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Original Research Paper Physics

Stabilization of Self Assembled 3D Photonic Crystals

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ABSTRACT We have synthesized Poly-methylmethaacrylate (PMMA) three dimensional (3D) Photonic crystals by tuning the size of PMMA nanospheres via self-assembly method and stabilizing its surface by coating it with Poly-vinylalcohol (PVA). We present a simple, low cost self assembly method to produce uniform, large area 3D photonic crystals using PMMA nanospheres and stabilizing the surface of these PhC's with PVA. The monodispersed PMMA nanospheres have been characterized by characterized using DLS, SEM, HR-TEM and UV-Vis spectroscopymeasurements..

KEYWORDS :Poly-methamethaacrylate (PMMA), Nanoparticles (NP), Photonic Crystal (PhC), self-assembly, Polyvinyl alcohol (PVA).

INTRODUCTION

PhC's are periodic arrangement of dielectric material (or refractive index) which changes periodically on wavelength scale. PhC's have the capability to control and modify the properties of electromagnetic waves. High dielectric constant and low dielectric constant regions coexist, which affect the motion of photons and propagation of electromagnetic waves. Coherent scattering takes place at these interfaces. Such photons with certain frequencies or energies are not allowed to propagate through these regions. This range of prohibited frequencies or energies is known as photonic band gap. PhCs which does not allow photons to propagate from any direction with any polarization have complete photonic band gap [1]. PhCs can be used in many applications such as Optical Waveguides [2], light emitting diodes (LEDs) [3], Photonic Light wave circuits [4], highly reflecting mirrors [5], and optical filters [6]. Apart from optical applications, PhCs can be used in bio applications also such as biosensing, bioseparation and screening biomolecules in suspension phase [7] etc. Poly methylmethaacrylate (PMMA) is a basic material to fabricate photonic crystals. It is a biocompatible material; hence it can be used as biosensors. PMMA has gained a lot of attention because of its low cost, biocompatibility and easy processing. Controlling PMMA particles size has become a great research area for the researchers as the particle size varies due to agglomeration and lack of monodispersivity. Fabrication of photonic crystals has been challenging since many years. Many top-down and bottom-up approaches were tried but were not very effective as either these techniques are very expensive or provide low yield. This attracted the attention of researchers and scientists to find a cost effective and high yield PhC fabrication process. Self-assembly can be achieved by several approaches such as Langmuir-Blodgett method [8], physical confinement [9], gravity sedimentation [10], membrane filtration [11] and vertical deposition [12]. In this paper, we present a simple, low cost self assembly method to produce uniform, large area 3D photonic crystals using PMMA nanospheres and stabilizing the surface of these PhC's with PVA. The monodispersed PMMA nanospheres have been characterized by Dynamic Light Scattering (DLS) technique. The PhCs have been imaged using Scanning Electron Microscopy (SEM) and Optical Microscopy.

EXPERIMENTAL METHODOLOGY

Colloidal particles of PMMA were synthesized from monomer Methylmethaacrylate (MMA). EGDMA (Ethylene Glycol Dimethacylate) (a cross-linking agent) was added to convert MMA into PMMA by polymerization reaction. Ammonium persulfate used as initiator. A glass substrate, 1x3 inch cleaned with freshly prepared piranha solution, 3:1 mixture of 98% sulfuric acid and hydrogen peroxide at 80°C for 30-40 minutes. These glass slides were dried and suspended in a glass vial of capacity 20 mL, in which one third of the volume is filled with colloidal suspension. This suspension was kept in a heating oven for 2-3 days at 65°C. The suspension evaporates and simultaneously PMMA nanospheres were deposited on glass substrate as shown in Fig. 1. The surface of these Phc's has been made stable against tearing with PVA solution of different concentration. The samples have been characterized using Scanning Electron Microscope (SEM), Optical Microscopy (OM), and Dynamic Light Scattering (DLS) technique.

