Grating couplers as highly sensitive transducers for refractive index measurements

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Planar waveguide sensors belong to fields of interest of the integrated optics. As with integrated optics systems for application in telecommunication they base on the waveguide optics and thin film technologies. Integration of many optical components on a common substrate helps to avoid their justification and makes such systems immune to vibrations. Application of planar technologies is also advantageous from a point of view of the repeatability in production process. It is necessary to use homogeneous waveguide films having high refractive index in order to achieve large integration scale. This condition must also be met to achieve planar waveguide sensors having high sensitivity [1].

There are three physical effects on the basis of which planar evanescent wave sensors operate on [2]: change in refractive index of the medium covering a waveguide, change in thickness of a sensitive film covering the waveguide and change in refractive of the waveguide film itself, what is happening if the waveguide film is porous. The interaction between guided modes and the medium covering the waveguide occurs through their part called an evanescent wave. One of the most frequently performed type of biochemical measurements is the measuring of refractive index changes, while the measuring of sensitive film thickness changes are used in immunosensors. Each of the aforementioned effects results in the change of effective indices of modes guided in the waveguide. In order to measure those changes it is necessary to use interferometers or resonators. Planar sensor structures making use of grating couplers are the subject of this presentation.

The grating couplers were fabricated using a nanoimprint method in waveguide films, which were fabricated using a sol-gel method and dip-coating technique. They were fabricated in a sol film just after deposition of the latter when it is susceptible to deformation. After impressing reliefs in sol films, deposited on substrates, they were subjected to an annealing process which ultimately defined refractive index and thickness of waveguide films as well as parameters of grating couplers. Fabricated grating couplers have periods of Λ=1000 nm, 800 nm and 417 nm.

The presentation will show the sol-gel method and dip-coating technique as well as results of investigations on fabricated sensing structures for measurements of refractive index. The operating principle of the grating coupler and the relationship between parameters characterizing waveguide films (refractive index and thickness) and both its sensitivities: homogeneous and surface, will also be shown as well as the relationship between grating coupler period and its measuring sensitivity. Precise measurements of refractive index using the grating coupler require that account be taken of the relationship between the disturbance resulting from the presence of the grating coupler and the effective index of modes guided in the waveguide below the coupler. The presentation will show the influence of amplitude of the grating on real and imaginary part of the effective index. They were determined by using the method proposed by Horvath at al. [3].

[1] P. Karasiński, A. Kaźmierczak, M. Zięba, C. Tyszkiewicz, K. Wojtasik, P. Kielan, High sensitive sensor structure based on sol-gel derived waveguide film and grating coupler, *Electronics*, 10(12) (2021) 1-17.

[2] W.Lukosz, Integrated optical chemical and direct biochemical sensors, *Sens. Actuators*, B, 29 (1995) 37-50.

[3] R. Horvath, L.C. Wilcox, H.C. Pedersen, N. Skivesen, J.S. Hesthaven, P.M. Johansen, Analytical and numerical study on grating depth effects in grating coupled waveguide sensors, Appl. Phys. B 81 (2005) 65–73.