Simulation of Bio-medical Waveguide in Mechanical and Optical Fields

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Abstract

An optical freestanding waveguide is designed for patients who undertook colon surgery. But there is a possibility of leakage after surgery which can lead to death. Detection time and detection sensitivity are dominant factors. Thus, a freestanding waveguide is proposed to achieve this goal [1]. The freestanding part is a thin membrane consist of TiO2 rib and SiN ridge, in which stress is one of the major challenge to be considered in order to maintain its mechanical stability. The stress-induced deformation will also influence the light propagation in the waveguide. The thickness of the freestanding membrane should be well defined. Mechanically, it should be thick enough not to break during fabrication process. Optically, it should be thin enough to provide evanescent waves on both surfaces to detect the bacteria captured on both surfaces. Modelling and simulations are conducted to investigate the parameters of the waveguide to meet the demands.

2D cross section is initially investigated in a COMSOL Multiphysics® simulation to get the desired effective mode index (shown in Figure 1). The transmitting wave profile can also be obtained in this step to visualize how much light penetrate into the air (Figure 2). Then it develops into 3D model as shown in Figure 3 to check how the light is channeled through the waveguide. Solid mechanics is added to apply initial stress to the model. Then the model deforms due to the initial stress (see Figure 4). For TiO2, inner stress is set as 560MPa [2], for SiN, it is 125MPa. Then, solid mechanics and optical are combined to simulate the light propagation in bent waveguide.

These simulations demonstrated the feasibility of the freestanding waveguide. Light is confined in the core of the waveguide and part of light penetrate through the surface into the air for detection purpose. It also proves that the mechanical stability of the waveguide, in which the maximum induced stress is 715MPa at the interface of SiN layer and TiO2 layer, which almost reached the fracture strength limitation of TiO2. The structure needs to be further optimized. For further research, scattering boundary and optical absorption in material will be added.

Reference

[1] A. Purniawan, G. Pandraud, P. J French and P. M. Sarro. TiO2 Freestanding Thin Film as Evanescent Waveguide Sensor for Biomedical Application. P. 2506-2509, Transducers'11, June 5-9, 2011.
[2] Y. Huang, G. Pandraud, and P. M. Sarro. Characterization of low temperature deposited atomic layer deposition TiO2 for MEMS applications. Journal of Vacuum Science and Technology. 31, 01A148 (2013).

Figures used in the abstract

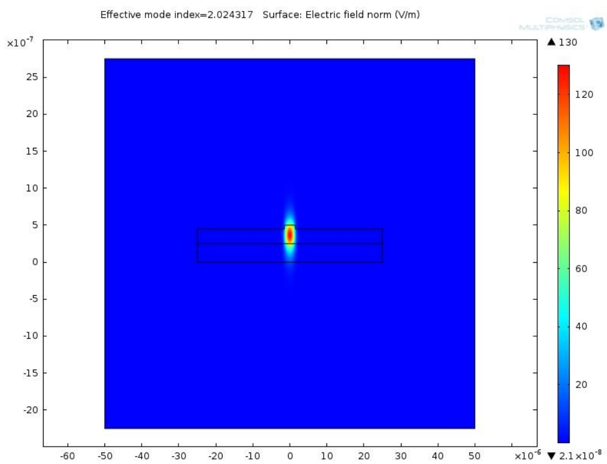

Figure 1: 2D simulation on the cross section of the waveguide

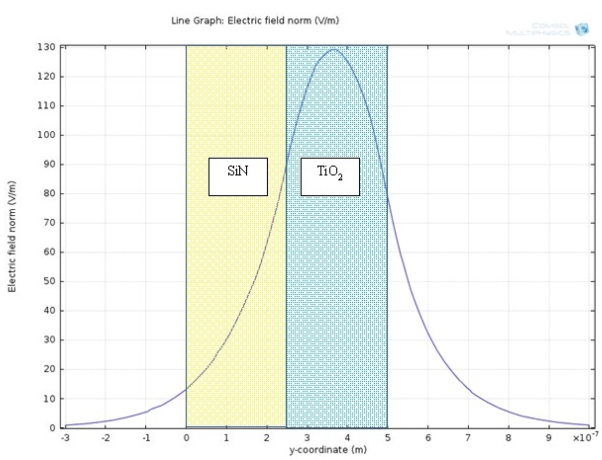

Figure 2: Evanescent wave on the surface of the waveguide

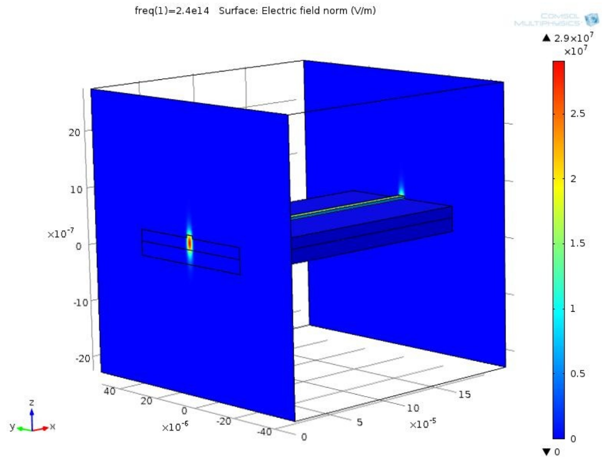

Figure 3: Light transmission in freestanding waveguide

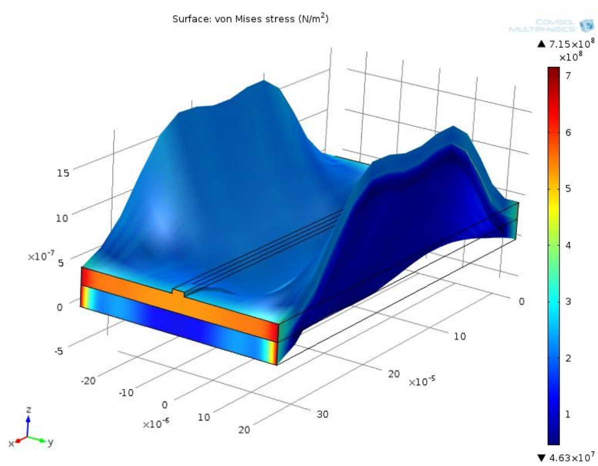

Figure 4: Deformation induced by material inner stress