

Observation of surface states within the stop-bands of a photonic crystal slab with asymmetric termination

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Infrared reflection and transmission spectra of a two-dimensional photonic crystal slab (PCS), fabricated by the technique of joint photo-electrochemical etching of deep macropores and trenches in silicon [1,2], were investigated theoretically and experimentally. The side-walls of the PCS were formed by unstructured interfacial silicon layers and serve for input and output of the incident light. These layers give rise to Tamm surface states within the photonic stop-bands of the PCS, which manifest themselves as defect modes in reflection and transmission spectra of the structure [3]. In the presence of scattering losses, these defect modes appear as wide peaks of large amplitude. Depending on the thickness of the interfacial layer, the position of these peaks within stop-bands is changed. The paper deals with optical characteristics of a PCS, having interfacial layers of different thickness on the different sides of the structure (see Fig. 1).

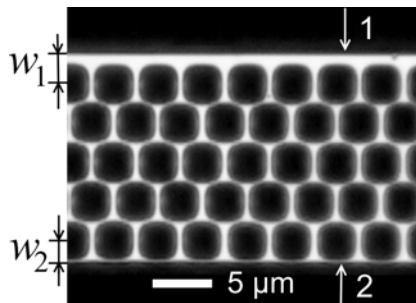


Fig.1. Optical microscope image of the PCS. Period of the triangular photonic lattice is $a = 3.75 \mu\text{m}$, filling factor $r/a = 0.446$, the direction of the light propagation is Γ - M. The thickness of the thick interfacial layer is $w_1 = 0.685a$ and of the thin interfacial layer is $w_2 = 0.552a$.

It has been found that the experimental reflection spectra depend on which side the light enters the structure (1 or 2 in Fig. 1), while the transmission spectra, in total accordance with the reciprocity principle, are identical in both cases. The peaks of surface defects were observed in certain stop-bands under reflection of light from one side of the structure and change their spectral position or disappear entirely under reflection from the other side of the structure (see examples shown in Figs. 2b and 3b). The experimental data were confirmed by calculations using scattering matrix method [4,5] (Figs. 2a and 3a). The light losses inside the structure were taken into account by introduction of the imaginary part to the refractive index of silicon in the same way as in Refs. [3,6,7]. As was expected, in the ideal structure without

losses both the reflection and the transmission spectra do not depend on which side the light enters.

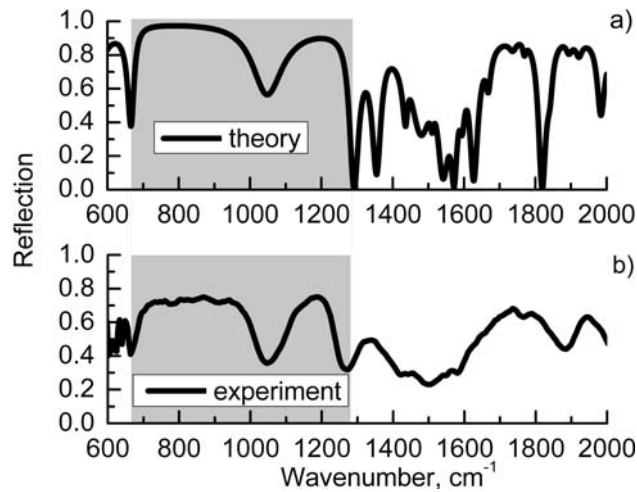


Fig. 2. (a) Calculated and (b) experimental reflection spectra under illumination of the infrared light from the side 1 (w_1) for TE-polarization. The peak, correspondent to the Tamm state at $\sim 1050 \text{ cm}^{-1}$, is seen in the middle of the lower stop-band (denoted by grey area). In calculation the complex refractive index of Si, $n_{\text{Si}} = 3.42 + 0.025i$, and the angle of light incidence of 15° were used.

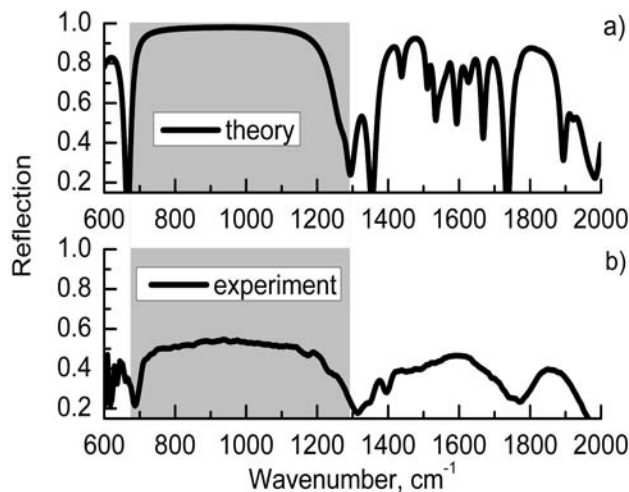


Fig.3. (a) Calculated and (b) experimental reflection spectra, obtained at the same conditions as in Fig. 2, under illumination of the infrared light from the side 2 (w_2). The peak, observed in Fig. 2 at $\sim 1050 \text{ cm}^{-1}$, is absent.

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