

# Dendrimer Finishing Influence on CO/PES Blended Fabrics Color Assessment

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**ABSTRACT:** Textile finishing includes all processes that help to maintain the value or increase the value of the textile material. It encompasses dyeing, printing, and all the finishing treatments to realize durable press, soil release, flame retardant, antistatic, antimicrobial, or water/oil repellency properties. When these properties are realized on dyed textile fabric, one effect could be ascribed to the color change induced by finishing operations. This research focuses on the assessment of color alterations occurring on the dyed cotton/polyester blended fabrics due to the nanoparticle-sized dendrimer (DWR), dendrimer-fluorocarbon (DWOR), and fluorocarbon (FWOR) finishing onto their surfaces. The dependence of color on the surface state of treated textiles is calculated in the context of spectrophotometric measurements. Modification of the surface roughness by reflectance spectrum and the absorbance of finishes in visible range were investigated to

determine color changes between the original (control fabric, dyed but not treated) and treated fabrics. As a result of color matching calculated by CIE-Lab values, color change is related to the surface roughness associated with absorbance values of applied finishes. In addition, fabrics mechanical properties were evaluated to estimate if finishing agents application gives rise to other changes, besides color alterations. The fabrics mechanical properties have been found not significantly altered by the aforementioned finishing treatments. These results could be applied for industrial needs (quality control), or in the artistic field of conservation, or restoration (to follow the color of paintings). © 2010 Wiley Periodicals, Inc. *J Appl Polym Sci* 120: 2122–2129, 2011

**Key words:** nanoparticle; dendrimers; fluoropolymer; dyes/pigments; surface modification

## INTRODUCTION

Chemical finishing procedures are widely used to improve some properties of natural and synthetic fibers and fabrics. For this purpose, textile materials are treated with different functional finishes, such as repellent, durable press, soil release, flame retardant, antistatic, and antimicrobial.<sup>1</sup> Among the various chemical finishing treatments, dendrimers are the most effective treating agents for water-repellent and oil-repellent finishes, because they do not impair a textile's permeability to air, vapor, and oily substances. Dendrimeric chemistry was developed as a branch of the conventional polymer chemistry and dendrimers are gaining importance due to their versatility. In contrast to linear polymers, dendrimers are highly branched, fractal-like macromolecules of well-defined, three-dimensional structure, shape, and topology, and their effect mechanism on repellency depends on being in a position to build-up

crystal structures in nanorange, which produces the aforementioned technological effects.<sup>2</sup> Along with novel dendrimer structures, therefore, came novel physical, chiral, electrochemical, optical, photophysical/photochemical, biological, and catalytic properties and thus new applications in many fields, as in the textile one. When combined with fluoro polymers, in particular, dendrimers force them to cocrystallize leading to a self-organization of the whole system and an enrichment of the fluoro polymers on the most outer layer of the textile.<sup>3</sup> Functionality and properties of dendrimers can be changed by filling their cavities or modifying the core and chain ends.<sup>4</sup> For dendrimer effect on interfacial properties phase isotherms, their conformational states, significance of small, mobile dendrons for stable and ordered films should also be taken into consideration.<sup>5</sup> It is essential to study both the long-term effects and the possible side effects of the treatments, when a textile fabric is subjected to a process for required finishing effects by specific chemicals; in particular, the tendency for changes in the color due to the influence of the nanoparticle finishing onto the textile surfaces is a very important parameter to be investigated. It is well known that when the surface of a colored object

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moves away from a perfect plane and becomes rough, the apparent color of the object changes. Indeed, color changes can be attributed to the structures of the agents along with the deposition process around the fibers. Finishing agents mostly form surface layers on the top of fabrics, and the particle size should designate the distribution and orientation of that film layer and linkage to the fiber. The purpose of the present work was to study the effect of particle sizes of different kind of oil–water repellency agents on surface roughness and on color assessment after treatment of cotton/polyester (CO/PES) fabrics. Particle size of repellent finishes plays in fact a vital role because, when the inorganic particle size is reduced, the surface area is increased; this leads to good interaction with the matrix polymer, and a higher performance is achieved.<sup>6</sup> When the particles size is reduced to a nanometer range, the finishes can substantially alter surface properties in some typical textile finishing applications and show the lower effect on the color change, which can be explained by a smoother reflecting surface.<sup>7</sup> For this investigation, three types of commercially available water repellent and water–oil repellent reagents were impregnated to dyed CO/PES blended fabrics and polymerized under optimum conditions. The dyeing of the fabric samples was carried out by commercial dyes. Since treated sample is a CO/PES fabric, dyeing was realized in two steps: in the first one, the PES component was dyed with disperse dye, then, in the second step, the CO component was dyed with reactive dyes. The color differences were calculated by CIE-Lab, a CIE defined color space that supports the accepted theory of color perception based on three separate color receptors in the eye (red, green, and blue) and is currently one of the most popular color spaces.<sup>8</sup> In the present article, surface reflectance, absorbance of finishes, and color coordinates of treated and untreated samples were measured to investigate the color modifications due to the different finishes. Finally, fabrics mechanical properties were evaluated to estimate if finishing agents application gives rise to other changes, besides color alterations.

