Advances in Optical Biomedical Sensing Technology

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***Abstract*—A study of the global healthcare trends shows that more people need health care across different ages and nations of the World. Therefore, there is a rapid growth and expansion of Healthcare Industry globally. This has led to increased demand on advanced biomedical sensors and devices for diagnosis, monitoring, treatment and care. This paper provides an overview of some recent developments in optical biomedical sensing technology. In this paper, the types, uses and unique benefits of novel optical sensors for biomedical applications are presented.**

***Index Terms*—biomedical sensors, health, optical fiber sensors**

I. Introduction

AN individual's state of health is crucial in ascertaining his or her well-being and productivity in life [1]. WHO defines health as, "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" [2]. Recent health challenges have led to depths of research and scientific findings of ways to improve performances of biomedical sensing capabilities, and innovate more accurate biomedical sensors [3]. Advances in this technology provide detailed information about a patient's state of health, which helps for diagnosis and treatment. The availability of smart biomedical devices for monitoring an individual's health status continuously and even real-time, has led to numerous benefits to the Healthcare providers and the patients as well [3]. These devices can capture the biochemical, bioelectric, biomechanical, bioacoustics, and bio-optical signals of the body.

There is a growing need for Minimally Invasive Surgery (MIS), Minimally Invasive Robotic Surgery (MIRS), optical fiber lasers, detection of infectious diseases, development of drugs and vaccines, and automation of biomedical devices. MIRS is a growing trend in the medical field and it is attractive to patients and surgeons because of its reduction of trauma, and reduced blood transfusions (due to low loss of blood) [4].

This paper is organized as follows: Section II gives an overview of biomedical sensors. Section III discusses the integration of optical fiber sensors for biomedical application, and presents some novel optical biomedical sensors. Then, conclusions are given in section IV.

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II. Biomedical Sensors

Biomedical sensors are devices used to safely measure biological, chemical and physiological parameters of the body, and they provide quantitative, qualitative and reliable results [4]. They are life-saving devices that can simply acquire and process physiological information [3]. Biomedical sensors are highly demanded because they are usually small, smart, reliable, selective, sensitive, biocompatible, fast, robust, appropriate for batch fabrication, and remotely controllable in nature [4]-[5]. They have the unique ability to select one parameter without interfering with other parameters. Types of biomedical sensors include, direct/indirect, contact/remote, invasive/noninvasive, real-time/static, and sense/actuate [6]. Each biomedical sensor consists of a sensing element with a physical transducer that converts a measurand into an output signal [7]-[8]. Fig 1 shows a basic biomedical instrumentation system.

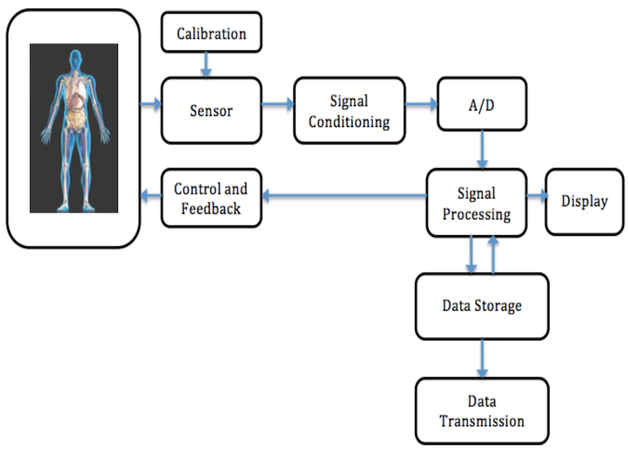

Fig. 1. Basic biomedical instrumentation system

Due to advent of wearable technology, some biomedical sensors or devices are been used as wearables for continuous monitoring, which have greatly advanced the medical field. Also, recent trends in the microelectronics industry with improved signal-processing techniques have increased the production of accurate and reliable novel biomedical sensors [7].

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There is a continuous demand on biomedical sensors due to the increase in the use of medical devices for quality health care. Biomedical sensors are currently widely used to measure or monitor vital parameters such as body temperature, heart rate, blood velocity, blood pressure, breathing rhythm, oxygen saturation, blood micronutrient level, sleep distortion, and daily exercise activities [3]-[7]. Furthermore, they are used for surgeries, therapeutic purposes, telemedicine purposes, and accurate diagnosis (of cardiovascular diseases, cancer and other deadly diseases.

