Modeling of a Diffraction Grating Coupled Waveguide Based Biosensor for Microfluidic Applications

Y. Wu[1], M. L. Adams[1]

[1]Auburn University, Auburn, AL, USA

Abstract

Optical biosensors are a powerful method to detect biological analytes and typically measure the change of the refractive index caused by an analyte binding to the optical element [1]. Diffraction grating coupled based biosensors have many advantages including: easy integration, cost effective production and relatively high sensitivity [2]. The model of a novel grating coupled waveguide based biosensor is presented. The sensor is comprised of the optical elements, a flow cell and a medium. Unlike traditional grating based sensors [3-5], the optical elements form a capping layer for the flow channel; thus the binding occurs on the dielectric slab of the optical elements instead of the grating itself. This technique allows for simple fabrication and an unobstructed light path to the grating. The sensor consists of two silicon nitride gratings, a silicon nitride waveguide between two waveguides, a polydimethylsiloxane (PDMS) flow cell, and an aqueous medium containing a reagent of interest, as shown in Figure 1. Due to the grating, the incident light is reflected and transmitted into several diffraction orders, and part of the light will be coupled into the waveguide which will then be diffracted out by the second grating for detection. The change of the refractive index of the binding layer will change the effective refractive index of the grating and the waveguide [6]. The analyte binding will influence the light coupled into the waveguide and cause a peak shift in the light spectrum. The Wave Optics Module of the COMSOL Multiphysics® software is used to simulate the change in refractive index induced by the binding of reagent to the optical element. The light is excited at the upper left side of the air and the transmitted power is detected at the upper right side of the air, as is shown in Figure 2. A parametric sweep is used to excite the different wavelengths of light and a scattering boundary condition is used to reduce the reflection from the boundary. Model results indicate good device sensitivity for measuring the change in refractive index of binding layer. When the refractive index of the binding layer is 1.65, 1.7, 1.75 and 1.8, as is shown as the Figure 3, a sensitivity of 370nm/RIU can be obtained. Furthermore, the effective mode index of the grating is related to the grating period, diffraction order and the angle of the incident light, so a change of the grating period, thickness of the waveguide or the coupling angle can result in the change of the effective index. This allows further optimization of the biosensor based on the reagent of interest.

Reference

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Figures used in the abstract

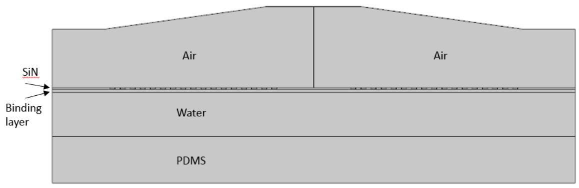

Figure 1: Geometry of the diffraction grating coupled waveguide based biosensor

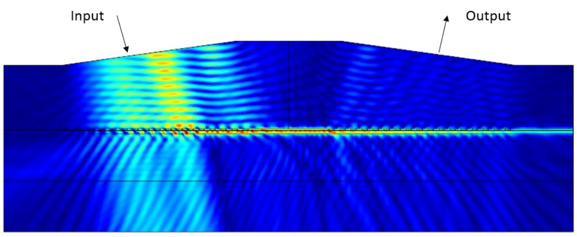

Figure 2: Electric field distribution of the diffraction grating coupled waveguide based biosensor

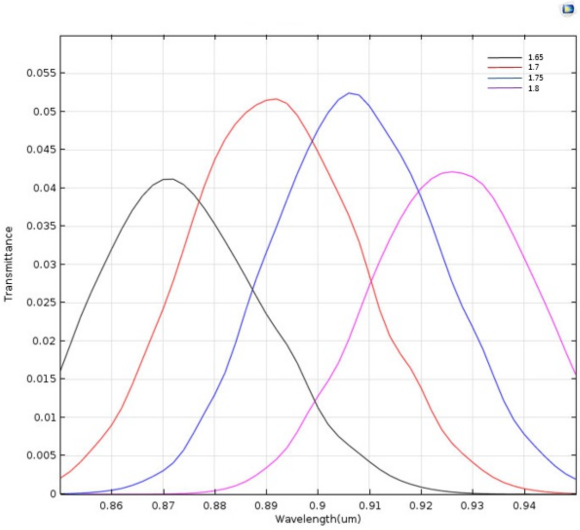

Figure 3: Transmittance spectra when the refractive index of the binding layer is 1.65, 1.7, 1.75 and 1.8