## EXPERIMENTAL

### Materials

Scoured and bleached woven CO/PES blended fabrics (95 g/m<sup>2</sup>) used in this study was initially treated in an aqueous solution with a liquor ratio 50 : 1 containing 0.5 g/L of sodium carbonate and 2 g/L of nonionic detergent (Hostapal CV, Clariant, Italy) at 60°C for 30 min, after which time it was thoroughly rinsed and dried at room temperature. The samples were then stored at laboratory conditions (20°C ±

**TABLE I**  
Dendrimer and Fluorocarbon Application Conditions

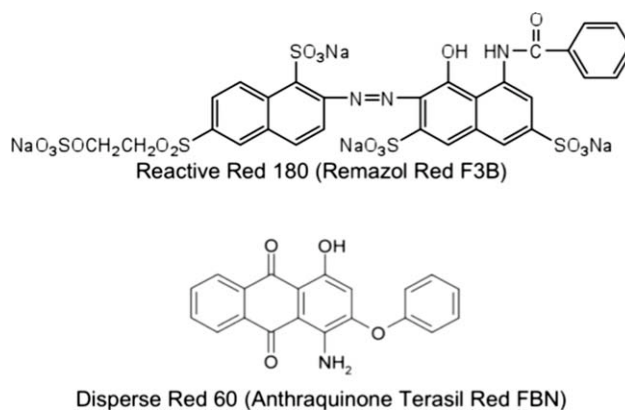
| Conditions           | DWR | DWOR | FWOR |
|----------------------|-----|------|------|
| Concentrations (g/L) | 130 | 50   | 50   |
| Pick up (%)          | 80  | 80   | 80   |
| pH                   | 5.5 | 5.5  | 5.5  |
| Fixation temp. (°C)  | 150 | 150  | 150  |
| Fixation time (min)  | 2   | 2    | 2    |

2°C and 65% ± 2% relative humidity) and used for dyeing and finishing throughout the study. Commercial Remazol (Dystar) reactive dyes with vinylsulphone groups (C.I. Reactive Red 180) were used for dyeing CO component; Terasil (Ciba) disperse dyes with anthraquinone (C.I. Disperse Red 60) groups were used for dyeing PES fiber components (Table I). All commercial dyes used for dyeing were used as received. The molecular structures are reported in Figure 1.

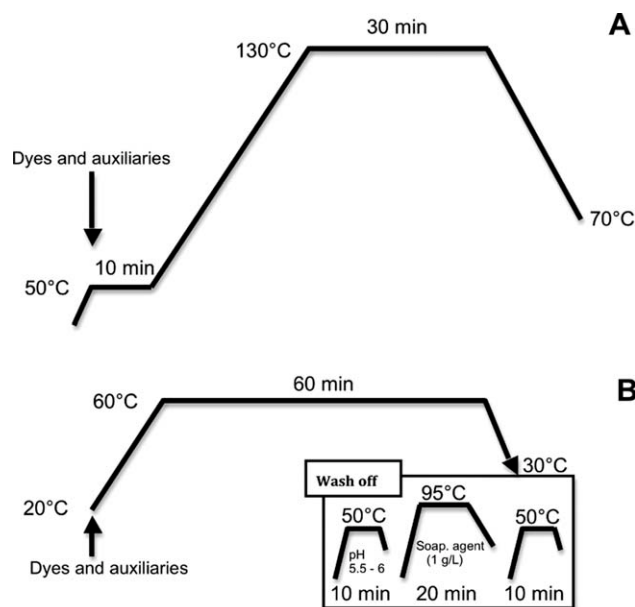
For level and consistent dyeing of CO/PES fabrics Bersol CM (1 g/L), Berdet WF (1 g/L), Super NSI Depsolube ACA (1 g/L) (sequestering, wetting, dispersator, and antcreasing agents, respectively, all kindly supplied by Europizzi, Urganio, Italy). All the other chemicals supplied from Sigma–Aldrich (Germany) were of analytical reagent grade.