Various biomedical sensors help to prevent and diagnose diseases with minimally invasive or non-invasive techniques, such as Magnetic Resonance Imaging (MRI), X-ray imaging, CT (Computed Tomography) scan, Ultrasonic imaging, Optical Coherent Tomography (OCT), Endoscopy, and Spectroscopy [3].

III. Optical Fiber Sensors For Biomedical Applications

It is important to know that optical fiber was originally proposed for medical endoscopic purposes before they were used for telecommunication applications [9]. Advances in biomedical field have led to the integration of various biomedical sensing technologies such as electrochemical, optical, electronics, mechanics, and acoustic wave sensing technologies [7]-[10]. This paper focuses on the optical biomedical sensing technology, which has greatly enhanced health care processes and deliveries.

Biomedical Sensing occurs in the cells, tissues and organs of the body. Optical sensing technology involves microscopy and spectroscopy techniques, which help to observe wide range of objects from organs and cells [4]. The advantages of optical biomedical sensors over other sensing technologies is due to the following fundamental characteristics [4]-[11]:

--Small size.

--Light weight.

--Non-electrical connection to patients.

--Ability to monitor numerous measurands.

--Biocompatibility with MRI and CT.

--Increased use of lasers and Fiber OCT probes, for optical imaging.

--Usage in high EM (Electromagnetic) or RF (Radiofrequency) environments, due to its high immunity to EM interferences.

--Minimally invasive or non-invasive technique, because of the inherent penetrating properties of light signal.

--Fast speed since light is used.

An Optical fiber sensor consists of a light source, optical fiber, photo detector, and external transducer [12]. It emits, receives, and converts light rays into electrical signals. They are used for biomedical sensing applications such as [4]-[11]:

--Illumination purposes in surgical operations or dental treatments, an example is a gage optic fiber probe.

--Laser deliveries in phototherapy, ablation, surgery and skin treatments.

--Radiation dosimeters in sterilization of medical supplies and radiation therapies.

--Imaging purposes in OCT.

A. *Novel Optical Biomedical Sensors*

The following 17 novel optical biomedical devices are presented below with their specific applications:

--Fiber Optic Blood Gas Sensor, measures blood gases and pH [4].

--Optical System for Non-Invasive Haemodynamic Monitoring, this optical system measures standard pulse oximeter parameters with other vital parameters for a proper diagnosis of the state of a patient's cardiovascular system [11]. It has been estimated that 30% of global death is due to cardiovascular diseases [13].

--Optical Fiber NIR (Near-Infrared) Oxymeter, determines hemoglobin concentration and blood oxygen saturation [4].

--Optical Fiber NIR Spectroscopy (NIRS).

--Fiber Optic Force Sensing in Ablation Catheter.

--Optical Fiber ECG and EEG Sensor, a mini-fiber optic electric field sensor detects Electrocardiography (ECG) signals and Electro-encephalogtraphy (EEG) signals.

--Optical Fiber Pressure Sensor For Monitoring Lung And Bladder Pressure [11].

--Fiber Optic Immunosensor, for drug sensing and blood protein sensing.

--Optical Fiber Radiation Dosimetry, for monitoring low dose ionising radiation (in radiotherapy) and high dose ionizing radiation (in sterilization of medical supplies) [11].

--Three-axis Optical Shear Sensor, measures shear (friction) stress for applications such as robot hands and skin, and prosthetic sockets [14]. In biomedical field, artificial devices (prosthesis) have been developed to bring comfort to patient that have one of their body parts (like a limb or hand) missing.

--Optical Fiber Sensor for Breathing Measurement, this non-invasive sensor in [15] was proposed for monitoring breathing rate, body movement and Ballistocardiogram (BCG) signals.

--An Extrinsic Optical Fiber X-ray Dosimeter, is to measure low doses of ionizing X-ray radiation in radiotherapy applications [16].

--Distributed Feedback Laser Biosensors (DFBLB), was discussed in [5], as an analytic procedure for detecting cytokine Tumor Necrosis Factor-alpha (TNFα).

--DNA Hybrid Optical Fiber Probe, this probe was described in [17] and it is used for detecting DNA.

--Optical Pulse Pressure Sensor, is used for monitoring blood volume pulse through the skin, thus enabling the measurement of pulse pressure [18].

--Dosage Form Analysis Optical Probe, is used in the pharmaceutical industry for drug quality control [19].

IV. Conclusion

This paper has studied new trends in biomedical sensing technology with focus on optical sensing. Different novel and emergent optical biomedical sensors have been reviewed in this study. Optical sensors have greatly enhanced diagnosis, monitoring and treatment of diseases.

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