Fluorescent Microspheres as Tags for Anti-Counterfeiting of Textiles

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ABSTRACT

We demonstrate the use of non-toxic, fluorescent microspheres for creation of a new class of anti-counterfeiting systems for textiles. Cotton fabric was immersed into solutions with different concentration of polystyrene microspheres. We achieved successful attachment of these particles after soaking for one hour. Stability of the particles on the fabrics was tested using pure water and water with addition of detergent. Results demonstrate that particles attach firmly to the surface. We demonstrate the ability to create different patterns of fluorescent signals from the microspheres, thus making it impossible to reproduce.

Keywords: Anti-counterfeiting, fluorescent microparticles, fabrics, security

1 INTRODUCTION

Recent reports clarify the significant market of products stolen by counterfeit goods:

- "The World Customs Organization reports that counterfeit goods account for nearly 10% of worldwide trade, an estimated $500 billion annually." [1]
- "By 2015, International Chamber of Commerce expects the value of counterfeit goods globally to exceed $1.7 trillion. That is over 2% of the world's total current economic output." [2]

One of the largest counterfeit targets is the textiles market, including clothing, furniture and soft goods; clothing manufacturers alone lose $12 billion in annual revenue due to counterfeiting. [1] However, current anti-counterfeiting systems lack the desired characteristics of lack of reproducibility, easy integration of their devices into valid products, and simple reading and assessment. New approaches to anti-counterfeiting are needed.

Criteria that must be met for a robust anti-counterfeiting system for soft goods include:

- Security tag must be hard to reproduce
- Security tag must be harmless
- Security tag must have robust adherence to the soft goods
- Detection of the security tag must be easy

One novel approach toward creating a new class of anti-counterfeiting systems is to leverage the capabilities of advanced materials and newly available mobile readers. [3]

We demonstrate a simple approach for creation of a new class of anti-counterfeiting systems for textiles using fluorescent particles. Our method allows creation of different patterns of fluorescent signals for different samples, thus making it impossible to reproduce.

2 MATERIALS AND METHODS

2.1 Chemicals and materials

Yellow-green fluorescent aminated polystyrene (PS) microspheres were purchased from MagSphere Inc. (Pasadena, CA). Average particle diameter was 10.3±0.5 μm. Pure white cotton fabric (100%) was purchased from Jo-Ann fabrics and crafts store (Christiansburg, VA). Ultra Tide regular powder detergent was used for stability studies.

2.2 Attachment of microspheres to fabrics

Aqueous solutions of PS microspheres with different loading of microspheres were prepared. Fabrics pieces of ~1x1 cm were immersed into the microsphere solutions for different periods of time (1, 3 and 24 h). Samples were then removed from solution and dried in air overnight.

2.3. Stability tests

Samples with attached microspheres were tested for stability under different conditions. First, we immersed fabrics/microsphere samples into pure water for 24 h. Second, samples were immersed in water with addition of detergent (0.01 g of detergent in 20 mL of water) for 24 h. Samples were dried in air overnight before characterization.

2.4 Characterization

The fluorescence of embedded microspheres as a function of concentration was characterized using a Leica Microsystems DMI6000B inverted microscope equipped with Leica EL6000 external light source for fluorescence excitation. A TxR (Texas Red) filter cube was used for detecting emission of the PS microspheres.

3 RESULTS AND DISCUSSION

Figure 1 shows the optical microscope images under fluorescence and in bright field mode of pure cotton fabric. The fabric strings and woven pattern can be easily seen on the images. There is no indication of any species that fluoresce on the pure cotton.