### Dyeing procedures

The dyeing of untreated CO/PES blend fabric under exhaust dyeing conditions was carried out in a laboratory dyeing machine, using conventional two-bath dyeing method as depicted in Figure 2. The alkaline dyeing of PES component [Fig. 2(A)] was dyed in the first bath with a liquor ratio 30 : 1 in distilled water using 1% of Terasil disperse dye concentration in the presence of 2 g/L Super NSI, 1 g/L Depsolube ACA while adjusting the pH of the dyebath at 4.5–5 using aqueous acetic acid solution. The PES fabric was introduced into the dyebath at 50°C and



**Figure 1** Structures of Reactive Red 180 ( $\lambda_{\max}$  = 541 nm) and Disperse Red 60 ( $\lambda_{\max}$  = 589 nm) dyes.



**Figure 2** Two-bath dyeing profile of polyester (A) and cotton (B) blend fabric.

the temperature was raised at a rate of 3°C/min to 90°C, then at a rate of 1°C/min to 130°C, and the dyeing continued for 30 min. After this time, the temperature of the dyebath was cooled down to 80°C. Then the sample was removed from the dye pots and neutralized with Na<sub>2</sub>CO<sub>3</sub> water solution (20 g/L). The blend samples were rinsed and then the CO component was dyed with reactive dye in a freshly prepared second dyebath at the typical dyeing procedure described in Figure 2(b). In a dyebath containing 1% of Reactive Red 180 dye, at a liquor ratio of 30 : 1, CO/PES samples of a predyed PES component was introduced at 20°C with 1 g/L Bersol CM, 50 g/L NaCl, 12 g/L Na<sub>2</sub>CO<sub>3</sub>, 1 g/L Berdet WF, and 1 g/L Depsoluble ACA while the temperature was raised to 60°C unless otherwise specified over 20 min. After which time the dyeing was continued at 60°C for a further 60 min, then after cooling, the dyed blended fabric sample was rinsed and neutralized with acetic acid solution (pH = 5.5–6), then washed with soaping agent water solution (1.0 g/L), and after with distilled water at appropriate temperature levels, to be finally left to dry under laboratory conditions.

### Fabric treatment

Under patent dendrimer water repellent (density = 1.1 g/cm<sup>3</sup>), fluorocarbon/dendrimer water–oil repellent (density = 1.03 g/cm<sup>3</sup>), and fluorocarbon water–oil repellent (density = 1.03 g/cm<sup>3</sup>) provided by Rudolf Chemie (Germany) were used as finishing agents and coded as DWR, DWOR, and FWOR, respectively. The predyed CO/PES blended fabric

was treated with finishing agents by laboratory pad-dry process. The samples, cut into strips of 200 × 300 mm<sup>2</sup>, were immersed in each solution and padded to get an uptake of 80%. The padding was carried out on horizontal pad equipment from Werner Mathis. The application conditions for the three tested finishes are reported in Table I: for all products concentration values recommended by supplier were investigated. The padded samples were dried at 85°C for 4 min and then cured in a laboratory oven (Werner Mathis) at 150°C for 120 s.

### Textile testing

The samples were conditioned at 20 ± 2°C and 65 ± 2% RH for 24 h before textile testing, according to standard ISO 139:2005. All measurements were repeated for the three equally treated samples and then averaged. The weight (the standard measurement of fabric weight per unit area), tensile strength (TS: the resistance of a material to rupture when subject to tension), and elongation at break (ELB: the increase in length when the last component of the specimen breaks) measured parameters considered in the present study are summarized in Table II.

The percentage change of fabric weight, measured by Mettler balance (± 10<sup>-4</sup> g), was calculated with eq. (1).

$$\text{Weight change(\%)} = \frac{W_1 - W_0}{W_0} \times 100 \quad (1)$$

where  $W_1$  is the weight of the substrate after treatment and  $W_0$  is the initial weight of the untreated substrate. TS and ELB were measured according to ISO 13934-1, using standard test methods on dynamometer Instron Tensile Tester model 4501 (CRE). Ten specimens were prepared for testing, five for warp direction, and five for weft direction. The standard deviations of all experimental results were lower than ±2.5%.