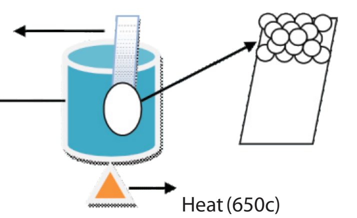


Fig 1: Self Assembly of PMMA nanospheres

RESULTS AND DISSCUSION

PMMA nanoparticles of various sizes were prepared by varying the concentration of the crosslinking agent. PMMA sizes were found to be in the range of 229.2 nm - 306.8 nm, shown in Fig. 2(a). With the increase in the cross linking agent concentration, it was found that the particle size reduces up to a certain value and size broadening starts to take place after that. Fig.2 (a) DLS spectrum showing the size distribution of PMMA nanospheres. Fig 2(b) SEM image showing self assembled PMMA nanospheres. During the deposition, these nanospheres were driven to liquid-solid interface by capillary forces. Solvent evaporates and spheres stick to the solid substrate gradually. While solvent was evaporating, liquid layer become thinner and interaction between spheres increases as shown in Fig. 1. That is why thick layers are obtained at the start of solvent evaporation and thin layers obtained at the end of solvent evaporation on glass substrate. The temperature of this process was 65°C. Optical image in fig.3 (a, b, c) shows the beautiful Colors of the optical micrograph indicate that we are able to achieve photonic band gap in fabricated photonic crystals. Different colors indicate the different sizes of PMMA nanospheres used to fabricate the PhC's.

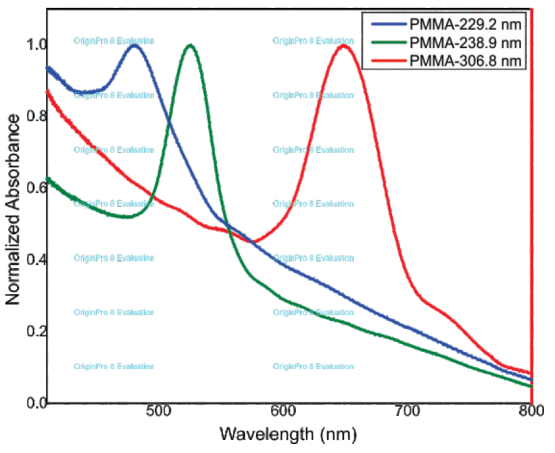


Fig.2 (a) DLS Spectrum

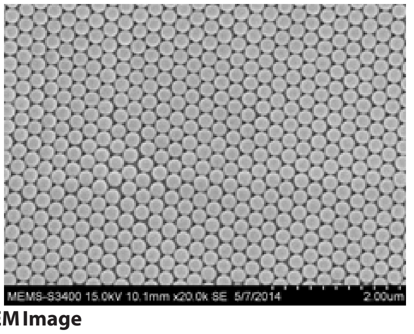


Fig.2 (b) SEM Image

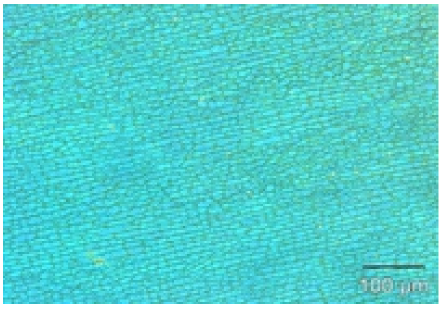
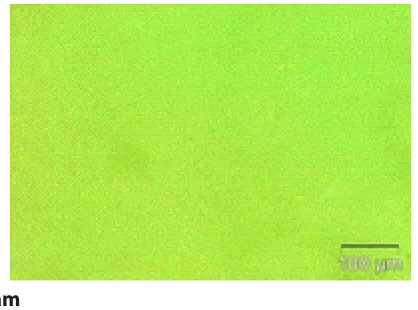


Fig. 3: (a) 229.2nm



(b) 238.9nm

(c) 306.8nm

CONCLUSION

We have successfully prepared PMMA nanospheres in the size range of 229.2 nm to 306.8 nm. Fine size tunability has been achieved by changing the crosslinking agent concentration. We have utilized vertical deposition method to self assemble PMMA nanospheres to fabricated photonic crystals. We have stabilized the surface of PhC against tearing and now it can used in many application where surface stability was a problem.

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