Brilliant Coloured Monochromatic Photonic Crystals Films Generation from Poly (Styrene-Butyl Acrylate-Acrylic Acid) Latex

1*IFIJEN, IH; 2MALIKI, M; 3OVONRAMWEN, OB; 1AIGBODION, AI; 2IKHUORIA, EU

ABSTRACT: A one-pot synthetic procedure was successfully used to synthesize monodispersed poly (styrene-butyl acrylate-acrylic acid) (P(St-BA-AA)) colloidal spheres via emulsion polymerization. A glass transition temperature (Tg) of 108 °C was obtained by DSC analysis. Core-shell morphology was revealed by TEM micrograph. Evaporative induced self-assembly process was used to fabricate photonic crystals from the as-synthesized P(St-BA-AA) latexes. Microscopic analyses of the fabricated photonic crystal films revealed the assembling of colloidal particles which rearranged into a fascinating compact three-dimensional periodic hexagonal structure with manifold layer arrangement. The photonic crystal films displayed mesmerizing monochromatic yellow, blue and green colours which were obtained by controlling the size of the microspheres. The prospect of deliberately obtaining photonic crystals with monochromatic colours would be very useful in the generation of photonic crystals for sensing application.

DOI: https://dx.doi.org/10.4314/jasem.v23i9.9

Copyright: Copyright © 2019 Ifijen et al. This is an open access article distributed under the Creative Commons Attribution License (CCL), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Dates: Received: 14 August 2019; Revised: 22 September 2019; 27 September 2019

Keywords: poly (styrene-butyl-acrylate-acrylic acid); photonic crystals; ter-polymer; monochromatic

The pleasant and amazing viewing potential under diverse illuminating environs has attracted numerous attentions towards the generation of reflective-type displays. These reflective-type displays can be achieved by controlling the reflectance of each pixel, as such giving rise to a coloured image under a light (Kim et al., 2018). A scheme that is capable of selecting reflecting colours or a transmissive colour filter array is required for the implementation of colours in reflective-type displays. The generation of full-colour reflective-type displays using electro-wetting (Yi et al., 2015), electrophoresis (Mukherjee et al., 2015) and interferometry (Hong et al., 2014), has been attempted by several studies. However, overcoming the insufficent colour depth, the low reflectivity and the colour loss is still very challenging. In recent times, photonic crystals (PCs) have attracted great attention as new materials for colour generation (Segal et al., 2015). The manipulation of either the refractive index or lattice constant by thermal (Dai et al., 2011, Markos, 2016), optical (Kim et al., 2018), and mechanical stimuli (Kim et al., 2018) can be carried out in order to tune the structural colours from the PCs. Previous studies have shown that a colour tunable PC is easier to obtain than PC with monochromatic colour (Ifijen et al., 2019).

This study, therefore, fabricated series of highly ordered three-dimensional monochromatic photonic colours from crystals of poly (styrene–methylmethacrylate-acrylic acid) colloidal microspheres via the vertical deposition technique.

MATERIALS AND METHODS

Materials: Styrene, Butyl acrylate (BA), Acrylic acid (AA), Acrilamide (AAm), Sodium dodecyl benzenesulfonate (SDBS), N, N-methylenbisacrylamide (99%) (BIS), ethylene glycol, N,N-methylenbisacrylamide (99%) (BIS), Ammonium bicarbonate, (EG), (KPS), pure nitrogen gas, Ammonium per-sulphate (APS) and dimethoxy-acetophenone (DMAP). All reagents are of analytical grade.

Synthesis of poly (styrene-butyl-acrylate acrylic acid) with variable diameters and coloured photonic crystal (PC) films fabrication: Monodispersed poly (styrene-butyl-acrylate-acrylic acid) (P(St-BA-AA)) colloidal microspheres were prepared via batch soap seeded emulsion polymerization technique as described by Ifijen et al. and Minghui et al. (Ifijen et al., 2019, Wang et al., 2016). In a typical experiment, sodium

*Corresponding Author Email: larylans4u@yahoo.com
deodecyl benzene sulphurnate (SDBS) (0.005 g), acrylic acid (AA) (0.720 g), ammonium bicarbonate (0.085 g) and styrene (St) (3.190 g) were transferred into a 50 ml flask containing distilled water (16.5 g). The mixture was stirred at 410 rpm in a nitrogen environment at a temperature of 90 °C for about 30 minutes. The mixture of butyl-acrylate (BA) (0.735 g) monomer and APS initiator (0.091 g) was then transferred into the reaction flask. The reaction was stopped after 13 hrs.

