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Polysiloxane features on different nanostructure geometries; nano-wires and nano-ribbons

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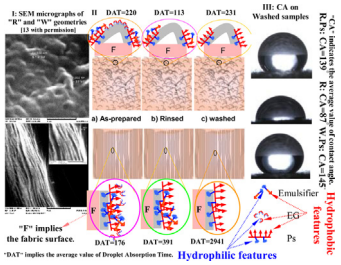
HIGHLIGHTS

- Disclosing the key role of nano-structure geometries on the after-treatment efficiency.
- Producing multifunctional textiles covered by polysiloxane shield nano-wires and nano-ribbons.
- Producing hydrophobic cotton fabrics, satisfying the complete stain repellency.
- Modeling polysiloxane features on different nanostructure geometries well interpreting all results.
- Boosting softness, wrinkle resistance, air permeability and washing fastness of the fabrics.

GRAPHICAL ABSTRACT



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ABSTRACT

In our previous study, nanostructures of silver with two anisotropic geometries of nano-wires and nano-ribbons were synthesized on the fabric surfaces via an in-situ process. In this research, the effect of cross-linkable polysiloxane (termed XPs) coating on the various properties of fabrics with these two geometries, prepared by the previous technique, has been investigated. The effects of this treatment on different properties of treated fabrics including washing durability, water repellency (contact angle and droplet absorption time), stain repellency, handle (bending length), wrinkle resistance, air permeability, UV protection properties and antibacterial efficiency have been evaluated. A hydrophobic feature has appeared on the surfaces by using the treatment, increasing droplet contact angle as well as droplet absorption time, and satisfying the complete stain repellency. The treatment also improved air permeability, softness, wrinkle resistance and especially washing fastness of the fabric samples. The most important finding revealed that the geometry of nanostructures mainly determined the efficiency of XPs treatment. In fact, the XPs treatment can provide a complete coverage on the nano-wires lying on the fabric surfaces, while the resin cannot completely cover the nano-ribbons due to their particular geometry. Then, water repellency in the case of XPs treated nano-wires was more than that of XPs treated nano-ribbons. This has also been proven by the evidence on the washing durability of these two treated geometries.

1. Introduction

Numerous methods to synthesize silver nanoparticles, including chemical reduction of the silver ions in aqueous solutions or non-aqueous solutions, ultrasound-assisted reduction, irradiation

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reduction, microemulsion method, biochemical reduction and so on have been reported [1–11].

Recently, nanoparticles production by a size-controlled or shape-controlled procedure has become an interesting research focus to optimize the physical and chemical properties [2,4,5,12]. In our previous research [13], a novel in-situ shape-controlled synthesis of nanostructures on fabric surfaces instead of the conventional two-step approach has been reported [13]. Nano-wires and nano-ribbons were synthesized by this technique using poly(vinyl pyrrolidone (PVP), ethylene-glycol (EG) and $AgNO_3$ under different conditions. In this method, cotton fibers were used as a template to control the growth of nanostructures. In fact, by gradual evaporation of solvent as well as developing reaction, Ag ion concentration increases to the saturation point and thus the nucleation occurs. Then, the controlled crystal growth can be pursued into porosity of the fibers as the perfect nano-reactors [13]. Although this provides an in-situ morphology-controlled synthesis of nanostructures, another challenge is the fastness of the synthesized nanostructures on the textile surfaces [14]. Our previous paper presented a major guideline for the design of a novel technique with outstanding advantages to stabilize different nanostructure materials on the textile surfaces providing a practical, fast and, affordable technique applicable to all textiles and all nanostructure types [15]. Our subsequent research endeavors [16–18] disclosed that the effect of this technique on the practical features of treated surfaces can be interestingly engineered by the orientation of nanostructures, the surface topology and roughness. Given the above, we assumed that its effect on end-use properties of treated surfaces can also be affected by the nanostructure geometries. Therefore, this paper conducts an investigation to address this question via using this treatment on nano-wires as well as nano-ribbons as the two main nanostructured-geometries synthesized on the cotton surfaces in our previous research [13].

