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PHOTONIC CRYSTALS RESONANCE STRUCTURE FOR OPTICAL BIOSENSORS

Photonic crystals are materials with refractive index which is spatially periodic modulated. Photonic crystals can be designed to provide photonic bandgaps, within which light propagation is prohibited for specific wavelengths [1]. Control of the light can be achieved by introducing certain defects in photonic crystals structure. The light is only allowed to exist within defect region. The photonic crystals structure exhibit significant confinement of light compared to conventional optical device. This feature allows downsizing of the device based on photonic crystals structure.

Nowadays there is an intensive theoretical and experimental research of photonic crystal properties, methods of analysis and different devices, which include photonic crystal structures such as channel drop filter, power splitter, light sources etc [2,3]. The studying of optical sensing based on photonic crystals has become a relevant topicin the recent years. Sensors based on photonic crystals allow performing a label-free detection based on the interaction of the evanescent field in the structure to detect changes in the refractive index induced by the target analytes [4]. The high sensitivity of photonic crystals-based sensing structures arises from the high confinement of the optical field in the defect regions designed for sensing purposes, as well as from the enhancement in the light-matter interaction provoked by the slow-light effect.

In this work we consider the dispersion characteristics of biosensors based on usage of photonic crystal resonators. The photonic crystals kind called a holes-on-dielectric structure is presented. This type is chosen due to several factors, including easiness of fabricating and coupling with single mode optical waveguides. Moreover, this structure allows obtaining wide photonic bandgaps for the TE polarization. Resonant cavity usually formed within the photonic crystal structure by changing of the one or some holes sizes. Principal parameters of the task in this work are holes radius *r*, the lattice constant *a* and permittivities of the photonic crystal ε and target analyte ε_1.

MIT Photonic-Bands (MPB) software is used to examine spectral properties and calculate dispersion characteristics [5].

In this report, a photonic crystal structure with a local defect is considered. Fig. 1 shows a basic configuration of the photonic crystal structure with triangular symmetry and holes with radius $r/a = 0.48$.

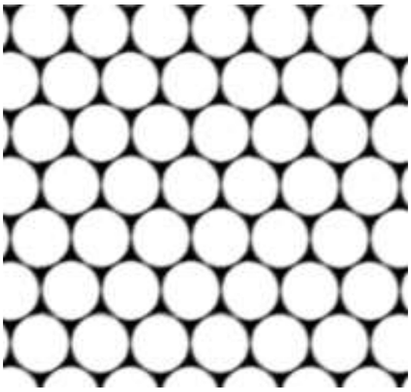

Fig. 1 – Scheme of the photonic crystal

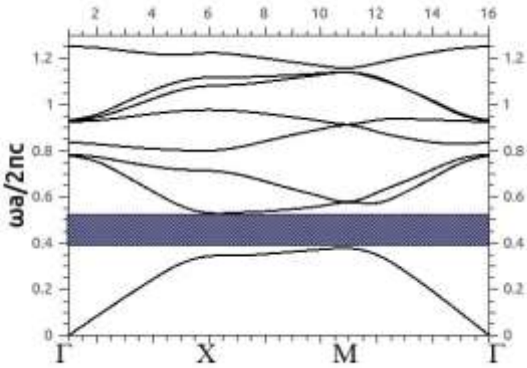

Fig. 2 – Dispersion diagram of the photonic crystal

Using package MPB we calculated dispersion characteristic of the infinite photonic crystal (Fig. 2). Here *c* – speed of light in vacuum. The photonic bandgap is shown by shaded zone and has boundaries at $\frac{\omega a}{2\pi c}=0.377$ and $\frac{\omega a}{2\pi c}=0.53$. Photonic crystal devices like a resonators and waveguides are developed for working frequencies within the photonic band gap.

Let's consider the photonic crystal where there is a hole which has a smaller diameter than other elements of the structure. This case is illustrated in Fig. 3. This phenomenon is called "the local defect of the periodic structure" [1]. A resonance frequency of this structure was calculated on the base of using MPB package. The resonance frequency equals $\frac{\omega a}{2\pi c}=0{,}493607$.

