

# Design and Simulation of a Metal-Assisted Guided Mode Resonance Based Biosensor for Visible Range Operation

Vipul Pandey<sup>1,2</sup>, Suchandan Pal<sup>1,2</sup>

Optoelectronics and MOEMS Group, CSIR-CEERI, Pilani, Rajasthan-333031, India  
Academy of Scientific and Innovative Research (AcSIR), CSIR-CEERI Campus, Pilani, Rajasthan-333031, India  
Author e-mail address: vipul.ei@gmail.com

**Abstract:** The design and simulation of a metal-assisted guided mode resonance (MaGMR) based biosensor is presented for sensing in the visible region. The MaGMR structure shows 76.3% sensitivity enhancement for 25nm analyte thickness in comparison with the standard guided mode resonance (GMR) structure with the same design parameters.

## 1. Introduction

Recent demand for high throughput cost effective point of care biosensors has led to an increased scientific interest towards GMR gratings working in the visible region [1]. This allows the use of regular smartphone cameras for readout, which can further reduce the overall system cost [2]. The sensitivity of GMR gratings is a function of grating period, which in turn, also determines the resonant wavelength of the structure. Working on the lower wavelength visible regime usually leads to lower device sensitivity [3].

MaGMR has been shown to improve the sensitivity of GMR structures by placing a metal layer underneath the GMR waveguide structure [4]. In this work, we have designed a MaGMR based sensor for operation in visible range of the spectrum. The sensitivity of the MaGMR and GMR sensors is then compared for a range of analyte thicknesses starting from 15nm to 100nm, with 25nm being the typical assay size for biosensors [1,3].

## 2. Design and Simulation

The GMR grating used in the present work is shown in Fig. 1(a). It consists of a silicon nitride based waveguide embedded with grating structure on top of a thick silicon dioxide layer. Initially, the waveguide thickness and grating height have been optimized, and their values have been considered as 120nm and 50nm respectively for all the simulations. A grating period of 400nm with 50% duty cycle is chosen for all the simulations in order to achieve the resonant reflectance peak within the visible region for the given design parameters (Fig. 1(c)).

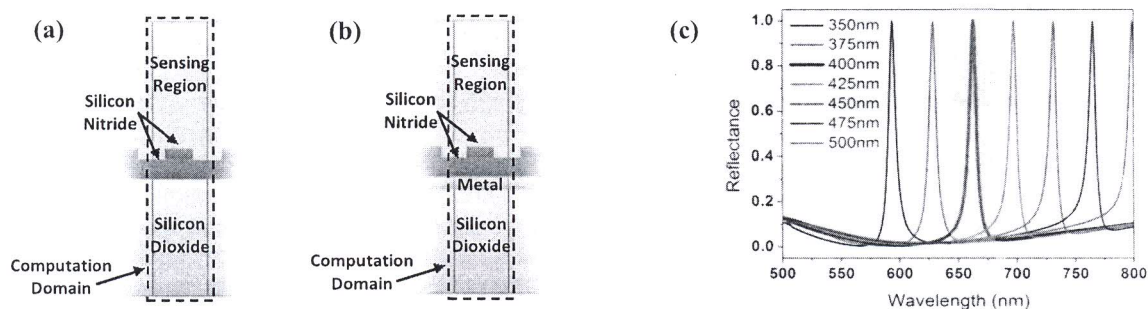


Fig. 1. Design geometry for the (a) GMR and (b) MaGMR structures used for simulation. (c) Resonant reflectance peaks for different gratings periods of the GMR structure.

A suitable metal underlayer is then selected to be used in the MaGMR structure shown in Fig. 1(b). The effects of metal properties and thickness on the behavior of MaGMR device are then studied to select the metal and the optimum value of the metal underlayer thickness. The performances of both of these devices are then compared for a variety of analyte thicknesses. All the simulations have been carried out in COMSOL Multiphysics<sup>®</sup> [5] software tool using TE-mode of excitation.

## 3. Results and Discussions

The field profiles for both GMR and MaGMR structures at the resonance are shown in Figs. 2(a) and 2(b). The metal layer acts as a reflector thereby leading to an asymmetrical field distribution, which is visible from the corresponding image (Fig. 2(b)). This causes the presence of a larger percentage of evanescent field in the sensing region which improves the device sensitivity.