### Characterization

The finishes particle size measurements were performed with a Malvern Instruments Mastersizer 2000. Samples in water solution, at a temperature of 25°C, were irradiated with red light (HeNe laser, wavelength  $\lambda = 632.8$  nm) and the intensity fluctuations of the scattered light (detected at a backscattering angle of 173°) analyzed to obtain an autocorrelation function. The angular intensity of the scattered light was measured by a series of photosensitive detectors whose number and positioning have been optimized to achieve maximum resolution across a broad range of sizes, using the cumulants analysis (according to the international standard ISO 13320-1:1999) and a

TABLE II  
Fabric Testing Details

| Parameter symbol | Description          | Instrument             | Unit             |
|------------------|----------------------|------------------------|------------------|
| Weight           | Weight per unit area | Mettler Balance        | g/m <sup>2</sup> |
| Weight change    | Weight change        | Mettler Balance        | %                |
| TS               | Tensile strength     | Instrom Tensile Tester | N                |
| ELB              | Elongation at break  | Instrom Tensile Tester | %                |

size distribution using a regularization scheme by intensity, volume, and number. The map of scattering intensity versus angle was used to calculate the particle sizes. Data were acquired in automatic mode, ensuring enough photons were accumulated for the result to be statistically relevant. The reflectance difference between undyed (untreated and treated) samples was obtained by subtracting reflectance of the treated fabrics by that of the untreated. All reflectance values were measured with a Lambda 950 Perkin Elmer apparatus, equipped with an RSA-PE-150 Labsphere accessory. Each reflectance value  $R$  (%) was determined as the average of four measurements, with an experimental error of about 1–2%. For a randomly rough surface for which the distribution of surface heights is defined by a Gaussian probability distribution, reflectance of rough surface can be related by the following relation<sup>9</sup>:

$$R_r = R_s \exp \left[ - (4\pi\sigma \cos \theta / \lambda)^2 \right] \quad (2)$$

where  $R_s$  and  $R_r$  are specular reflectances of perfectly smooth and rough surfaces, respectively,  $\sigma$  is the surface roughness parameter defined as the standard deviation about the mean plane of the surface ( $\mu\text{m}$ ),  $\theta$  is the angle of incidence, and  $\lambda$  is the wavelength of the incident light ( $\mu\text{m}$ ): the equation is valid when  $\sigma < \lambda$ . Changes in surface roughness of treated fabrics were measured by atomic force microscope (Digital Instrument DI 5000 AFM) and expressed as differences in the root-mean-square of the vertical  $Z$  dimension values within the examined areas, which were calculated using the following equation:

$$\text{RMS}_{xy} = \sqrt{\sum_{x,y=1}^N \frac{(Z_{x,y} - Z_{\text{average}})^2}{N^2}} \quad (3)$$

The ultraviolet–visible (UV–vis) absorption spectra of finish water solutions were recorded on a Thermo Nicolet Evolution UV–vis 500 spectrophotometer and Vision 32 software, using a 1-cm path length cell. All the spectra were recorded at room temperature in the wavelength range from 350 to 750 nm at the rate of 300 nm/min. Finish/dye solutions were diluted (1 : 100 with water) to an absorbance of less than 1 and evaluated from the change of absorbance

at the  $\lambda_{\text{max}}$  of the dye in the UV–vis spectra of the sample solution. Color difference evaluation was based on the surface reflectance in the visible waveband: indeed, any effects that change the reflectance cause a color difference. The color coordinates of dyed CO/PES (untreated and treated) samples dye-stuffs selected for dyeing CO/PES fabrics were measured on a Thermo Evolution 500 UV–vis spectrophotometer equipped with an integrating sphere with a 10 mm opening, under a D65/10<sup>0</sup> illuminant according to ISO 105 J01. The spectrophotometer measurements were made using the  $L^*a^*b^*$  system. A white thermo electronic calibration plate was used. The evaluation of the overall color difference ( $\Delta E^*$ ), obtained before and after finishing, in the 3D color space is given by:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (4)$$

