Elaboration of the planar optical waveguide transducer using ring resonators for application in evanescent wave spectroscopy

A waveguide is the optical element composed of a core and a cover. The core is fabricated from material having refractive index higher than the cover. Light is guided in the waveguide basing on the principle of total internal reflection. Upon each reflection, a part of the guided wave penetrates the cover to a depth being of the order of fraction of the wavelength. This way changes of optical properties of the cover result in changes of parameters describing guided optical waves (amplitude, phase and polarization). This phenomena is called Evanescent Wave Spectroscopy (EWS) and is a principle of the measurement technique named after it. The EWS measurement technique is being used by optical waveguide sensors. There are two major issues concerning design of a waveguide chemical/biochemical sensor. The first one concerns fabrication of the suitable sensitive film. The second issue concerns design and fabrication of the optical transducer, which is responsible for detection of changes of sensitive film properties, rendered by changes of a quantity going to be detected or measured. This project proposal concerns elaboration of planar optical waveguide transducers which can be applied in evanescent wave spectroscopy. In order to achieve high sensitivities to changes in properties of the cover or a sensitive film being an integral part the optical sensor, application of high refractive index and low loss optical waveguides is required. Concerning the application field, the material from which the waveguides are made from, should be resistant to chemical agents. Lack of waveguides meeting these criteria, have limited development of planar waveguide sensors so far. In our research group, there have been elaborated waveguide films made from amorphous and highly homogeneous composition of silica (SiO_2) and titania (TiO_2), which are perfectly meeting conditions described above. These waveguides, fabricated using a sol-gel method, have high refractive index and extremely low optical losses. On their bases we have elaborated fabrication technology of rib waveguides, directional couplers and grating couplers. Elaborated technologies (know-how) and experience gained so far in a field of their theoretical analysis, are foundations of this project proposal.

The main goal of this project is elaboration of planar waveguide structures for application in chemical/biochemical sensors, and their verification in a refractometer system and in a biochemical sensor detecting a presence of E. coli bacteria.

In planar waveguide structures fabricated from sol-gel based SiO_2-TiO_2 waveguide films there will be integrated ring resonators, functioning as a measurement transducer, the input coupler composed of a grating coupler and planar waveguide adiabatic tapper and the splitter based on a directional coupler or a multimode interference section. We are assuming that the planar waveguide structures elaborated in a scope of this project will be suitable for application in chemical/biochemical sensors. We are going to verify them in a sensor of refractive index changes and in a biochemical sensors for detection of E. coli bacteria.

Realization of this project is important for development of integrated optoelectronics in Poland. Almost every element of structures being the subject of this project have been a subject of our investigations. However, their integration in complex interferometric structures require solving many problems subjecting theoretical analysis of each elements, their fabrication technology and characterization methods. In a scope of this project we will improve quality of waveguide elements fabricated thus far. A planar waveguide ring resonator is a new structure which, so far haven't been investigated in our group. For all structures being a subject of this project, there will be developed their theoretical models allowing analysis of their properties and determination of optimal parameters with regard to some specific application. For interferometric sensor structures photo-detection systems will be designed and fabricated. Elaborated integrated optical systems will be highly versatile. They will be able to be applied in biochemical sensors detecting other bacteria and viruses. These sensors will be different only in kind of a sensitive film.

In the industries of medicine, pharmacy, farm and food and environmental protection, there are demands for highly sensitive chemical and biochemical sensors. New emerging threats connected with a terrorism and a mass migration of people create necessity for detection of dangerous substances or viruses causing illnesses in population centers (e.g. in airports). The sensors fabricated on basis of the interferometric structures being a subject of this project may find their place in these application fields. There is a demand for fast methods allowing determination of a kind of bacteria infection in many hospital wards. Short diagnosis time many times decides on patient survival. Our project makes an effort to meet such demands.