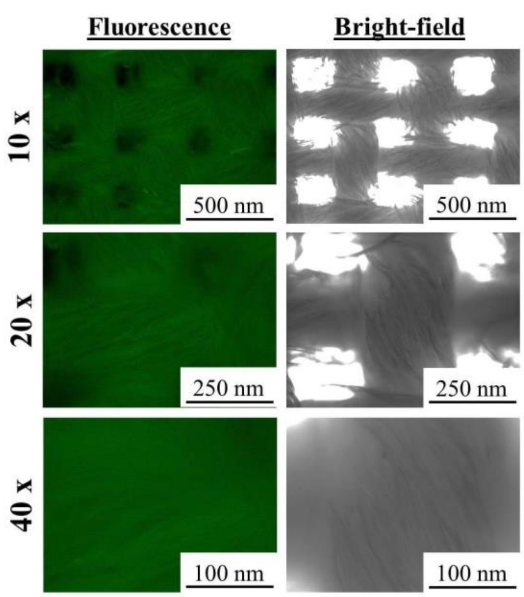

Figure 1 Microscope images in fluorescent and bright field modes of pure cotton fabric at different magnifications, as indicated

We then soaked the fabric in aqueous solutions of PS microspheres. We tested the following concentrations of microspheres: 0.005, 0.05, and 0.5 weight %. Soaking time was varied from 1 hour to 24 hours. We expected to achieve microspheres attachment to the fabrics through electrostatic interaction between hydroxyl groups of the cellulose in cotton and amine groups of the PS microspheres. Figure 2 shows the fluorescent microscope images of samples with attached microspheres. Bright green dots on the images are PS microspheres, darker green lines represent the cotton threads, and black areas are empty spaces between threads. It is evident that with increase of concentration the amount of attached particles increases. Samples immersed into 0.005 wt. % solution did not exhibit heavy attachment of particles. Only few PS microspheres were found on these samples for all times tested. Samples treated with 0.05 wt. % PS microspheres solution displayed higher attachment of particles to the surface (number of particles per image 5 – 15, for different areas of samples and exposure times (10 x magnification)). Amount of attached particles increased significantly with increasing the concentration to 0.5 wt. % (20 – 50 particles per image taken at 10 *x* magnification). Figure 3 shows the images of the same spot of the fabric taken at different magnifications. It is clear that by varying magnification we can change the appearance of the fluorescent map of the same sample. At magnification of 10 x we selected two high intensity signals from microspheres (red circles); we also chose two nearby signals with relatively milder intensity (blue circles). Increasing magnification to 20 *x* provided a view on the particles in red circles, particles in blue circles could still be observed. Increasing magnification to 40 *x* provided a better view on the particles in red circles while particle sin blue circles disappeared from the view. Therefore, we were able to observe different patterns of fluorescent signals from particles by simply varying the magnification. Thus, this method can provide the basis for creating security patterns/maps.

We then tested the strength of attachment of PS particles to the cotton under different conditions. We tested the cotton/PS samples in pure water and in water with addition of detergent. Each sample was immersed in solution for 24 h before imaging. Figure 4 shows the fabrics soaked in 0.5 wt. % aqueous solution of PS microspheres for 1 hour before and after application of external washing agents. Note that number of fluorescent particles on the cotton surface is much higher than previously observed (compare with Figure 2). Hence, we demonstrate random and non-reproducible nature of the patterns of embedded

