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Tunable Photonic Crystals

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Abstract

The focus of this work was to investigate the optical properties of photonic crystals, as well as periodic mesoporous films, and then integrate these two materials to form one structure which will then act like a chemical sensor. Using self assembly, the photonic crystals of various dimensions were fabricated utilizing silica spheres. The periodic mesoporous films were then coated on top of the photonic crystals, and after that, another photonic crystal was grown on top of that. Optical spectra and scanning electron microscopy indicate that the structures are of fairly high quality. The dip shown in the stop band in the combined structure indicated that the film is acting like a cavity, and its index of refraction can probably be changed in order to vary the dip, resulting in the structure behaving like a chemical sensor.

Introduction

During the last decade, there has been a interest in photonic crystals, artificially engineered structures in which the index of refraction is modulated in one, two, or three dimensions.[1,2] These structures have potential applications in telecommunications and sensors, and they can also be used to demonstrated fundamental phenomena. Because of the difference in the index of refraction, light is reflected almost completely from a photonic crystal at a particular band of wavelengths, which is called the stop band of the structure. This is the mechanism in which we observe different colors in a peacock's feather (see Fig. 1), which is a natural photonic crystal.[3]

Out of the several methods available to fabricate photonic crystals, self-assembly seems a very promising route. By starting with spheres of some material, for instance, silica, photonic crystals can be assembled on glass substrates.[4] The stop band's position can be changed by varying the diameter of the spheres, and also the intensity can be changed by putting down more layers.

As researchers have optimized the parameters pertaining to self-assembly of photonic crystals, one important aspect that needs attention is its tunability so that greater functionality can be built into a single structure. In this work, we have introduced a defect layer into the photonic crystal in order to tune the stop band of the structure.

