Photoswitchable silica nanoparticles for the production of light responsive smart textiles: from fabrication to coating technology

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Abstract

The design of high-performance multifunctional textiles has been one of the greatest challenges for Textile Industry, motivated by consumers and markets demand for fabrics with enhanced properties such as (super)hydrophobicity, antimicrobial and fire retardancy.[1] Photochromic textiles emerged as a new niche market for the production of smart clothing due to their switchable sensing properties and protection against the harmful effects of UV radiation; furthermore, they confer fancy color effects to fashion and interior design decoration.[2–4] Organic (or inorganic) photochromic dyes are potential scaffolds to produce smart textiles due to their switchable color generation/disappearance in response to solar light. Concerning organic photo-active species, the most commonly reported are spiro-based compounds – spiropyrans, spirooxazines and naphthopyrans – because of their excellent photoswitching capability and fatigue resistance.[5,6] However, the incorporation of photochromic dyes onto textiles has not been translated into significant commercial success, mainly assigned to technical limitations (dye degradation with high temperatures and low dye uptake) and to their lower performance upon immobilization.[2–4,7,8] Nevertheless, the immobilization of photochromic dyes onto inorganic matrices constitutes a promising route for the design of photochromic textiles with efficient color switching, high comfort and dye stability.[4] Moreover, SNPs have been successfully applied to textiles to provide novel functionalities, while preserving the pristine textile properties (appearance, touch and washing fastness).[2,9] Although silica embedded with photochromic dyes has been used to produce functional hard surfaces (e.g. glass and plastic films), its use in textiles has been less explored.[4] To the best of our knowledge, no work concerning the textiles functionalization with photochromic silica particles with nano dimensions (<100 nm) has been published.

The purpose of this work was the fabrication of a novel generation of light responsive textiles with enhanced photochromic properties. To achieve that goal, naphthopyrans were firstly incorporated onto SNPs (~15 nm particle size) and then the resulting photochromic nanomaterials were incorporated onto cotton fabrics by advanced screen-printing processes. All nanomaterials were characterized in terms of morphology, structure and chemical composition by transmission electron microscopy with energy-dispersive X-ray spectroscopy (TEM-EDS), elemental analysis (EA), thermogravimetric analysis (TG), Fourier transform infrared spectroscopy (FTIR) and solid-state ^{29}Si and ^{13}C nuclear magnetic resonance (NMR). The characterization techniques confirmed the successful immobilization of the photo-active naphthopyran molecules onto the SNPs surface and the preservation of their structure. The photochromic properties in the solid-state were evaluated by UV-Vis spectroscopy and colorimetry before and after UV exposure (λ = 365 nm). All hybrid nanomaterials revealed excellent photo-switching behavior, showing fast coloration/decoloration kinetics (coloring in 1 min and bleaching in less than 2 min), good optical density (ΔOD ~ 1) and good color difference values (ΔE ~ 55); moreover, they presented promising resistance to photodegradation upon prolonged exposure to UV light (1 h). In the case of the functional textiles, FTIR-ATR and TG analyses proved the incorporation of the hybrid nanomaterials on the screen-printed textiles. Additionally, the resulting functional fabrics showed notable photochromic behavior (**Figure 1**), with a fast color change upon UV/visible light irradiation (within seconds) and good reversibility (a few minutes) for more than 12 UV/Dark cycles without loss of their photochromic performance; furthermore, the textiles showed high resistance to photodegradation upon prolonged exposure to UV light (1 h).

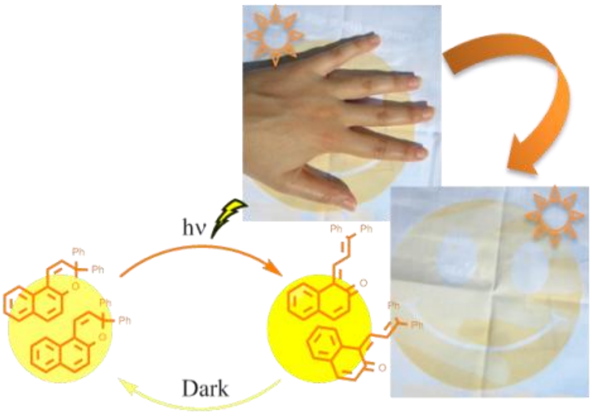

Figure 1. Schematic representation and photographs of photochromic textiles prepared by screen-printing using SNPs functionalized with organic compounds.

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References

[1] S.L.P. Tang, G.K. Stylios, Int J Cloth Sci Tech. **18** (2006) 108–128..
[2] T. Lin, X. Wang, Int J Nanotechnol. **6** (2009) 579–598.
[3] M. Aldib, R.M. Christie, Color Technol. **129** (2013) 131–143.
[4] T. Cheng, T. Lin, R. Brady, X. Wang, Fiber Polym. **9** (2008) 301–306.
[5] R. Pardo, M. Zayat, D. Levy, Chem Soc Rev. **40** (2011) 672−687.
[6] R. Klajn, Chem. Soc. Rev. **43** (2014) 148–84.
[7] N. Malic, J. a. Campbell, A.S. Ali, C.L. Francis, R. a. Evans, J Polym Sci Pol Chem. **49** (2011) 476–486.
[8] A.F. Little, R.M. Christie, Color Technol. **127** (2011) 275–281.
[9] T. Cheng, T. Lin, R. Brady, X. Wang, Fiber Polym. **9** (2008) 521–526.