

Structural coloration of chitosan-cationized cotton fabric using photonic crystals

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Introduction

Conventional textile coloration is a wet process involving high levels of water and chemicals consumption and wastewater generation. However, colour in textiles can also be generated by other mechanisms such as: absorption, emission, diffraction, interference and photochromism.[1] Chromotropic effect refers to reversible colour transformation due to external chemical or physical influence.[2] Photonic crystals are an important class of chromotropic materials. Colloidal crystals with a periodicity on the scale of half the wavelength of visible light exhibit structural colours similar to natural opals due to a diffraction effects that result in the appearance of a photonic band gap that forbids propagation of certain wavelengths.[3] Structural coloration is emerging as an innovative technology to produce colourful textiles materials.[4] Various colours impossible to reproduce by chemical coloration can be created by modifying the periodicity of the nanostructures or the environmental conditions using a single material.[5, 6] Photonic crystals can be applied on textile fabrics by colloid self-assembly and the structural colours can be controlled by adjusting the microspheres size and the viewing angles.[7] However, their application for textile structural coloration has been barely reported.[8] In this work, P(St-MMA-AA) composite nanospheres were deposited onto chitosan-cationized woven cotton fabrics. The structural colours of the deposited photonic crystals on the fabrics and its washing fastness were investigated.

Materials and methods

Black dyed cotton fabric 7 x 7 cm samples with a warp density of 34 threads cm⁻¹, a weft density of 30 threads cm⁻¹ and areal density of 140 g m⁻² were used in this study. Mono dispersed latex spheres of poly (styrene-methyl methacrylate-acrylic acid) (P(St-MMA-AA)) were synthesized by soap-free emulsion polymerization as previously described.[9] Three types of samples were tested: (1) Cotton sample was dipped in a 8% photonic colloid solution for 5 minutes and then dried at 60 °C; (2) A cationized cotton sample obtained impregnating the fabric into a 1% chitosan using a padding machine (1.5 bar, 4 rpm, 80% pick-up) and then treated as sample 1; (3) Sample 2 followed by a second impregnation in 1% chitosan solution and dried again at 60 °C. Morphological analyses were carried out in an Ultra-high resolution Field Emission Gun Scanning Electron Microscopy, NOVA 200 Nano by FEI. All samples were tested for colour and washing fastness according to ISO C06. The reflectance measurements were measured with a spectral photometer (Konica Minolta 3600d, Japan).

Results and discussion

SEM images indicate that the photonic crystals are even coated on the cotton surface only in the chitosan treated sample (Figure 1A). The colloid spheres present an average diameter of 280 nm and display a cubic close-packed structure with hexagonal alignment (Figure 1B). Cotton crosslink with

chitosan resulting in cationic groups on the fibre surface that promote electrostatic interaction with photonic crystals.[10] Chitosan post-treatment (sample 3) increases the colour yield of the samples due to the higher amount and uniform distribution of the absorbed crystals on the fabric. Fabrics produce bright reflection at local area where the angles of incidence and reflection were the same only after chitosan treatment (Figure 2A, 2C and 2E). After washing, in sample 1 and 2 no photonic crystal can be detected on the fabric surface (Figure 1C, 2B and 2D). However, sample 3 that received a chitosan post-treatment showed a remarkable washing fastness maintaining a certain degree of iridescence (Figure 1D and 2F). Chitosan fills the spaces between the polymer spheres in the matrix stabilizing the photonic structure. Sizeable variations in lattice spacing will allow colour variations using more flexible non-close-packed photonic crystal arrays in chitosan hydrogels matrices. [2]

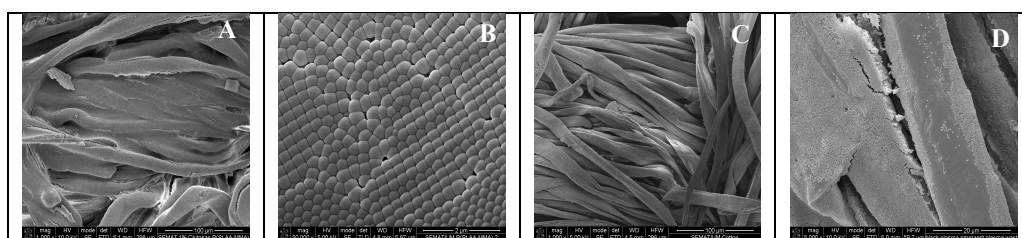


Figure 1. SEM images of samples before washing (A, B) and sample 1, 2 (C) and 3 (D) after washing.

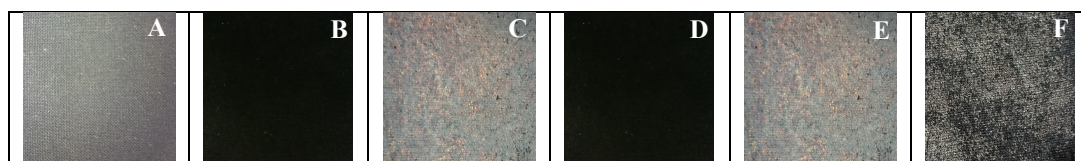


Figure 2. Optical images of samples 1 (A, B), 2 (C, D) and 3 (E, F) before and after washing.

Conclusion

We have demonstrated a practical and cheap method to create structural colour on textile fabrics using colloidal photonic crystals and chitosan multilayer structures. The control of relative reflectivity could provide in future a full optical palette of structural colours.

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