AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Electronics Engineering and Electrical Communications

Nanoantenna for Sensing Applications

A Thesis submitted in partial fulfilment of the requirements of the degree of

Master of Science In Electrical Engineering

(Electronics Engineering and Electrical Communications)

By

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Bachelor of Science In Electrical Engineering
(Electronics Engineering and Electrical Communications)
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Statement

This thesis is submitted as a partial fulfilment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Thesis Summary

This thesis studies optical antennas in the IR range. Optical antennas have been studied based on two sections. The first section is studying Silicon-on-Insulator (SOI) grating coupler for coupling the light between an optical fiber and a strip waveguide at operating wavelength 1550 nm based on the available techniques of fabrication. However, the grating coupler has a drawback in the method of coupling as it depends on the incident angle of the light. Therefore, the second section of the thesis solves the problem mentioned above by studying the nanoantenna for coupling and sensing. Nanoantennas can be used for coupling the light, and the incident light, in this case, is perpendicular to the nanoantenna structure. Furthermore, different nanoantenna arrays structures have been studied to be operated at near-infrared (IR) and mid-IR, paving the way to be used as a compact sensor for condensed phase analytes or biomedical enzymes with high efficiency.

Finally, this thesis suggests a design of highly doped semiconductor nanoantenna array operating in the Mid-IR, which can be used for sensing condensed phase analytes. These analytes work as biomarkers to detect the enzymes in the blood and work as a biomedical sensor.

The thesis is divided into five chapters, as listed below:

Chapter 1:

This chapter introduces a summary of the other chapters starting with the IR range applications and then briefly discusses the optical properties of the IR range materials, including the plasmonic material and the plasmonic effect. It will then briefly discuss the optical waveguides concentrating on the SOI waveguides and Gap-SPP waveguide as it will be discussed in chapters 3 and 4, respectively. Then a brief discussion about the classification of nanocouplers is introduced. Finally, it presents detail for each chapter.

Chapter 2:

This chapter starts with a review of the nanoantenna. Based on chapter one, it discusses nanoantennas applications as a coupler with nanophotonic waveguides at the near IR range. Also, it presents a grating coupler review to illustrate the literature designs for SOI grating coupler to couple the nanophotonic waveguide with an optical fiber. Furthermore, the nanoantenna arrays review is presented too. Then it briefly discusses a literature review about decreasing the gap distance of the nanoantenna array.

Chapter 3:

This chapter discusses the methodology for designing SOI grating coupler for input and output coupling between the nanophotonic waveguide and an optical fiber at an operating wavelength based on the available techniques of fabrication. This type of coupling technique depends on the angle of the incident light. Hence, the coupling efficiency between the nanophotonic waveguide and the optical fiber is discussed in detail. FDTD simulations of the design are included to clarify each parameter's effect to obtain the maximum coupling efficiency. These parameters, like the grating period, the thickness of the nanophotonic waveguide, the inclination angle of the optical fiber, and the grating width.

Chapter 4:

This chapter is starting with designing a simple structure of dipole nanoantenna coupled with a nanophotonic waveguide. Then, it discusses different structures of nanoantenna arrays in the near IR-range by using gold metal. Next, studying a modification on those structures to be used as an efficient sensor to detect a minimal change of the surrounding medium. Furthermore, sensitivity analysis is proposed for each design. The second section of this chapter discusses an efficient, highly doped germanium nanoantenna array, which can be used as a sensor for condensed phase analytes operated at the Mid-IR range. The incident light in this design is perpendicular to the nanoantenna array. The sensing technique in the aforementioned structure depends on the reflection, which can be used as a biomedical sensor.

Chapter 5:

This chapter summarizes the outline of the thesis and discusses the recommendations and suggestions in future work.

Keywords: Nanoantenna, Plasmonics, Semiconductor nanoantenna, Sensing, Grating Coupler, Silicon photonics, Doped Ge, SOI.

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