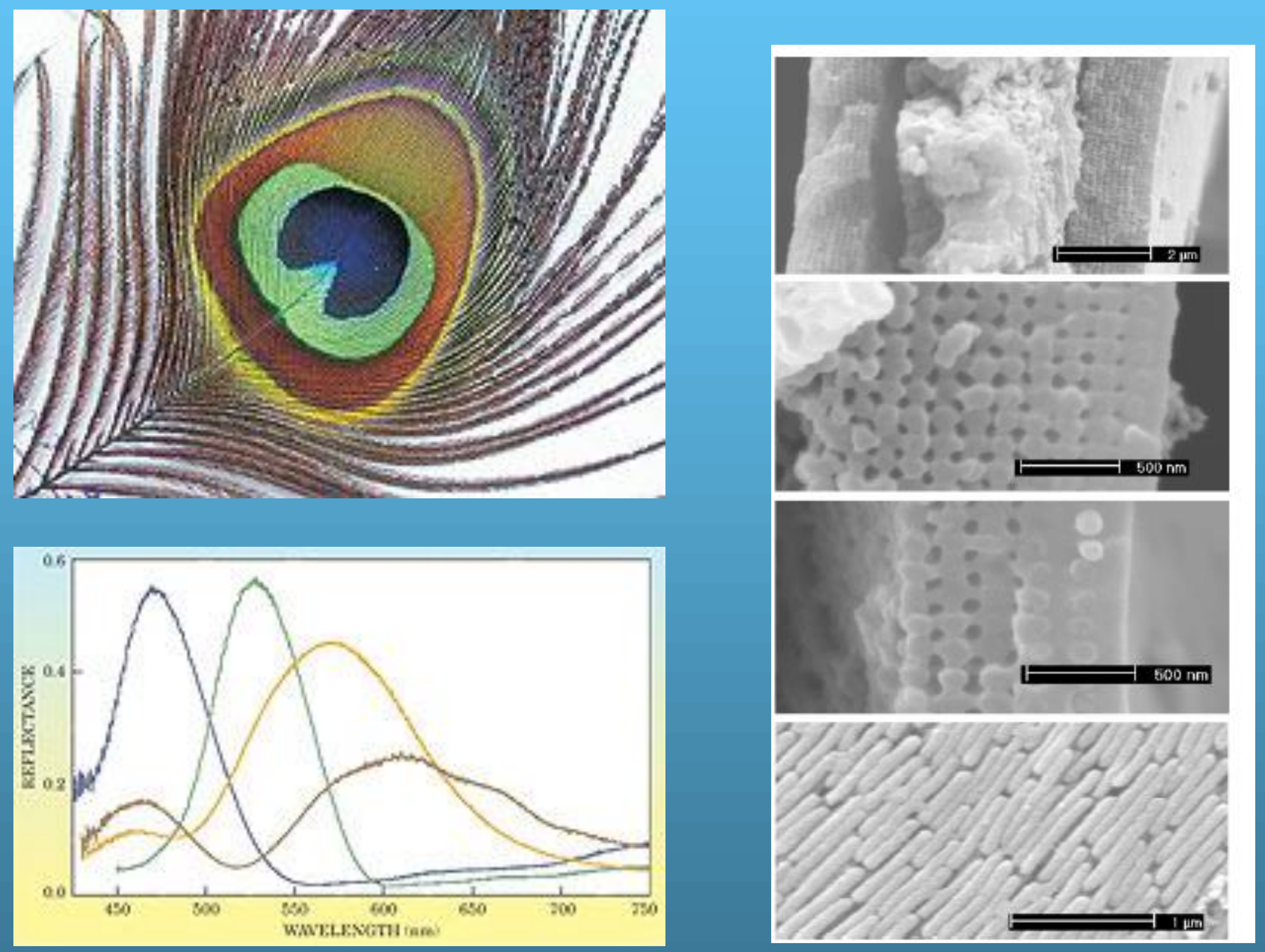

Fig 1. Cross sectional view of a peacock's feather indicates that is composed of rods which are organized to form a photonic crystal. By changing the rod's diameter, the peacock is able to change the color of it's feather.

Experimental Details

By starting with a solution in which the silica spheres are dispersed in ethanol, a glass substrate can be placed vertically inside the vial as shown in Fig. 2. As the ethanol evaporated, the silica spheres start to from in the meniscus. By changing the concentration of the original solution, one can change the number of silica layers in the final sample.

Once the sample is assembled, scanning electron microscopy is done to check the quality of the sample. This is shown in Figure 3. After that a UV-VIS reflectivity experiment is performed to determine the optical properties of the sample, as shown in Figure 4.

