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Review Invited

Selected optoelectronic sensors in medical applications

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ABSTRACT

Optoelectronic technology plays an important role in medical diagnosis. In the paper a review of some optoelectronic sensors for invasive and non-invasive human health test is presented. The main attention is paid on their basic operation principle and medical usefulness. The paper presents also own research related to developing of tools for human breath analysis. Breath sample unit and three gaseous biomarkers analyzer employing laser absorption spectroscopy designed for clinical diagnostics were described. The analyzer is equipped with sensors for CO, CH_4 and NO detection. The sensors operate using multi-pass spectroscopy with wavelength modulation method (MUPASS-WMS) and cavity enhanced spectroscopy (CEAS).

Contents

1. Introduction

Optoelectronic sensors (OS) are applied in many life and scientific activities, e. g.: environmental monitoring, industry, chemical analysis, biology, and medicine. Current medical applications of OS include pulse oximetry, heartrate monitoring, measuring the amount of oxygen in the blood, blood glucose monitoring, urine analysis, dental colour matching, and exhaled biomarkers monitoring. These sensors must meet strict requirements, they should be safe, biocompatible, reliable, stable, suitable for sterilization, immune for biologic rejection and miniaturized. Maintaining of these devices should be as simple as possible.

Idea of the OS operation bases on analyses of light-matter interactions. Main processes which occur in the matter illuminated by

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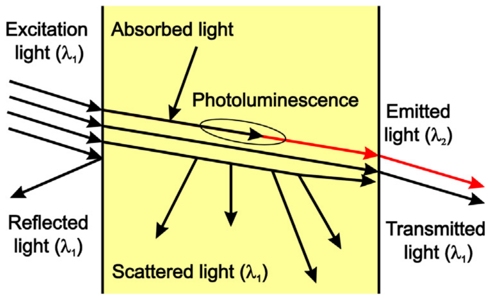

Fig. 1. Some phenomena caused by the light-matter interaction [1].

Table 1
Selected medical parameters [3].

Physical parameters	Chemical parameters
Pressure	Bilirubin concentration
Temperature	pH
Blood flow	Oxygen partial pressure
Humidity	Carbon dioxide partial pressure
Cataract onset	Lipoproteins
Radiation dose	Lipids
Biting force	

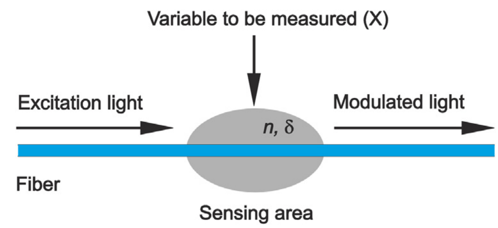

Fig. 3. Idea of operation optical fiber intrinsic sensor.

radiation at a given wavelength λ_1 are schematically shown in Fig. 1.

The nature of the interaction depends on specific features of the matter. The result of the interaction can be used as matter signature (marker). For example, scattered light is used for liquid investigation (blood flow monitoring or glucose detection). Substances characterization (identification) by analysis of their specific absorption spectrum is of high significance for medical measurements. OS based on absorption usually quantify the change in intensity and spectrum of light that is transmitted through the sample. Reflectance sensors are also designed for such specific analysis but for the substances of low transparency. When excited molecule of the sample returns to the ground singlet state S_0, it can emit photons at longer wavelength range than the absorbed one (Fig. 2). The absorbed radiation can also cause *fluorescence* at wavelength different than λ_1 (λ_2 in Fig. 1). Due to internal conversion the molecule can also return to the S_0 state via triplet state T_1 in case of *phosphorescence* phenomenon. This effect lasts longer than fluorescence, and produces lower energy radiation (longer wavelength). For both cases, the emission intensity is proportional to concentration of excited molecules.

Parameters measured commonly in medical diagnosis can be divided into physical and chemical ones (Table 1). Since stimuli are not electrical, there is several energy conversion steps in the medical sensor before it produces an electrical signal, that is measured and interpreted as representing the parameter of interest. In case of the OS, photon flux is always detected by a photodetector providing a conversion into the electric signal. For example, a periodic stress acting on a fiber-optic pressure sensor, first results in strain in the fiber, which causes a change of its refractive index and change of optical transmission, which finally results in modulation of the photon flux registered by a photodiode.

In fiber-optic OS, the light may be directly modulated either by the parameter being investigated and acting on the fiber or by special reagent connected to the fiber. The optical properties of the reagent vary with the change in the stimulation agent of measured medium. Such a probe is often called an optrode. Fluorescence, absorption, Raman scattering, evanescent-wave and plasmon resonance are the main physical phenomena of its operation. The simplest fiber OSs classification is based on the subdivision in *intrinsic* and *extrinsic sensors*.

In intrinsic sensors (Fig. 3), the fiber plays a role of a light guider and transducer. In this case, the investigated substance modifies refraction index (n) or losses coefficient (δ) of the fiber. Then the

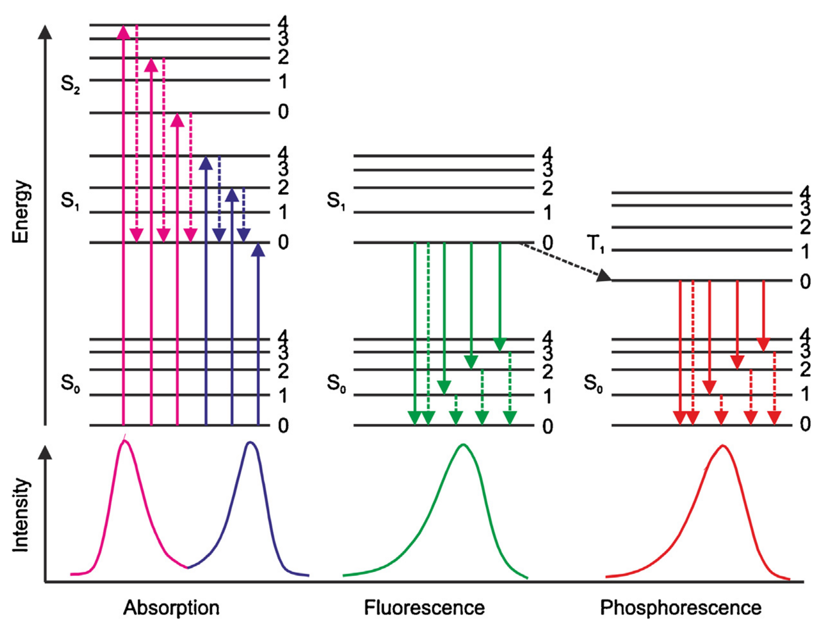

Fig. 2. Jablonski diagram representing energy levels and spectra. Solid arrows indicate radiative transitions as occurring by absorption (violet, blue) or emission of a photon [2].