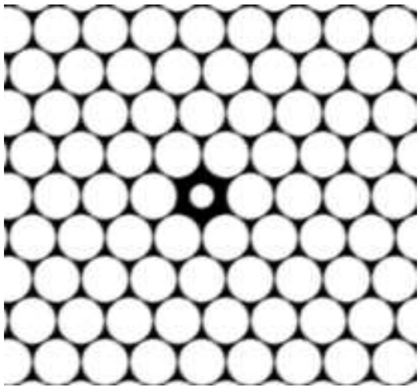

Fig. 3 – Local defect of a periodic structure

The next step of the investigation is infiltrating the another dielectric into hollow local defect of the photonic crystal. Fig. 4 shows the dependency of the resonance frequency on the resonator core permittivity. For example, defect is infiltrated by biological liquid (blood-serum) with $\varepsilon = 1.8$ [6]. As a result, the resonance frequency shifts from initial value to value 0.490312. Changing values of the permittivity allows us calculating the sensitivity of the biosensor, which is defined as the normalized frequency shift per permittivity unit.

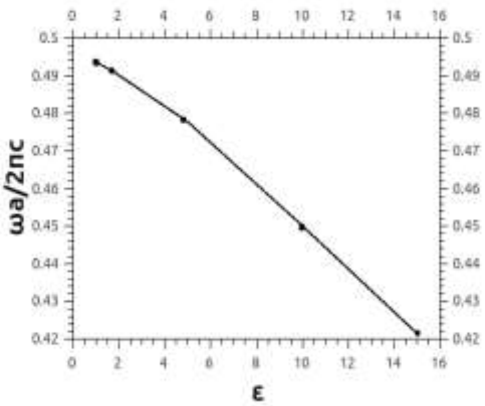

Fig. 4 – Resonance frequency vs permittivity.

In Fig. 5 spatial distribution of the magnetic field in the resonator is showed. Obviously, in this case the field intensity maximum forms inside of defect hole. It provides an intensive interaction between an electromagnetic field and analytes. This leads to an increase of the sensor sensitivity.

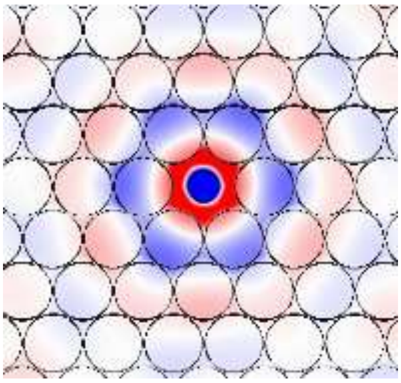

Fig. 5 – Spatial distribution of the magnetic field in the sensor area.

In this work a model of biosensor that bases on the photonic crystal resonance structure was developed. Resonator is formed on base of a local defect of PC. Calculations of the resonance frequency for various values of the permittivity of the infiltrated substances are carried out. Sensitivity of this sensor structure was defined.

References:

1. Lourtioz J.M.,Henri Benisty H., et al. Photonic Crystals. – Springer-Verlag, 2008. – 514 p.
2. Joannopoulos J.D., Meade R.D., Winn J.N. Photonic Crystals: Molding the Flow of Light. – Princeton Univ. Press, 1995. – 137 p.
3. Skorobogatiy M., Yang J. Fundamentals of Photonic Crystal Guiding. – Cambridge University Press, 2009. – 267 p.
4. D. Dorfnera, T. Zabela, T. Hürlimanna, Photonic crystal nanostructures for optical biosensing applications // Biosensors and Bioelectronics. – 2009. – Vol. 24. – pp. 3688–3692.
5. Johnson S. G., Joannopoulos J. D. Block-iterative frequency-domain methods for Maxwell's equations in a planewave basis // Optics Express. – 2001, No. 3. – P. 173-190.
6. El-Kashef H., Atia M.A. Wavelength and temperature dependence properties of human blood-serum // Optics & Laser Technology. – 1999. –Vol. 31. – pp. 181-189.