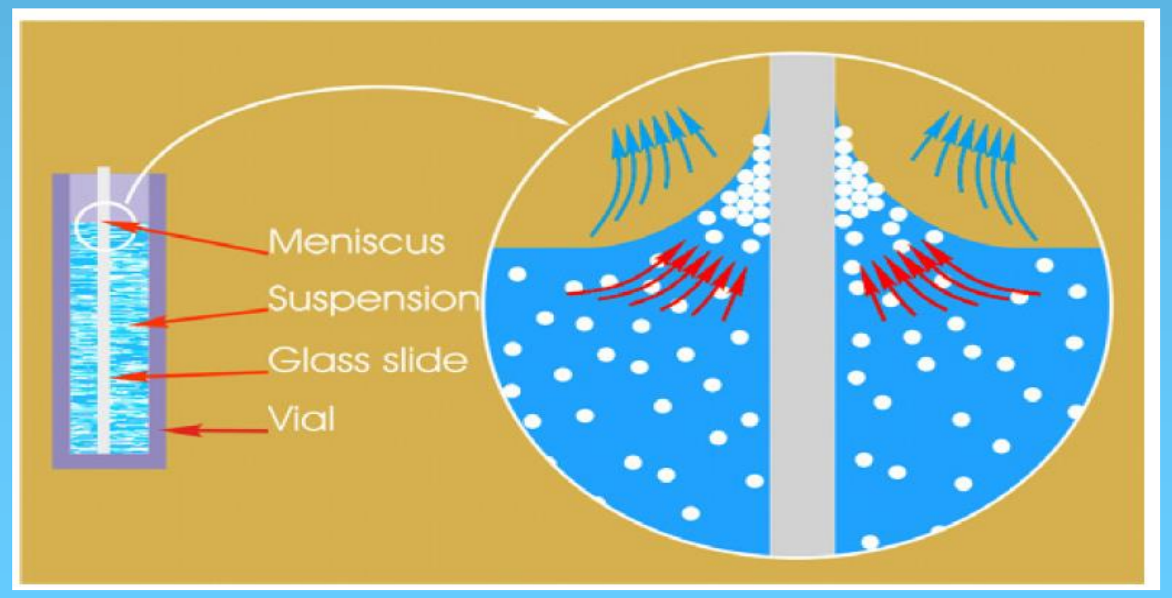

Fig 2. This diagram shows how the silica spheres are assembled to form the photonic crystal. (Taken from Lopez, J. Opt. A. Pure Appl: Opt. 8, R1 (2006))

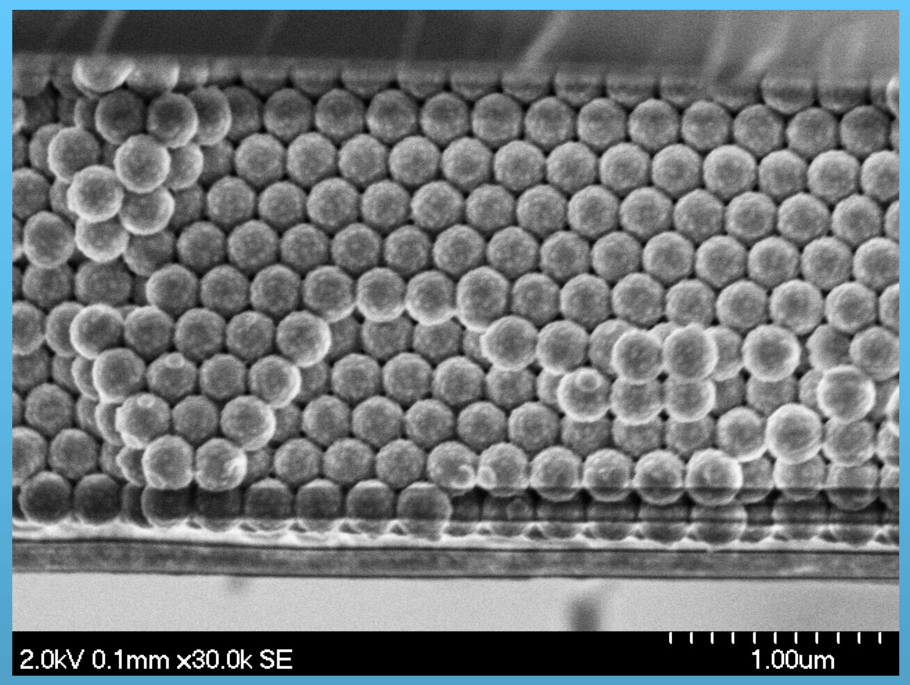

Fig 3. Scanning Electron Microgram of a SiO_2 photonic crystal. This sample had around 20 layers, and is made out of ~250 nm silica spheres.

