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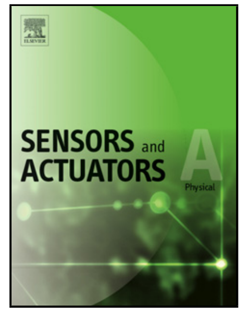

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Sensitivity Optimization of a Photonic Crystal Ring Resonator for Gas Sensing Applications

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HIGHLIGHTS

A design for high Q factor photonic crystal ring resonator (PCRR) is presented. The PCRR is based on 2D pillar type photonic crystals. The high quality factor (3.85×10^5) of the cavity, along with strong overlap between analyet and the field of the resonance mode of PCRR, which have low group velocity, consequence into enhance sensitivity for gas sensing applications. Most of the works that focused on the utilization of the slow light phenomenon until now, dealt with the slow light effect in the high-refractive area of the PhC structure. In contrast, in this work, we illustrate a new concept to enhance the sensitivity of gas sensors for optical sensing by enhancing the light-matter interaction in low refractive area of the PhC, which corresponds to the region filled by the analyte.

Abstract

In this work we report on a computational study regarding the enhancement of the absorption of mid infrared (MIR) light for gas sensing applications. In order to address this goal, a photonic crystal ring resonator (PCRR) with a quality factor of more than 3.85×10^5 was designed. The considered PCRR is based on 2D pillar type photonic crystals, which consist of a hexagonal array of silicon rods. The high quality factor of the cavity, along with strong overlap between the field of the resonant mode and the analyte (0.76) and low group velocity of PCRR modes consequence into enhance sensitivity for gas sensing.

Keywords: photonic crystal ring resonator; gas sensor; resonators; integrated optics

1. Introduction

Measuring the optical properties of fluids plays a central role in chemical analysis. An optical sensor operates by measuring the changes in a property of light as it passes through an analyte. In this framework, photonic technology has significantly enhanced fluid sensing performance, particularly in the area of light-analyte interaction, multiplexing and device miniaturization. Different integrated optical sensors have been proposed, such as micro-ring resonators [1] and photonic crystals [2] [3]. Over the past few years, photonic crystals triggered a lot of interest in lab-on-chip optical technology in connection with their significant potential with respect to, e.g., confinement of light in small volumes, possibility of convenient integration with waveguides, and achievable ultra-high quality factors in case of resonators [4]. Photonic crystals have a wide range of applications including antennas [5], sensors [6], filters [7], etc. PhC-based sensors have been also proposed as gas sensors in mid infrared (MIR), since many gases (e.g., CO2, CH4, CO) exhibit characteristic absorption lines in mid-IR wavelength region which is why this region is often referred to as “figure print” region. A review of gas and liquid sensors based on PhC is presented by Y. Zhao et.al. at 2011 [8]. This work introduces a photonic crystal ring resonator (PCRR) for gas sensing in the mid infrared region. The general sensing mechanism is based on designing a resonator featuring electromagnetic fields in the analyte, which occupies part of the resonator volume, such that the characteristics of the device are affected by the absorption in the sample (a gas, for instance). PCRRs were first introduced in 2002 to realize a hexagonal waveguide ring laser [9]. A PhC sensor based on a ring resonator cavity has been, e.g., proposed for monitoring the level of seawater salinity between 0% to 40% in 2012 [10]. In a review paper, Robinson et.al. present an overview on photonic crystal ring resonators [11].

In this paper we particularly address the utilization of the slow light phenomenon corresponding to waveguide modes featuring very low group velocities. Most of the works that focused on the utilization of the slow light phenomenon until now, dealt with the slow light effect in the high-refractive area of the PhC structure. In contrast, in