Preface

With the disruptive progress in the field of electronics, ubiquitous wireless networking has become a reality. Smartphones and wireless devices are becoming more of a necessity of our daily routine rather than just a luxurious gadget, as they used to be some years ago. These advances have resulted in a surge in the number of connected smart devices. According to CISCO® report, the number of connected devices has reached more than double the population (2.2×) in 2015 and is predicted to reach more than three times the population (3.4×) by 2020 [1]. The ubiquity of the wireless networking and the abundance of smart devices have led to the invention of the "Internet of Things" concept. The Internet of Things (IoT) refers to the concept of connecting everything, including ourselves and personal items, to sense the environment, communicate together, and come up with informative decisions about their actions, without human intervention. IoT is expected to cover every aspect of our life, starting from waking us up with a fresh brewed coffee and our bath ready, along with a smart car (potentially self-driven) driving us to work, up to every small detail of our life. IoT fields include, but not limited to, smart city, intelligent transport system (ITS), smart housing, eHealth, agriculture, etc., along with new fields that will be introduced in the future [2, 3].

With the emergence of the Internet of Things (IoT) (also sometimes referred to as the Internet of Everything (IoE)), most devices are becoming smarter and connected to one another. Devices are now designed to intelligently act on their own, based on information received from other devices or information about the environment surrounding them. This development requires multiple types of sensors, to be deployed in different environments; hence the sensor industry has become the center of attention of many research efforts in recent years. Due to the huge number of required sensors in the coming generation of IoT, sensing devices need to be cheap, easy to design, and resilient, in addition to their accuracy and instantaneous response. One of the attractive emerging methods is the optical fiber sensing, which has been attracting lots of attention due to its low cost and resilience. The recent reports about coupling optical fiber sensors to smart devices make optical fiber sensing a promising field, with a huge potential market in the area of IoT. Additionally, those reports have increased the growth of optical fiber sensor markets and their field of action. Optical fiber sensing techniques are nowadays widely and commonly implemented for monitoring physical parameters including strain, temperature, refractive index, pressure, humidity, etc., in addition to the monitoring of health parameters (e.g., heartbeat, blood pressure).

Due to a surge in the interest in optical fiber sensing, this brief provides a review of the evolution of optical fiber sensing solutions and its applications. Following such path, a review of the working principles of optical fiber sensing is given. The different production methods are presented and discussed, highlighting their evolution and analyzing their complexity. Under this scope, the brief presents a review of the existing silica optical fiber sensor and polymer optical fiber sensor solutions, comparing its field of action (sensitivity, accuracy), complexity of manufacture, and economical costs. A special attention is given to low-cost production methods. The brief evaluates different existing techniques and assesses the accuracy and suitability of these sensors for possible IoT integration, depending on different considered scenarios.

Our brief represents a timely report of the state of the art of an emerging topic “optical fiber sensing” that is expected to play a big role in the world of the Internet of Things (IoT) and the smart city of tomorrow. The authors believe that this brief should be used as a handbook for readers interested in the field of optical fiber sensing, as well as in the general field of sensors and their production. Readers, new to the field of optical fiber sensing, will find this brief a very useful starting point for their career. Readers are encouraged to read the following outline and guide on how to use this brief, to find the best way to benefit from our work.

Brief Outline

This book provides a brief overview of optical fiber sensing, with its different sensing techniques, characteristics, and advantages while going through various proposed solutions to overcome their limitations, targeting low-cost production, higher sensitivity, more resiliency, and wider range of applications, by increasing their range of measuring. The book outline goes as follows.

The first chapter is a general overview of the optical fiber sensing concept, highlighting the idea behind using optical fibers for sensing and the different mechanisms inherent to optical fiber light propagation used for measuring external physical parameters. This chapter serves as a perfect starting point to readers, who are new to the field. It introduces the basics and principles of optical fiber sensing, as well as the different methodologies used in measuring external physical parameters.

Optical sensing can be achieved by monitoring the variation of light properties passing through fiber; hence optical fiber sensing can be either intensity-based, phase-based, wavelength-based, or polarization-based. The first chapter describes all those types of sensing techniques, going through the multiple subcategories of each type. The advantages, applications, and limitations of each type are explained.

Additionally, optical fiber sensors (OFSs) are perfect for the manufacture of distributed sensing systems, which are also introduced in this chapter.