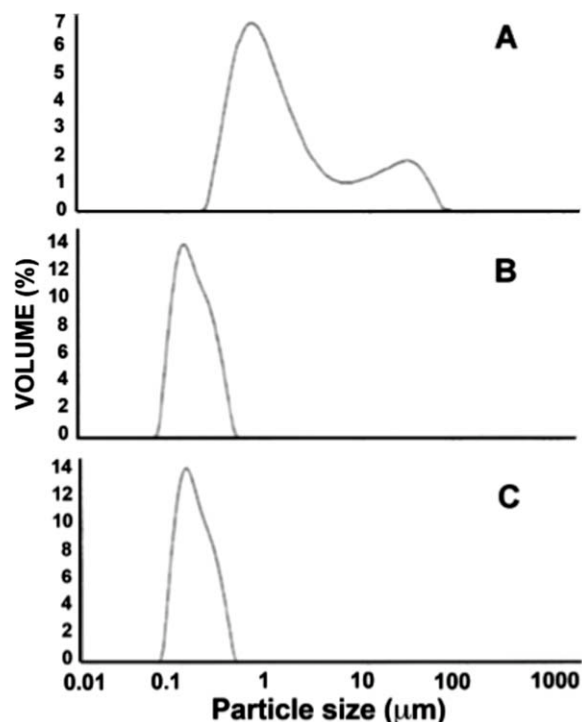
where  $\Delta L^*$  represents the lightness difference;  $\Delta a^*$  and  $\Delta b^*$ , the differences in  $a$  and  $b$  values, wherein  $a^*$  is a measure of redness/greenness and  $b^*$  is a measure of yellowness/blueness. The  $a^*$  and  $b^*$  coordinates approach to zero for neutral colors (white and gray) and increase in magnitude for more saturated or intense colors. The advantage of the CIE-Lab system is that color differences can be expressed in units that can be related to visual perception and clinical significance.<sup>10</sup> Four reflectance measurements were made on each sample; the samples were rotated 90° before each measurement, and the averages of the reflectance values (%) at wavelengths between 400 and 700 nm were recorded.

## RESULTS AND DISCUSSION

### Particle size and surface roughness

In Figure 3, the volume distribution produced by a typical algorithm is reported and the contributions in terms of % volume are shown as a function of particle diameter for DWR, DWOR, and FWOR finishing agents in water solution. For an ideal monodisperse sample, the peak in the intensity distribution is expected to be very close to the  $Z$ -average size from the cumulant fit.

While the volume distributions of DWOR and FWOR finishes versus particle diameter in micrometers

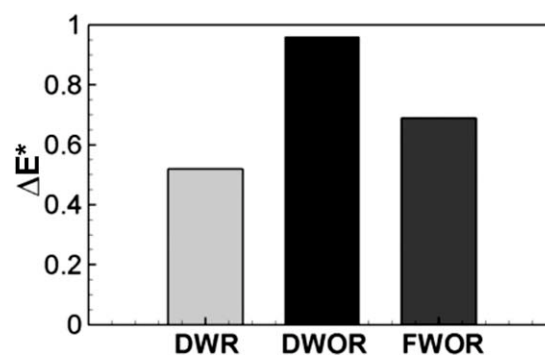


**Figure 3** Particle size distribution of DWR (A), DWOR (B), and FWOR (C) finishes in water.

are characterized by a single peak about 0.2  $\mu\text{m}$ , DWR shows a double peak distribution in the particle size range 10–100  $\mu\text{m}$ , probably due to a self-assembling of dendrimers.<sup>11</sup> Table III reports concentration and  $\text{RMS}_{xy}$  values for treated and untreated samples.  $\text{RMS}_{xy}$  values are computed using eq. (3). As expected, for the selected chemicals concentrations, the smaller the particle size, the smoother the polymer over the textile surface. Particle surface area, in fact, increases as the particle size decreases: the highest particle surface area is achieved when there is a high concentration of nanosized particles. This is probably the reason why a higher concentration of DWR is required to obtain the same repellency effects of DWOR and FWOR. Textile samples treated with small particle sized chemicals (DWOR and FWOR), having a higher surface area, give a more uniform dispersion, a smoother reflecting surface, and thus higher reflectance values (%).

**TABLE III**  
Root-Mean-Square (RMS) of  $z$  Values by AFM of Untreated and Treated Samples

| Samples   | Concentration (g/L) | RMS (nm) |
|-----------|---------------------|----------|
| Untreated | 0                   | 25.4     |
| DWR       | 130                 | 13.7     |
| DWOR      | 50                  | 6.9      |
| FWOR      | 50                  | 7.1      |