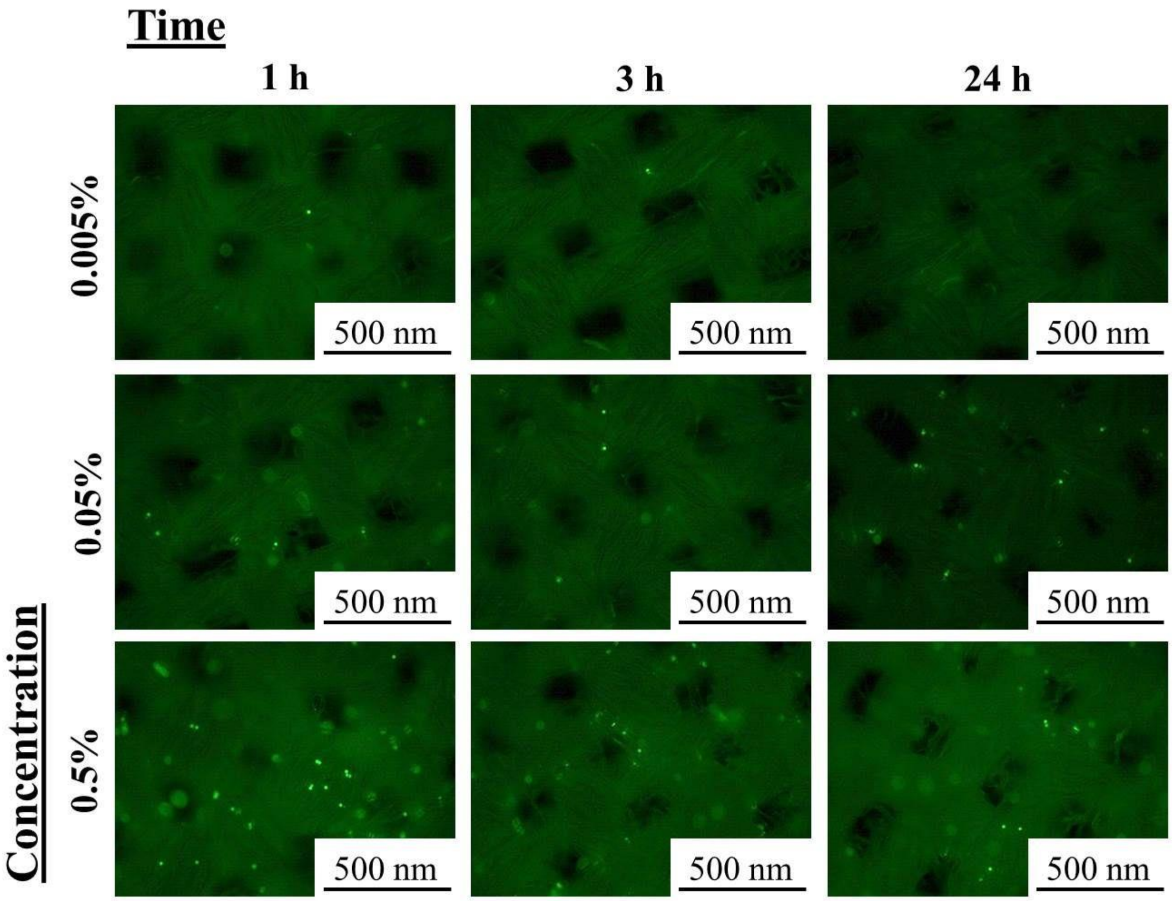

Figure 2 Fluorescence microscope images of cotton fabric soaked in aqueous solutions of Polystyrene microspheres. Concentrations of microspheres were 0.005, 0.055, and 0.5 weight %. Soaking time varied from 1 to 24 hours, as indicated.

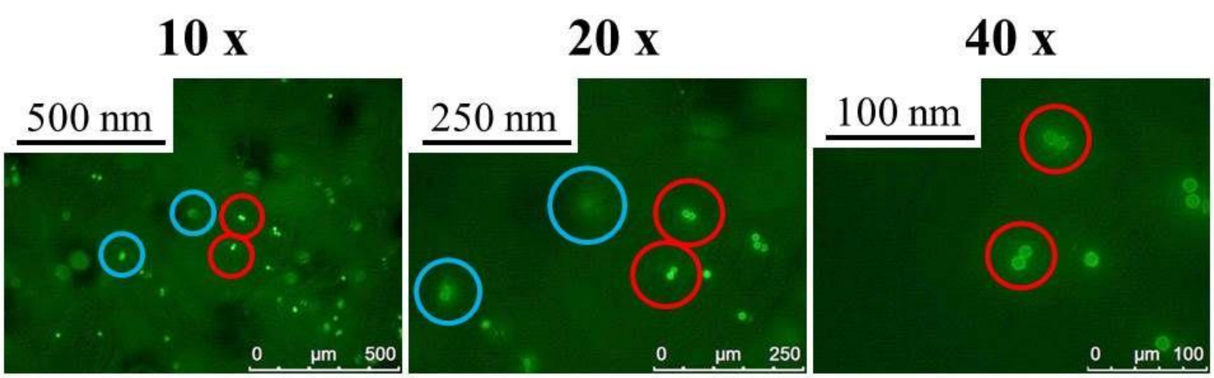

Figure 3 Fluorescence microscope images of cotton fabric soaked for 1 hour in 0.5 weight % aqueous solutions of Polystyrene microspheres. Images were taken at different magnifications, as indicated.

