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Plenary paper

Integrated optical chemical and direct biochemical sensors â˜†

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Abstract

An overview is given on work by the author's group on integrated optical (IO) sensors. The sensors make use of guided waves or modes in optical waveguides, in particular of the orthogonally polarized TE_0 and TM_0 modes in very thin planar waveguides of high refractive index. The principle of *all* direct (bio)chemical waveguide or IO sensors is as follows. A chemically selective coating on the waveguide surface binds the analyte molecules contained in the gaseous or liquid sample. Thus, the refractive index of the medium near the waveguide surface (more precisely, within the penetration depth Î”z of the evanescent field of the guided wave) is changed. This effect in turn induces changes Î”N_{TE_0} and Î”N_{TM_0} of the effective refractive indices N_{TE_0} and N_{TM_0} of the guided modes. for example, in biochemical affinity sensors the chemically selective coating contains receptor molecules that specifically or selectively bind certain ligands as analyte molecules; in particular, in immunosensors or immunoassays the receptors are antibodies (or antigens, respectively) and the analyte molecules are the corresponding antigens (or antibodies). These â€˜directâ€™ affinity of immunosensors eliminate the use of (e.g., fluorescently) labelled reagents. Effective refractive-index changes Î”N can also be induced by two other effects; namely by unspecific adsorption of molecules on the (uncoated) waveguide surface (or in pores of a waveguiding film F itself if it is microporous) and by refractive-index changes Î”n_C of the liquid sample. In the latter case the IO sensors work as refractometers. The effective refractive indices N give the phase velocity Î½$_{ph}$ = c/N of the guided modes, where c is the velocity of light in vacuum. This means that the effective refractive-index changes Î”N can be measured by various optical means. Consequently, a number of different types of IO sensors can be used, in particular, grating couplers and interferometers. In the paper, I report on our own work on IO sensors including: the discovery of the basic sensor effect with grating couplers as sensors for relative-humidity changes, the theory of the sensor sensitivities, and experimental results obtained with three different types of IO sensors developed in our laboratory, namely input grating couplers, output grating couplers and the difference or polarimetric interferometer. The experiments have been performed with dip-coated SiO_2Î—¸TiO_2 waveguiding films of refractive index n_F â‰ˆ 1.75â€“1.88, on glass, silica and silicon wafers with oxidized buffer layers as substrates. The sensors working as refractometers are tested, for example, with glucose solutions of different concentrations. The adsorption of proteins (h-IgG, BSA, protein A, avidin) is monitored in real time. Not only the surface concentration Î“, with a resolution of a few pg mm$^{\text{âˆ’2}}$, but also the thickness $d_{\text{Fâ€²}}$ and the refractive index $n_{\text{Fâ€²}}$ of the adsorbing (mono)layers are determined as functions of time. Also immunoreactions (e.g., between h-IgG and anti-h-IgG, and between IgGs and protein A) and affinity reactions (between avidin and biotinylated proteins, such as biotin BSA) are observed in real time. The feasibility of IO immunosensors or affinity sensors or immunoassays with sub-nanomolar detection limits is demonstrated.

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Keywords

Biochemical sensors; Chemical sensors; Integrated optical sensors

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