**Figure 4** Color differences between treated (with DWR, DWOR, and FWOR) and untreated dyed CO/PES fabric samples.

### Color difference measurements

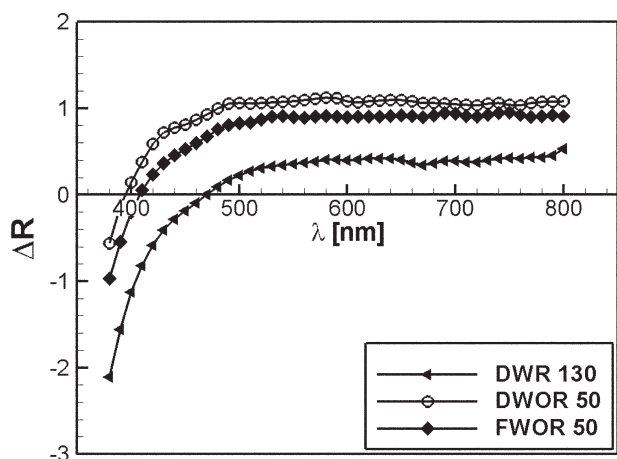
Color-difference evaluation in the visible waveband (400–700 nm) computed on the basis of eq. (4) is depicted in Figure 4 for the three tested finishes on the CO/PES fabric samples. The CIE-Lab system was chosen to record color differences because it is well suited for the determination of small color differences. It can be observed that the application of the three finishes has an effect on color change in any color, whether in hue, chroma, or lightness.<sup>12</sup>

The total color difference  $\Delta E^*$ , relative to the unfinished dyed sample (Fig. 6), increased from DWR to DWOR and showed an influence of finishing onto color assessment of treated textile fabric. In Table IV, it is also possible to notice how the three finishes applications have an effect on color change in all the components.

According to these results, DWOR finishing shows the highest  $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$  values. Both DWR and DWOR samples had positive  $\Delta L^*$  and  $\Delta a^*$  values, resulting in a lighter and redder hue compared with FWOR, while the negative  $\Delta b^*$  values for the three finishing indicate that the samples are more blue. The influence of finish onto color differences of textile could be due to a change in surface roughness, induced by the finishing application, to absorbance, caused by particles in the visible range, or to a finishing agents—dyestuff interaction: the influences of the aforementioned elements on color matching have been extensively studied to understand the most probable origin of the phenomena and are described in the following sections.

**TABLE IV**  
Color Differences ( $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$ ) on CO/PES Fabrics Between Untreated and Treated (DWR, DWOR, and FWOR Finishing) Dyed Samples

|      | $\Delta L^*$ | $\Delta a^*$ | $\Delta b^*$ |
|------|--------------|--------------|--------------|
| DWR  | 0.21         | 0.13         | -0.46        |
| DWOR | 0.58         | 0.38         | -0.66        |
| FWOR | -0.21        | -0.25        | -0.61        |



**Figure 5** Reflectance differences of DWR, DWOR, and FWOR at the best water and oil repellency performance concentration (DWR 130 g/L; DWOR 50 g/L; and FWOR 50 g/L).

#### Reflectance difference measurements and surface roughness

One of the major reasons for color modification after finishing can be related to a surface roughness change, as suggested above. Figure 5 reports the distribution of reflectance difference ( $\Delta R$ ) from 380 to 800 nm, obtained by subtracting reflectance of the treated fabrics by that of the untreated.<sup>13</sup> The curves are related to different finish products studied at the best water and oil repellency performance finish concentrations. The results show that the finishing treatment changes the reflectance values of the fabric, depending on the chemical type; samples treated with chemicals that are smaller in particle size generally give higher reflectance values than untreated samples, with the exception of the short wavelength of visible spectrum range.

DWR, DWOR, and FWOR finishes have similar reflectance curves. They stabilize after 500 nm around an almost constant level of about 0.4 for DWR, 0.9 for FWOR, and 1.1 for DWOR, showing that all the agents have a refractive index higher than the fabric itself. For  $\lambda > 500$  nm, the different  $\Delta R$  values can be explained by the difference in the measured particle size values: in fact, the tested DWR particle size is much higher than that of the other two finishes. Samples treated with fluoro polymer exhibit a stronger increase in the reflectance and positive values over most of the investigated wavelength domain. A smaller particle size, thus, allows the finishes to have a high surface area and to obtain a uniform dispersion in the fabric, giving a smoother reflecting surface. This behavior is even more pronounced when fluorocarbon is combined with dendrimers (DWOR) and can be related to a higher orientation of fluorocarbon chains achieved by dendrimers. For  $\lambda < 500$  nm,  $\Delta R$  values of all the finishes decrease