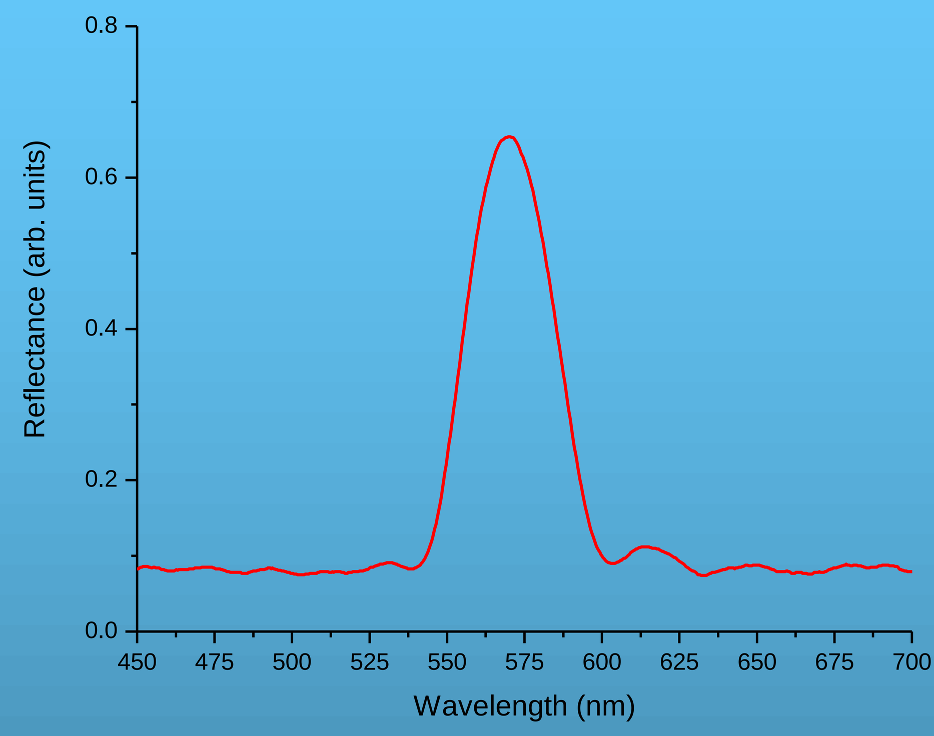

Fig 4. UV-VIS reflectivity spectrum of the photonic crystal. The stop-band is of this sample is around 560 nm.

Results

After the photonic crystals are fabricated, the stop band cannot be altered usually. In order to tune the stop band one has to introduce a defect layer, which a thin film sandwiched between two photonic crystals. The film we selected was a periodic mesoporous silica layer, which has a pore structure built into a silica wall inside the material.

The periodic mesoporous silica was synthesized, and later, spin coated onto the photonic crystal to form films. After that another photonic crystal was grown on top of the film.

Results (continued)

As shown in Figure 5, the scanning electron microgram of the final structure shows the incorporation of the thin film in between the two photonic crystals nicely. A closer look at this picture also indicates some defects, and areas in which the film has not adhered to the bottom photonic crystal. These problems have to be rectified in the future in order to obtain high quality structures..

The optical spectra of the final structure is shown in Figure 6. This spectrum is different to the one shown in Figure 4, as it has a dip in the stop band. This indicates that the light is transmitting at this wavelength, and this is because the film is able to act as a cavity to allow this transmission.

The final goal was to introduce various chemicals into the structure, such as water, acetone, and ethanol. These chemicals will go and get stuck inside the pores of the thin film. Due to this reason, one would expect a change in the index of refraction, which will then alter the dip in the optical spectrum. Therefore the structure would then act like a sensor for these chemicals. Unfortunately, time constraints did not allow us to complete this part of the project.