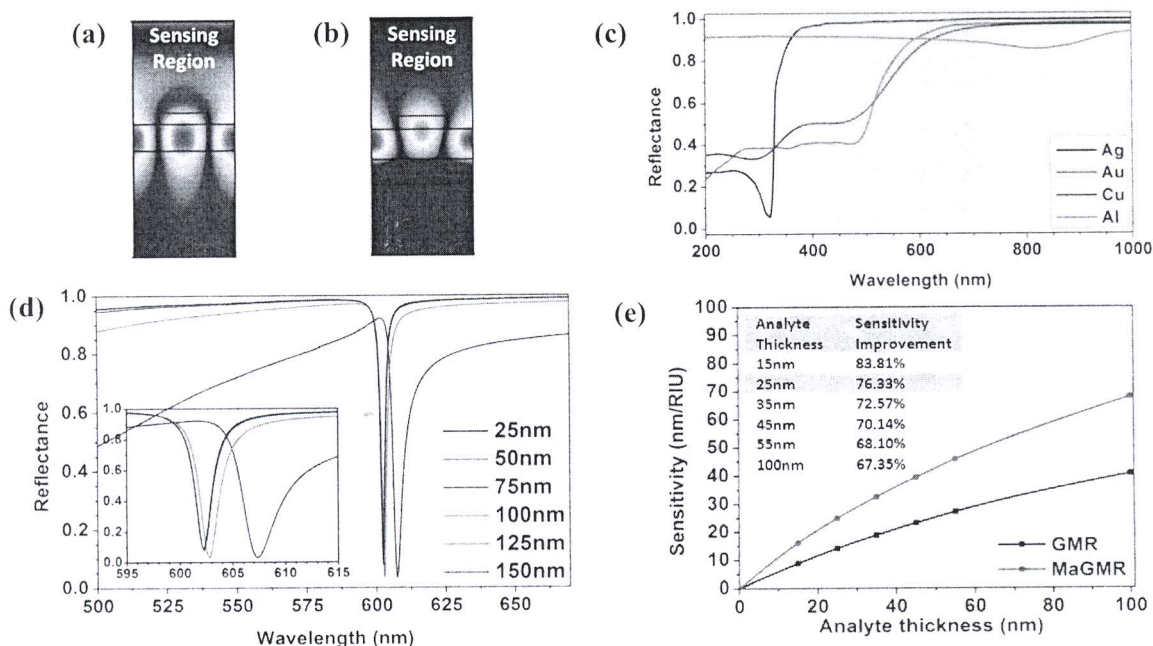


Fig. 2. Resonance field distributions for (a) GMR structure and (b) MaGMR structure. (c) Reflectivity of different metals for a range of incident wavelengths. (d) Reflectance spectra for the MaGMR structure with different metal (Ag) layer thickness. (e) Sensitivity comparison for GMR and MaGMR structures with different analyte thicknesses. The dots represent the thicknesses for which simulations are done.

Fig. 2(c) shows the reflectance spectra for different choices of metal underlayer. Silver is considered as metal underlayer for the rest of the simulations due to its constant high reflectance over a major part of the visible spectrum. Variation in the thickness of Silver underlayer is then examined where it has been found that increasing the underlayer thickness over 100nm has no effect on the device performance as shown in the Fig. 2(d). A Silver underlayer thickness of 100nm has been considered for the final structure. Finally, the sensitivity of the designed MaGMR structure is compared with the original GMR structure for analyte thicknesses of 15nm, 25nm, 35nm, 45nm, 55nm and 100nm. The results for the same can be seen in Fig. 2(e). For the assay thickness of 25nm, the MaGMR sensor shows a 76.33% sensitivity improvement over the usual GMR sensor with same design parameters.

#### 4. Conclusion

A MaGMR based biosensor has been designed and simulated for the visible range operation. Introduction of the additional metal layer to GMR structure has led to a considerable increase in the sensitivity of the device for all the analyte thicknesses. The MaGMR device has shown sensitivity improvement of 76.3% for 25nm analyte thickness, which is the typical sensing domain reported for biosensing applications.

#### 5. Acknowledgement

Authors would like to acknowledge CSIR for sponsoring HCP0012 project and the Director, CSIR CEERI for his encouragement. One of the authors (VP) would also like to thank CSIR for his JRF fellowship.

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