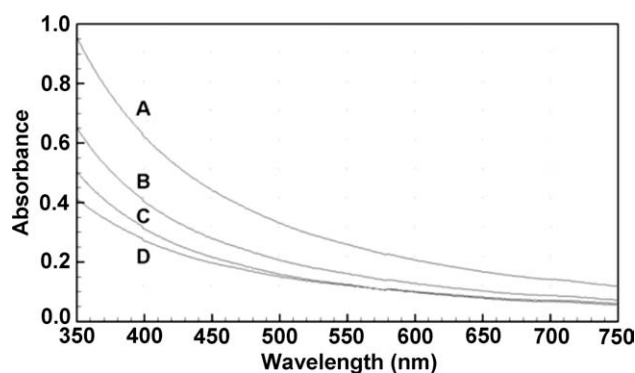
quickly, probably for the scattering of short wavelengths of the visible spectrum caused by surface roughness. The reflectance change of the treated fabric seems to be strongly related to the particle size and distribution of the chemical applied, even though several factors could also influence this difference, such as the incident angle of light, the non-planar surface of the sample, and the color coordinates of the fabric.

#### Absorbance measurements

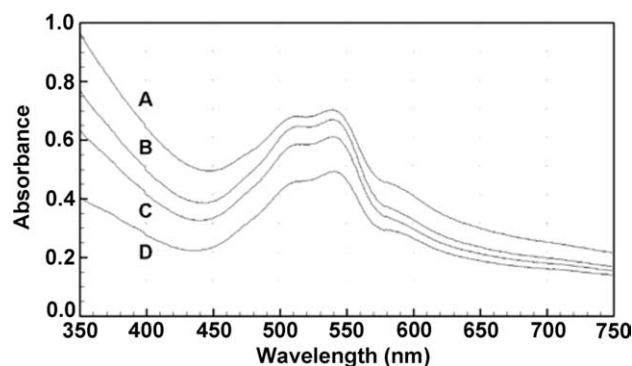
Figure 6 compares the absorbance curves measured over the 350–750 nm wavelength range of the three tested finish and gives new information about the effect of finishing agents on color differences. The finishing agents concentrations selected for the measurement are related with the application concentrations of the products over the textile surface. In particular, for DWR finishes, the 130 and 50 g/L concentrations have been both tested: the first are for comparison with the best water/oil repellency best performances, as experimentally determined in a previous research,<sup>9</sup> the second one for comparison with the other finishes concentrations.

There are two distinct zones in each absorbance curve for identical concentration samples (B, C, D; 0.50 g/L). The first one is approximately in the range of 350–500 nm wavelength, indicating a stronger absorption of products and higher differences between each other. For  $\lambda > 500$  nm, the rate of absorbance gradually reduces and the differences become smaller. DWR solutions show an enhancement in absorbance values with concentration rising. The absorbance curves for the three finishing products are reported in Figure 7 for the anthraquinone disperse dyestuff combined with VS reactive dye in equal portion. Equal ratios of the dyestuff combination and water/product solutions are also shown for comparison.

As seen in Figure 7, there is no change in the absorbance spectrum profile of dyestuff solution with finishing



**Figure 6** Absorbance spectrum of DWR (A: 1.3 g/L; D: 0.5 g/L), DWOR (B: 0.5 g/L), and FWOR (C: 0.5 g/L) solutions in the visible range.



**Figure 7** Absorbance spectrum of Remazol Red F3B and Anthraquinone Terasil Red FBN combination in water solution (D) and in solution with DWR (A: 1.3 g/L), DWOR (C: 0.5 g/L), and FWOR (B: 0.5 g/L) products in the visible range.

agents but an overlay of the absorbance values in the short wavelength. This means that the dyestuffs do not interact with finishing agents but only show a small variation of the  $\lambda_{\max}$ . Absorbance values at  $\lambda_{\max}$  of dyestuff with water and finish product solutions at the same liquor ratio (1 : 1) are reported in Table V.

### Color difference evaluation

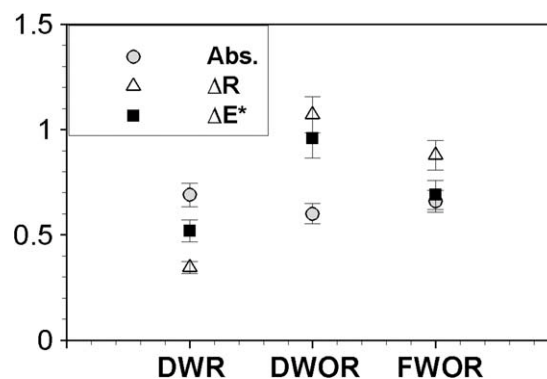
Absorbance values decrease from DWR to FWOR and to DWOR, in an opposite behavior in comparison with their  $\Delta R$  values. Surface reflectance difference ( $\Delta R$ ) and absorbance data have to be considered together to understand  $\Delta E^*$  modification. Because of the highest absorbance value and lowest  $\Delta R$  value characterizing DWR finish, the color difference  $\Delta E^*$  shown by DWR is always lower than other finishes. Vice versa, because of the lowest absorbance value and the highest  $\Delta R$  value characterizing DWOR finish, the color difference shown by DWOR is the highest of all the finishes. Figure 8 summarizes the above information about  $\Delta R$ ,  $\Delta E^*$ , and absorbance values related to color differences between treated and untreated dyed CO/PES fabric samples.