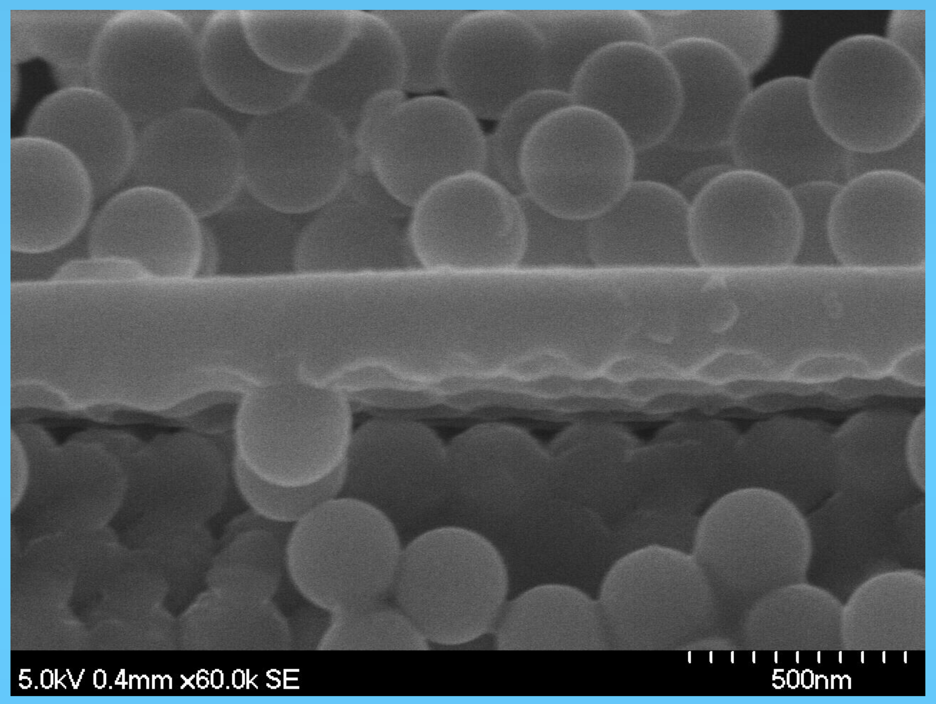

Fig 5. Scanning electron micrograph of a photonic crystal in which the thin film is sandwiched between two photonic crystals..

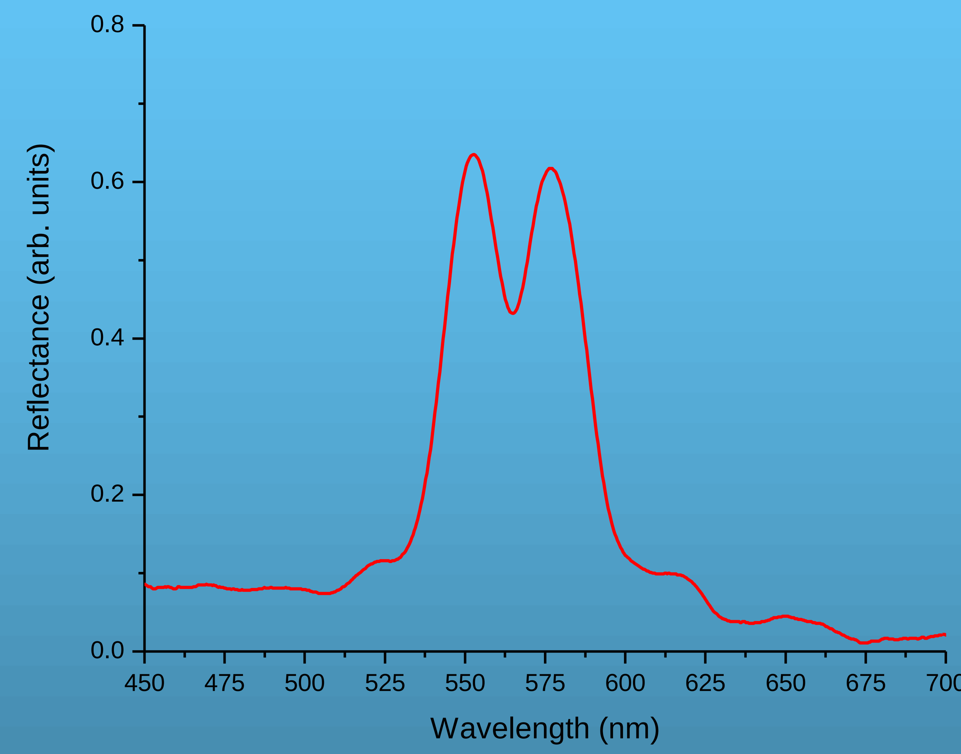

Fig 6. UV-VIS reflectivity spectrum now shows a dip in the stop band where light can now transmit through the structure.

References

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