Low loss, sol-gel derived optical waveguide films for applications in evanescent wave sensors technology

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The evanescent wave spectroscopy is the basis of the operation of a certain class of optical waveguide chemical and biochemical sensors. Evanescent wave is a part of the electromagnetic field distribution associated with a given mode, propagating in a waveguide, and located in a medium covering the waveguide. Changes in a cover refractive index or a thickness of a sensitive film result in changes in effective refractive index of propagating modes. The latter can be measured in interferometric or resonant systems. The first effect is the basis for operation of refractometers, whereas the second for immunosensors. It is necessary to use waveguides having high refractive index contrast in order to achieve high sensitivities. Moreover, those waveguides should have high chemical resistance. These requirements are met by composite SiO_x:TiO_y waveguide films which fabrication technology was elaborated in our research group. Those waveguides, fabricated using a combination of a sol-gel method and dip-coating technique, have high refractive index (>1.8 for λ=632.8 nm) and low optical losses (<0.5 dB/cm).

The sol-gel method is a name for a class of chemical processes for preparation of materials from liquid phase [1]. Respective alkoxides of metals or nonmetals are precursors in a process of the synthesis of their oxides. Sols are synthesized as a result of a hydrolysis reaction, but almost simultaneously with hydrolysis starts a reaction of polymerization. The latter eventually leads to the formation of a gel. Except for precursors, water and alcohol are used in sol-gel processes as homogenizing agents. Reactions of hydrolysis and polymerization are controlled by a catalyst, temperature and time. We use tetraethyl ortosilicate $Si(OC_2H_5)_4$ and tetraethyl ortotitanate $Ti(OC_2H_5)_4$ as the precursors for silica and titania, respectively. Water, ethanol, and hydrochloric acid (catalyst) are the remaining reagents.

The presentation will show application of the sol-gel method and dip-coating technique for the fabrication of waveguide films. In particular, will be presented relationships between a withdrawal speed and fundamental waveguide film parameters: their thickness and refractive index. The latter were measured using a monochromatic ellipsometer. The results of the UV-Vis spectrophotometry investigations will be shown next. They allowed us to determine the width of optical band gaps. Analysis of reflectance spectra allowed to infer about the uniformity of refractive index distribution in the direction perpendicular to the surface of investigated waveguide films [2]. Morphology of waveguide film surfaces was investigated using atomic force microscopy. These investigations allowed to determine surface roughness of substrates and waveguide films as well as the auto-correlation length. Waveguide transmission losses were determined using a streak method. Transmission losses determined experimentally are comparable with values predicted by Lacey and Payen model, which confirms that their only source is the scattering on waveguide film interfaces. In the presentation will be shown planar structures realized with the application of elaborated silica-titania waveguide films [3].

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