tags. After 24 hours in pure water the number of attached particles is still significant. However, after 24 h in water and detergent mixture the quantity of fluorescent microspheres attached to the fabric visibly decreased. Such reduction of fluorescence signal strength must be considered when designing a robust anti-counterfeiting system.

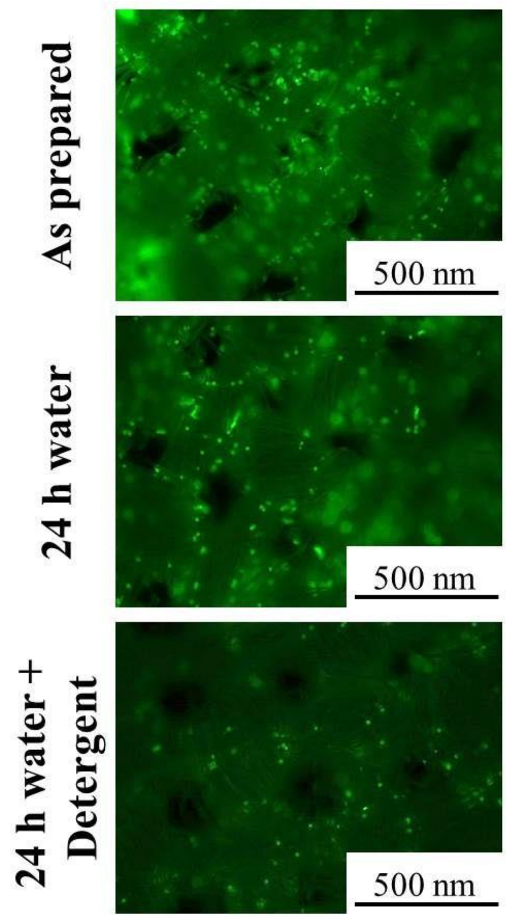

Figure 4 Fluorescence microscope images of cotton fabric soaked for 1 hour in 0.5 weight % aqueous solutions of Polystyrene microspheres before and after exposure to pure water and water with detergent.

4 CONCLUSIONS

We describe the method to create security patterns on fabrics using fluorescent microparticles. Specifically, fabric was introduced to aqueous solutions with different loadings of PS fluorescent microspheres. It was shown that with increase of concentration and soaking time the amount of particles attached to the surface increases. Variation in magnification provides the basis for creating security patterns. This approach has the following advantages:

- Random attachment of particles to the fabric that cannot be reproduced even by the manufacturer
- Unrestricted variation of particles that can be used as tags (different size, color, shape)
- Easy and fast detection of the particles

Future experiment will include more detailed stability of the particles towards washing agents and conditions. In addition, samples will be imaged at the same spot before and after exposure to various conditions to provide statistical analysis on amount of particles attached or lost during the experiments.

5 ACKNOWLEDGEMENTS

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REFERENCES

[1] "The Most Counterfeited Products," BusinessWeek, October 2008; accessed March, 2013 http://images.businessweek.com/ss/08/10/1002_counterfeit/1.htm

[2] 1 "Counterfeit goods become more dangerous," September 27, 2012; accessed March, 2013 http://money.cnn.com/2012/09/27/news/economy/counterfeit-goods/index.html

[3] Z. Smith, K. Chu, A.R. Espenson, M. Rahimzadeh, A. Gryshuk, M. Molinaro, D.M. Dwyre, S. Lane, D. Matthews, S. Wachsmann-Hogiu, "Cell-phone-based platform for biomedical device development and education applications," March 2011, PloS One, Volume 6, Issue 3, 1-11.