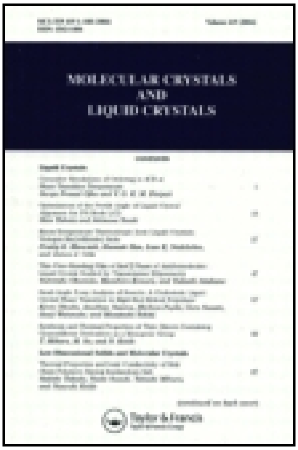

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Optical Properties of $(C_6H_5C_2H_4NH_3)_2PbI_4$ Film on Grating Substrates

Teruya Ishihara [a], Tohru Fujita [b], Atsushi Seki [b] & Hisashi Nakashima [b]

[a] Frontier Research System, The Institute of Physical and Chemical Research (RIKEN), 2-1 Hirosasa, Wako, 351-0198, Japan

[b] Faculty of Engineering, Horoshima University, 1-4-1 Kagamiyama, Higashi-Hiroshima, 739-8527, Japan

Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2001, Vol. 371, pp. 167-170

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TERUYA ISHIHARA, TOHRU FUJITA*, ATSUSHI SEKI* and HISASHI NAKASHIMA*

*Frontier Research System, The Institute of Physical and Chemical Research (RIKEN), 2-1 Hirosasa, Wako 351-0198, Japan and *Faculty of Engineering, Horoshima University, 1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan*

Optical properties of bis- (phenethylammonium) tetraiodoplumbate film on two-dimensionally (2D) patterned quartz substrate are investigated. Such structure can be regarded as a 2D photonic crystal. The dips in transmission spectrum is due to the excitation of wave guide modes in the film. The photonic band diagrams are determined for the structures.

Keywords photonic crystal; grating; inorganic-organic perovskite

Photonic crystal is a periodic arrangement of dielectric media which may exhibit photonic band gaps where no propagating wave is allowed. Although the fabrication of three-dimensional structure at the visible range of spectrum is still challenging, two-dimensional structure has now attracted increasing attention because of its direct application to photonic integrated circuits. In order to reduce the size of the active components, adoption of exciton resonance would be inevitable and worth exploring. In a material with large excitonic oscillator strength the strong coupling between the confined light and the exciton polarization gives rise to a new eigen state, termed as the cavity polariton. We have carried out investigation along this line by incorporating an inorganic-organic perovskite, $(C_6H_5C_2H_4NH_3)_2PbI_4$ into the grating substrates [1-4]. The compound has multiple quantum well structure, where the inorganic layers are considered to be wells while the organic layers are barriers [5-6]. By virtue of the small screening effect in the barriers due to its small dielectric constant, an electron and a hole in an exciton interact strongly through the Coulomb interaction through the barrier layers. The binding energy amounts to 220 meV and the oscillator strength is 0.5 per formula unit. Thin film with good quality can be obtained simply by spin coating their organic solution. Anticrossing between the exciton and light dispersion has been observed at room temperature with a separation of 100meV. In this paper we present the first report of fabrication and optical characterization of 2D photonic crystals using this material system.

Square lattice grating structures are fabricated on quartz substrates by means of electron beam lithography. Both positive and negative resists are respectively used to make positive and negative structures from a grid exposure pattern. We used the same inorganic-organic perovskite semiconductor of $(C_6H_5C_2H_4NH_3)_2PbI_4$ as the active structure, which was used in the investigation of the polaritonic nature of the optical response. In this report, however, we confine our discussion to the transparent region of the spectrum in order to focus on the 2D photonic band structures. We overcoated polystyrene film in order to concentrate the electric field into the waveguide structures. We measured the transmission spectra in such structures. Light beam is incident from the free space.

Figure 1 shows incident angle (measured from the normal) dependence of transmission spectra for "positive" (a) and "negative" (b) structures with period of 720nm. The absorption band at 2.4 eV has been ascribed to exciton transition. Note that it is observed even at room temperature, which is ascribed to the large binding energy. An additional absorption line with much sharper width is also observed due to the excitation of the wave guide modes by means of the reciprocal lattice wave vectors. This absorption line splits depending on the incident angle. For θ >10 degree, another absorption line enters into the spectrum range of the present experiment. By plotting the dip energies as a function of the wave vector $k = \omega \sin \theta / c$, we can reproduce photonic band structures in such systems.

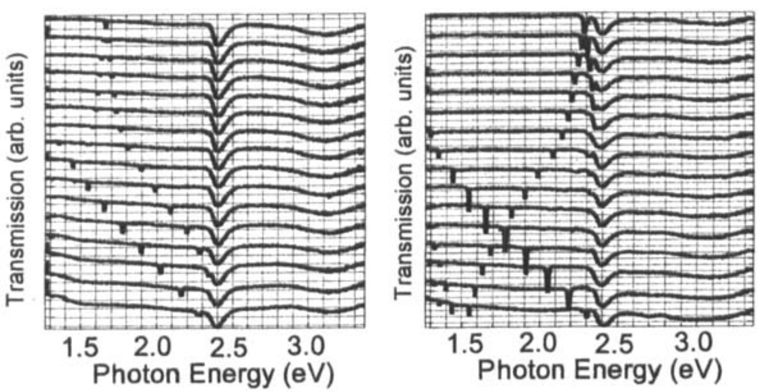

Figure1 Transmission spectra of the (a) "positive" and (b) negative structures for some incident angles. From the top, 0, 1, 2, 3, 4, 5, 7, 10, 15, 20, 25, 30, 35, 40, 45 and 50 degrees.

The dispersion relations are plotted in Fig. 2. Note that there are modes with different slopes, which suggests different group velocity. The energy dependence of the dispersion of the band is due to the energy dependence of the dielectric constant, which is due to the polariton effect. In Fig.1b, one may notice that the depth of the absorption is different from the ones in Fig.1a while the dip positions are the same. The absorption depth can be explained by the matching of the wave functions of the eigen mode in the waveguide structure and in the free space

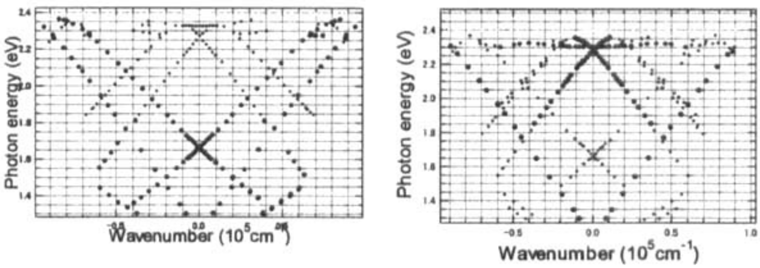

Figure 2 Photonic band diagrams determined from the angle dependence of the transmission spectra. (a) "positive" and (b) "negative" structures with 720 nm grating pitch. Larger marks represent stronger absorption.

In conclusion, we have demonstrated 2D photonic band structures for a film spin coated on the substrates with square grating structure. System of film on patterned substrates are rich in physics and will play an important role in future photonic devices.

References

[1] T.Fujita et al., Phys.Rev.B57,12428 (1998).

[2] T. Fujita and T. Ishihara, J. Phys. Soc. Jpn. **68**, 2918 (1999).

[3] T.Fujita et al. , J. Luminescence **87-89**, 847 (2000).

[4] T.Fujita et al. , Phys.Stat.Solidi(b) **221** (2000).

[5] T.Ishihara, Optical Properties of Low-Dimensional Materials, eds. T. Ogawa and Y. Kanemitsu, 288-339 (1995).

[6] T.Ishihara et al. , Phys.Rev.B **42**, 11099 (1990).