

Application of Ion Beam Assisted Deposition and Prism Coupling Characterization Techniques for a Resonant Optical Waveguide Biosensor

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ABSTRACT

Fieldable biosensor devices which allow for quick detection of a broad spectrum of hazardous biological agents are of growing importance. The Stacked Planar Affinity Regulated Resonant Optical Waveguide (SPARROW) biosensor is a device being developed that exploits evanescent wave interactions and power transfer between two waveguides for biohazard detection and identification¹. The SPARROW structure has potential advantages over other integrated biosensor devices due to its reduced complexity of fabrication and optical alignment. The SPARROW sensor consists of two planar, single mode aluminum oxide waveguides separated vertically by a lower refractive index silicon dioxide layer. The thicknesses and indices of all layers are designed to make the waveguides resonant, with matched modal indices in the presence of a water superstrate, allowing for the periodic exchange of the input power between the top and bottom waveguides. The width of a PDMS channel bonded to the top alumina waveguide determines the length of the interaction with the aqueous analyte. This width is typically designed for an odd number of coupling lengths so all power transfers to the opposite waveguide to which it was coupled. The extension of the evanescent field into the superstrate above the waveguides makes the tuning of the top waveguide sensitive to refractive index changes of the superstrate. Attachment of bio-agents to a specially designed biolayer above the waveguides changes the effective refractive index of the biolayer and detunes the top waveguide, changing the amount, periodicity, and rate of optical power transfer between the waveguides. This power change can be correlated to the refractive index of the bio-agent, allowing for detection of target molecules.

A key aspect of this device's fabrication procedure is the ion beam assisted deposition (IBAD) electron beam evaporation technique used to produce the aluminum oxide and silicon dioxide layers. Conventional electron beam evaporation of these films often exhibit porosity and poor stoichiometry due to the columnar nature of electron beam evaporation. The voids present cause the film to be of lower density than bulk material and unstable in air due to the relative humidity and the voids' tendency to fill with water. An oxygen ion source is used to bombard the surface with energetic ions as the film is depositing, disrupting the columnar deposition and increasing film density towards that of the bulk material, due to the depositing molecules' increased energy and subsequently increased mobility on the substrate. The fabricated structures have RMS roughnesses of 0.3 nm - 0.5 nm, as seen through AFM characterization and a range of refractive indices varying from 1.62 to 1.654 as a function of varying ion beam parameters². IBAD deposition results as a function of varying ion source parameters will be presented.

Waveguide propagation losses are measured using the scattered power image capture technique. Prism coupling is used to couple optical power into the films for loss measurements and allows us to experimentally determine the modal indices of the waveguides. The optical power propagation in each of the waveguides is captured using a CCD camera and propagation loss is measured using digital image processing and curve fitting analysis. The propagation losses for the TE₀ (Transverse Electric) mode of the alumina films at 632.8 nm were found to vary between 2dB/cm – 6dB/cm as a function of ion beam parameters³. Additionally, new work concerning the benefits of annealing waveguide films in atmosphere to improve guiding properties and loss characteristics will be discussed. Preliminary results show that annealing can lower waveguide losses to less than 1 dB/cm.

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¹ D. Lloyd, L. A. Hornak, S. Pathak, D Morton, and I. Stevenson, "Application of Ion Beam Assisted Thin Film Deposition Techniques to the Fabrication of a Biosensor Chip With Fieldability Potential for Important Biohazard Detection Applications" 47th Annual Technical Conference Proceedings, Soc. of Vac. Coaters, ISSN 0737-5921 (2004).

² J. R. Nightingale, T. Cornell, P. Samudrala, P. Poloju, L. A. Hornak, D. Korakakis, "Reactive Deposition of Dielectrics by Ion Beam Assisted E-beam Evaporation," MRS Fall 2006 Conference Proceedings

³ P. Poloju, P. Samudrala, J. R. Nightingale, D. Korakakis, L. A. Hornak, "Characterization of Alumina Optical Waveguides Grown by Ion Beam Assisted Deposition for SPARROW Biosensors," MRS Fall 2006 Conference Proceedings