Tunability of Optical Stop Band Energy Utilizing Thermochromism of Synthetic Opal Infiltrated with Conducting Polymer as Photonic Crystal

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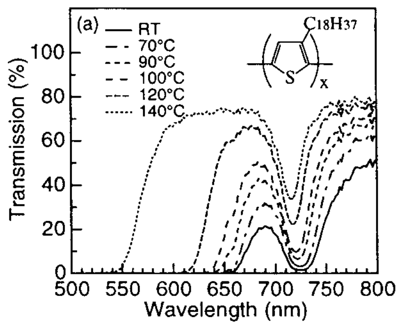
Photonic crystals with a three-dimensional periodic structure of the optical wavelength order have attracted much attention from both fundamental and practical viewpoints, because the prediction of new concepts such as a photonic band gap, and various applications of the photonic crystals, such as thresold-less laser have been proposed. We have reported that various materials, such as conducting polymers, dyes and liquid crystals, can be infiltrated into the interconnected nanoscale voids of synthetic opal which was prepared by the sedimentation of monodispersed SiO_2 spheres of several hundred nanometers in diameter, and we have also demonstrated that novel functionality can be realized in these infiltrated opal.[1-4]

Among the various materials, conducting polymers with extended π-conjugation in their main chains exhibit numerous interesting properties such as thermochromism and solvatochromism.[5-7]

In this paper, we report the control of optical properties such as the stop band of synthetic opal infiltrated with conducting polymer by utilizing the thermochromism of conducting polymer, as an example of tunable photonic crystals.[8]

Synthetic opal film of 75 μm in thickness with a three-dimensional periodic was fabricated by the sedimentation of the suspension of monodispersed SiO_2 spheres of 300 nm in diameter.[3] The obtained opal film has a face-centered cubic (f.c.c.) structure and a nanoscale interconnected regular array of voids. In this study, we used a conducting polymer, poly(3-octadecylthiophene) (PAT18) synthesized by the previously reported method.[9] The molecular structure of PAT18 is shown in the inset of Fig. 1(a). PAT18 was infiltrated



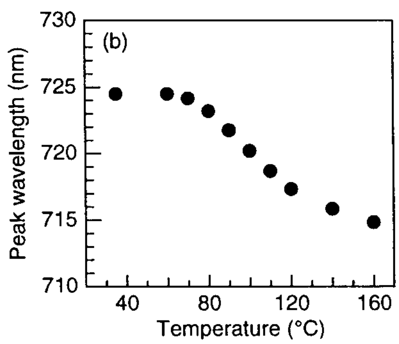


Fig. 1. (a) Change of transmission spectra of an opal thin film infiltrated with PAT18 as a function of temperature. The inset shows the molecular structure of PAT18. (b) Temperature dependence of the peak wavelength of transmission spectra.

into the nanoscale voids of the opal thin film in the liquid phase. By this infiltration, the wavelength of the stop band shows a red shift.

The change of the transmission spectra of the synthetic opal infiltrated with PAT18 as a function of temperature is shown in Fig. 1(a). As is evident from this figure, the peak wavelength of the stop band shows a blue shift with increasing temperature. This change is observed at high temperature above melting point of PAT18. It should also be noted that these shifts of the transmission spectra with temperature were confirmed to be reversible. The details of the shift in the peak wavelength of stop band at various temperature is more clearly shown in Fig. 1(b).

The refractive index of PAT18 in synthetic opal is evaluated from the stop bands. That is, the periodicity of the opal is evaluated from the stop band of the opal before infiltrating PAT18. Then, utilizing this periodicity, the refractive index of infiltrated PAT18 is calculated utilizing the wavelength of the observed stop band in Fig. 1(a). On the other hand, the refractive index of PAT18 was directly estimated to be 1.667 ± 0.01 by measuring the refraction angle of laser light of 682 nm in wavelength through a wedge-type cell.

As shown in Fig. 2, the change in the refractive index of PAT18 evaluated from the shift of the stop band with increasing temperature corresponds to that of the directly evaluated value. That is, the blue-shift of the peak wavelength of the stop band can be interpreted to be attributed to the decrease of the refractive index of PAT18 which is due to the increase in the band gap energy of PAT18 with increasing temperature.

We have demonstrated that the tunability of the stop band energy of synthetic opal infiltrated with conducting polymer can be realized, by utilizing the thermochromism of conducting polymer.

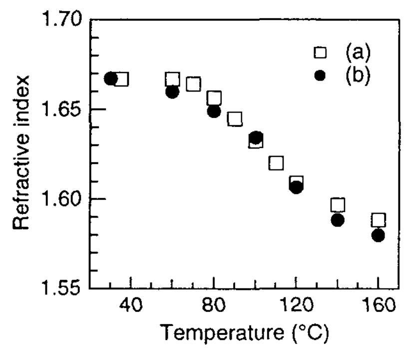


Fig. 2. Temperature dependence of the refractive index of PAT18: (a) directly measured and (b) evaluated from the stop band.

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