After the introduction of basics and principles of optical fiber sensing in Chap. 1, Chap. 2 takes a step forward to discuss the different production methods used for the manufacture of different types of OFSs. Each subsection discusses one type, introducing the different production methods used and the advantages, along with the most suitable applications. The chapter also addresses the challenges within the different methods, along with some proposed solutions to overcome those challenges. The chapter should be treated as a guide into the production methods of optical fiber sensing systems. Readers, already familiar with the topic of optical fiber sensing, would be able to use such chapter as guiding catalogue, which production method to use, based on their preferences; which can be less complex of production method, sensitivity, or cost-effectiveness; etc.

Optical fiber sensing can provide competitive performance compared to more traditional mechanical and electronic sensors, especially when it comes to sensitivity. They even provide more advantageous solutions, due to their compact size and weight and resilience to external harsh environments, along with their immunity to electromagnetic interference. However, for OFSs to reach their potential market share surpassing other traditional types of sensors, OFSs have to provide low-cost production methods. Chapter 3, hence, introduces solutions aiming at designing new and cost-effective production methods for silica-based OFSs. The performance of those cost-effective silica OFSs is compared to similar sensing devices, usually produced by more complex and expensive methods.

All three previous chapters have considered the more common type of fiber used in OFSs, namely, silica fiber. Chapter 4 then introduces polymer (or plastic) optical fiber (POF)-based sensing, which represents an economical alternative solution that has been gaining lots of interest in the research and also on the industrial level. POF offers an attractive cost-effective solution. The various production methods of POF-based sensors are explored. The chapter also discusses the possible physical parameters that can be measured by POF sensors, along with their most common applications. The performance of POF-based sensors is then compared to that of silica OFSs and electronic-based sensing devices.

Having thoroughly discussed the concept of OFSs, exploring its different types and production methods, Chap. 5 concludes the brief by an overview of the application of OFSs in the world of the Internet of Things (IoT). The chapter starts with a brief introduction to IoT and its various application categories. The chapter discusses the technological enablers of IoT and its value proposition. At the heart of IoT, sensing exists as one main and critical enabler. Sensing provides the required context for IoT to exist. Without sensors, smart devices would not be able to acquire the required knowledge about their surroundings, which is a main factor in the smart concept of IoT. Based on this fact, the chapter sheds more light on sensing within the concept of IoT, emphasizing the role of OFSs in such concept. Finally, the chapter presents different applications, where optical fiber-based sensing has been used or has good potential in the future. This list provides the vital link between optical fiber sensing and the future world of the Internet of Things, which acts as the perfect conclusion to the brief.

At the end, conclusion and summary are presented in Chap. 6.

Reading Guide

This part presents a guide on how to use the presented brief. The brief consists of five chapters, covering different topics, as explained above. Based on the reader's experience and knowledge of optical fiber sensing and the specific question he/she is trying to answer, the reader is advised to read a certain chapter(s).

Firstly, a reader, who is new and unfamiliar with the field of optical fiber sensing, is advised to start from Chap. 1 and go through the brief in the typical order. Chapter 1 provides a good starting point to the field covering the basic concept and principles of optical fiber sensing and the light properties used to sense external parameters, along with the different types and subcategories of OFSs in general.

If the reader is already familiar with the topic, the reader can skip Chap. 1. Depending on the question he/she is trying to answer, the reader can decide which chapter to read. A reader, looking to learn about the production/manufacturing of OFSs, should read Chap. 2. He/she can also find more answers in Chap. 3, with regard to producing lower-cost sensors.

Chapter 3 is also advised for readers familiar with production methods, but who are looking for more cost-effective methods or solutions to overcome the high costs of one certain production method they are interested in.

Readers, who are familiar with silica OFSs and want to learn about other alternatives, are advised to read Chap. 4, which offers information about polymer OFSs, their production methods, applications, efficiency, and limitations.

Finally, Chap. 5 is devoted to readers, who are already familiar with optical fiber sensing technologies, but are new to the topic of the Internet of Things. Chapter 5 provides them with the basics of IoT, listing multiple application domains, where OFSs can fit. It has to be noted here that this brief provides basic information about IoT and how OFSs fit in the world of IoT, but should not be used as a guide of or a book on the concept of IoT.

Although this section guides readers on which chapter(s) to read based on their level of expertise and requirements, the authors still think that for maximum value, this brief is best read as a whole and in the presented sequence.

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Springer

http://www.springer.com/978-3-319-47348-2

Optical Fiber Sensors for IoT and Smart Devices
Domingues, M.F.F.; Radwan, A.
2017, XVI, 89 p. 31 illus., Softcover
ISBN: 978-3-319-47348-2