**Generation of coloured photonic crystal (PC) films:**
The coloured PCs were generated following a published procedure (Ifijen et al., 2019). Here, P(St-BA-AA) crystal films were generated from the as-synthesized latexes via the evaporative induced self-assembly of colloidal suspension made from P(St-BA-AA) latex and water on the surface of glass slides. The crystal films were obtained by carrying out the assembly process at 60 °C for 24 hr in a water bath. The self-assembling of the latex particles was instigated by the capillary force between the convective force and the interface of the glass substrate generated by the evaporation of solvent.

**Characterization Techniques:** High-resolution transmission electron microscopy (TECNIAI F2G20 HRTEM) and Atomic force microscope in the tapping mode (Bruker Multimode, Germany), were used to determine the arrangement pattern of the prepared P (St-BA-AA) latex and the generated photonic crystal films. The functional groups’ determination of the synthesized latex samples was achieved using Perk spectrum one FT-IR spectrometer.

**RESULTS AND DISCUSSION**
Figures 1, 2 and 3 revealed the functional groups of P (St-BA-AA) latex. C-H out-of-plane bending vibrations in methylene and benzene groups are due to the peaks at 696 cm⁻¹ and 757 cm⁻¹ respectively.

The peaks at 1449 cm⁻¹, 1509 cm⁻¹ and 1589 cm⁻¹ are assigned to aromatic C=C-C stretching vibration (Omorogbe et al., 2019). The observed peaks at 2924 cm⁻¹ and 3027 cm⁻¹ are caused by methylene and aromatic C-H groups respectively. The peaks at 1725cm⁻¹ and 1198 cm⁻¹ are caused by carboxylic acid (C=O stretch) and C-O stretching vibration (ester bond) (Ifijen et al., 2019) respectively.

Figure 4 revealed the SEM micrographs of the fabricated photonic crystal films with insets of coloured films and their multi-layer views. The results revealed an ordered hexagonal arrangement of spherical particles with manifold layers (Figure 4).

![Fig. 1: Fourier transform infrared spectroscopy (FTIR) (b) Differential scanning calorimetry (c) UV–visible absorption spectra (DSC) of P(St-BA-AA) latex](image)

![Fig 2: display the spectra of P(St-BA-AA) latex. A Tg of 108 °C was observed for the prepared P(St-BA-AA) latex. The obtained Tg is a pointer that the glassy and non-flexible state of the P(St-BA-AA) latex can consistently be preserved whenever they are applied within the aforementioned Tg. Although, their glassy and non-flexible state becomes rubbery like when this Tg is passed.](image)
when trying to generate colour responsive photonic crystals.

**Fig 3:** displays the UV spectra of P(St-BA-AA) latex. The result revealed a typical UV absorption for Pi-bonding to Pi-anti-bonding transformation ($\pi \rightarrow \pi^*$) at about 228 nm, 258 and 255 nm respectively. This indicates the presence of conjugated double bonds latex structures.

![UV spectra of P(St-BA-AA) latex](image)

**Conclusion:** This study successfully fabricated photonic crystal films with beautiful yellow, blue and green monochromatic colours from as-synthesized poly (styrene-butylacrylate) latexes by varying their particle diameters. The possibility of deliberately obtaining photonic crystal films with monochromatic colours by controlling the sizes of the microspheres would be very useful in the creation of photonic crystals for sensing applications.

**Acknowledgements:** The authors appreciate the financial support of TWAS for this research and also the parents of Dr Ifijen, Ikhazuagbe Hilary (Mr. & Mrs Ifijen) for their support.

**REFERENCE**


