, K Dasgupta and P Radhakrishnan, "*A biosensor for the detection and estimation of cholesterol levels based on long period gratings*", Sensors & Transducers, Vol. 149 (2), pp. 83-88 (2013).

[3]. **C Bobby Mathews**, T M. Libish, and P Radhakrishnan, "Etched fiber Bragg grating sensor for the measurement of total cholesterol", (Communicated).

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[6]. T M Libish, **M C Bobby**, J Linesh, S Mathew, P Biswas, S Bandyopadhyay, K Dasgupta and P Radhakrishnan, *"The effect of annealing and temperature on transmission spectra of long period gratings written in hydrogen loaded standard single mode fiber*", Optik - Int. Jn. for Light and Electron Optics, Vol. 124 (20), pp. 4345-4348 (2013).

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[13]. J Linesh, T M Libish, **M C Bobby**, P Radhakrishnan and V P N Nampoori, "*Comparison of thermal and refractive index sensitivity of symmetric and antisymmetric modes of long period fiber gratings*", AIP Conf. Proc., Vol. 1391, pp. 397-391 (2011).

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International Conferences

[1]. **Bobby Mathews C**, T M Libish, V Vivek, Mathew P Abraham and P Radhakrishnan, "*Design and development of a cholesterol sensor based on the refractive index sensing of tilted fiber Bragg grating*", Photonics 2016: Int. Conf. on Fiber Optics and Photonics, OSA, IIT Kanpur, India (2016).

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National Conferences

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Abbreviations

CGCRI	:	*Central Glass and Ceramics Research Institute*
DNA	:	*Deoxyribonucleic Acid*
EDFA	:	*Erbium Doped Fiber Amplifier*
EFBG	:	*Etched Fiber Bragg Grating*
EWS	:	*Evanescent Wave sensors*
FBG	:	*Fiber Bragg Grating*
FOS	:	*Fiber Optic Sensors*
HDL	:	*High Density Lipoprotein*
HF	:	*Hydrofluoric Acid*
IgG	:	*Immunoglobulin G*
IPA	:	*Iso Propyl Alcohol*
LDL	:	*Low Density Lipoprotein*
LP	:	*Linearly Polarized*
LPG	:	*Long Period Grating*
MCVD	:	*Modified Chemical Vapour Deposition*
OSA	:	*Optical Spectrum Analyzer*
PMC	:	*Phase Matching Curve*
PVC	:	*Poly Vinyl Chloride*
RI	:	*Refractive Index*
SEM	:	*Scanning Electron Microscope*
SPP	:	*Surface Plasmon Polariton*
SPR	:	*Surface Plasmon Resonance*
SRI	:	*Surrounding Refractive Index*
TFBG	:	*Tilted Fiber Bragg grating*
TIR	:	*Total Internal Reflection*
UV	:	*Ultra Violet*