2. Experimental

2.1. Materials

Poly(vinyl pyrrolidone) (PVP, M_w10,000) was purchased from Aldrich Chemical Company. Silver nitrate ($AgNO_3$) with 99% purity and ethylene-glycol were purchased from Merck Chemical Company. Polysiloxane CT 208 E emulsion, was kindly supplied by Wacker Finish.

2.2. Methods

Among the samples, prepared in our previous study [13], two samples by two main different morphologies of in-situ synthesized nanostructures; including nano-ribbon (termed as R in this paper) and nano-wire (termed as W) were selected and XPs was coated on them. Briefly, nano-wire geometry was fabricated on mercerized cotton fabrics treated with a solution containing PVP, $AgNO_3$ and EG dried at 30 °C while nano-ribbon geometry appeared on unmercerized cotton fabrics treated with a solution containing PVP, $AgNO_3$ and EG dried at 160 °C, as previously reported in detail [13]. Producing nanostructures has been approved in previous research by using various analytical devices [13]. The after-treatment by XPs was performed as follows. Each sample was immersed in 1 wt% polysiloxane solution for 1 min and squeezed by pad to 100% wet pick-up. Then, the padded samples were put in oven at 100 °C to be completely dried. The polysiloxane treated samples were marked by adding Ps at the end of their code (W.Ps and R.Ps) and were compared to samples without the polysiloxane coating.

2.3. Characterization

2.3.1. Water droplet absorption time

The hydrophilicity of samples was studied by measuring the time required for water droplet to be completely spread on the fabric surfaces. To this end, water was dropped from 1 cm on the fabric surface by a small syringe [16]. The time of the complete absorption of 10 μl water droplets on the fabric surfaces was measured for 10 replicates and the average value was reported. Water droplet absorption times were evaluated before and after rinsing with distilled water. For rinsing, samples were immersed in distilled water at 40 °C for 10 min and this was followed at a subsequent distilled water bath for 5 min.

2.3.2. Air permeability

Air permeability in different pressures 5, 10, 15 and 20 mm H_2O was measured in three replicates of different points of each sample according to ISO 9237, 1995, employing a Shirley Air Permeability Tester.

2.3.3. Stiffness

The Shirley stiffness test was used as a criterion for stiffness and the bending length was reported for test specimens cut in 25 mm width and 200 mm length parallel to the warp. This experiment was performed for all samples with 6 replicates.

2.3.4. Crease recovery angle

The wrinkle recovery angle in the warp and filling fabric directions was measured according to the standard Shirley, tester with 4 replicates. Crease recovery angle of warp plus filling (W + F)° of the fabrics were reported.

2.3.5. UV protection properties

Evaluating the color changes of wool fabrics dyed by a highly UV sensitive dye (0.5 wt% Methylene Blue) which were covered by different modified and unmodified samples under UV irradiation was considered as a criterion for the comparison of the UV protection properties of samples [16,17]. UV irradiations were provided by a philips Cleo UV lamp HPA 400S located 25 cm above the covered samples for 18 h. After UV irradiation, the color changes were studied based on reflectance data using an X-rite Spectrophotometer according to the formula reported in reference 16.

2.3.6. Washing durability

First, all samples were washed for 20 min at 40 °C with 1 g/l standard soap solution and then rinsed. The washing process was replicated for five cycles. The silver remaining on the washed samples was extracted in the 6 M nitric acid solution [19], and the silver concentration remaining on each sample was determined by inductively coupled plasma spectrometry test (ICPs Perkin Elmer Plasma 400), and was compared with each other. Water droplet absorption time was also evaluated after 5 cycles of washing.

Washing standard test according to AATC 61 (2A)-1996 was modeled and were repeated to provide 20 times laundering washing conditions. Each cycle of laundering was performed for 40 min at 40 °C with shaking 5 g/l standard soap, equaled to five launderings washing at 38 °C. The effluent of each washing cycle was collected for later analysis. The silver remaining on the samples extracted and the silver concentration in each sample were determined by inductively coupled plasma spectrometry test (ICPs Perkin Elmer Plasma 400) and were compared with each other. The silver concentration in each collected effluent was also evaluated by means of ICPs.