Inverse opal photonic crystals for sensing the composition of liquid mixtures

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Abstract. The possibility of using inverse opal films from ethoxylate trimethylolpropane triacrylate (ETPTA) photoresist as sensors for determining the concentration of alcohols in water has been studied. The spectral position of the transmittance dip corresponding to the first photonic stop band is used as the analytical signal. Impregnation of an inverse photonic crystal with water-ethanol and water-ethylene glycol mixtures results in a red shift of the transmittance minimum. Refractive index sensitivity is about $\Delta\lambda/\Delta n$ = 414 nm/RIU.

1. Introduction

Photonic crystals (PhCs) have attracted much attention because of possessing tunable photonic band gaps, which could induce tunable color. The structural color is given from the periodic structure of photonic crystals and is characteristic of a particular material [1]. The position of the photonic stop band can be considered as a convenient analytical signal for detecting the composition of water-alcohol mixtures [2]. In this work we investigated the possibility of using inverse PC from ETPTA as sensors of the composition of water-alcohol mixtures and determined the sensitivity of the analytical signal to the studied liquids.

2. Experimental

Inverse photonic crystal films were prepared by template method using photopolymerization of photocurable resin ETPTA [3]. Opal PhC films composed of close packed SiO_2 colloidal microspheres were used as templates. SiO_2 colloidal microspheres of 250 nm in diameter were synthesized by the method presented in [4]. After the removal of SiO_2 colloids free-standing ETPTA inverse opal PhCs were obtained. Fig. 1a shows the typical SEM image of the surface of the resultant ETPTA inverse opal film. Lambda 35 (Perkin Elmer) spectrophotometer was used to study the possibility of using the obtained inverse films as chemical sensors of the composition of liquids by recording their transmission spectra in the normal direction after impregnation with different liquids: water, ethanol, isopropanol, ethylene glycol, and their mixtures with water. The transmittance spectra were recorded in spectral range of 350–750 nm with the monochromator slit width of 0.5 nm and a registration step of 0.2 nm. The position of the transmittance dips was determined using cubic approximation. Taking into account all random errors, the accuracy of determining the minima was approximated about ±0.5 nm.

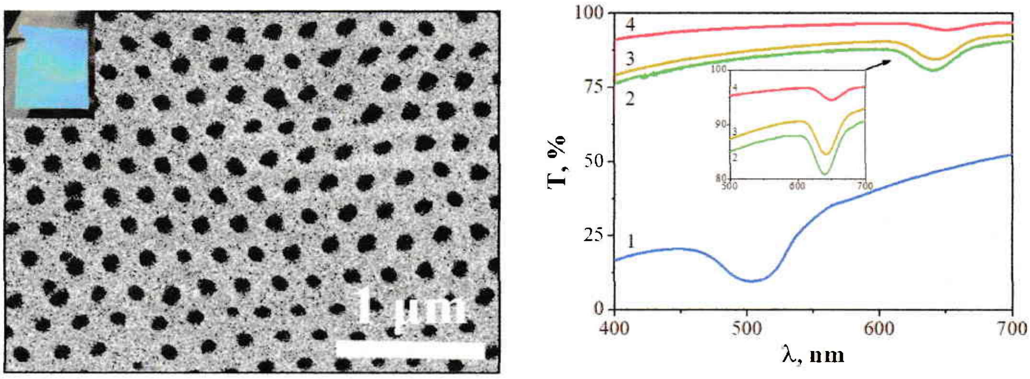

Fig. 1 (a-b). (a) Scanning electron microscopy image of surface of ETPTA inverse opal PhC. Inset: inverse opal film's photograph; **(b)** Transmission spectra for the ETPTA inverse PhC sample in dry state (1) and immersed in various liquids: 2-ethanol, 3-isopropanol, 4- ethylene glycol. Inset: minima of curves 2-4 in the enlarged scale.

3. Results

Fig. 1a shows a high degree of ordering of the inverse PhC films. In the inset of fig.1a a photograph of ETPTA inverse PhC with a characteristic structural color is shown. The minimum on the transmittance curve of the dry sample was about 509 nm. Inverse photonic crystals based on ETPTA photoresist films demonstrate clear stop band shift with the impregnation by different liquids. Fig. 1b shows examples of transmittance spectra of the ETPTA inverse PhC sample infiltrated by ethanol, isopropanol and ethylene glycol (curves 2-4). The red shift in transmittance spectra was observed when refractive index of the studied liquids increased. The observed red shift of the stop band with an increase in n is associated both with an increase in the effective refractive index of inverse PhC (n_{eff}) and with an increase in the interplane distance due to the swelling of the ETPTA photoresist. In accordance with transmittance spectra the dip locates at 609 nm for water (n = 1.333) and at 650 nm for ethylene glycol (n = 1.432). Based on these data, we can calculate the refractive index sensitivity of our samples as $\Delta\lambda/\Delta n$ = 414 nm/RIU.

4. Acknowledgments

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