### Textile properties evaluation

When finishing products are applied, it is very interesting to have the possibility to estimate if, besides color alterations, also mechanical properties have changed. The various characteristics of the experimen-

**TABLE V**  
Absorbance Values of Dyestuff with Water/Product Solutions at  $\lambda_{\max}$

| Dyestuff           | $\lambda_{\max}$ (nm) | Absorbance |      |      |      |
|--------------------|-----------------------|------------|------|------|------|
|                    |                       | Water      | DWR  | DWOR | FWOR |
| Anthraquinone      | 589                   | 0.27       | 0.43 | 0.30 | 0.34 |
| Anthraquinone + VS | 541                   | 0.48       | 0.69 | 0.60 | 0.66 |



**Figure 8**  $\Delta R$ ,  $\Delta E^*$ , and absorbance values for the treated (with DWR, DWOR, and FWOR) dyed CO/PES fabric samples.

tal samples treated at optimized conditions of finishes along with control sample are given in Table VI. It was observed that in correspondence with a higher concentration of the finishes, a higher increase in weight on textile is obtained. In this way for treated textile fabrics with DWR, a weight gain of 6% was carried out. Otherwise for the samples treated with DWOR and FWOR, applied to the same concentration lower than DWR, an increase of 2.5% was measured. From the data, it followed that the elongation at maximum load as well as the tenacity at maximum load were essentially equal from a statistical point of view. Thus, all the finishing did not influence the mechanical properties of the textile fabric treated that are in the range intrinsic to the untreated sample.

After DWOR and FWOR treatments, only a low decrease in TS and elongation values were observed, 10% and 4% respectively, which may be related to the presence of fluoro polymers. In fact, after curing, heat treatment causes an orientation of the perfluoro chains to almost crystalline structure generally followed by compactness of textile molecular chains in the amorphous region, which increases the brittleness of the polymer backbone. As a result, polymer backbone with higher stiffness fails to withstand higher load and breaks easily at lower loads, resulting in a decrease in ELB and TS.

## CONCLUSIONS

So far, the use of dendrimers as textile dyeing auxiliaries is fairly unexplored and their application is

**TABLE VI**  
Textile Properties of Treated Fabrics (Average Values)

| CO/PES                           | Untreated    | DWR          | DWOR         | FWOR         |
|----------------------------------|--------------|--------------|--------------|--------------|
| Weight ( $\text{g}/\text{m}^2$ ) | 94.50        | 100.50       | 96.00        | 96.00        |
| Weight change (%)                | 0.0          | 6.0          | 2.5          | 2.5          |
| Tensile strength (N)             | $520 \pm 5$  | $520 \pm 5$  | $500 \pm 5$  | $500 \pm 5$  |
| Elongation at break (%)          | $40.0 \pm 3$ | $40.0 \pm 3$ | $35.5 \pm 3$ | $35.5 \pm 3$ |

still to be optimized; in this context, their influence on color assessment is worthy of investigation. This article has given interesting results associated with the evaluation of color assessment of dyed textile fabric due to nanoparticle sized finishing. Color matching of dyed samples before and after repellency treatments has shown an influence of finishing onto color difference due to a close relation between the surface roughness and the absorbance values of the finishes applied. From the presented results, the following conclusions can be drawn:

- The reflectance changes are related to the particle size distribution of the applied chemicals. DWOR finished samples, characterized by the lowest particle size and the lower surface roughness, as well as by a more regular distribution of the fluorocarbon chains in the fabrics outer layer surface, showed the highest  $\Delta E^*$ . On the contrary, because of the highest absorbance value, the highest particle size and the lowest  $\Delta R$  value, the color difference  $\Delta E^*$  shown by DWR is always lower than for the two other finishes.
- Absorbance and concentration data of finishes also play a role in determining the influence of chemicals on color change: DWR, in fact, whose

application was performed with the highest concentration, gave the highest absorbance values.

It has been showed that there is no change in the absorbance spectrum profile of dyestuff solution with finishing agents. This means that the dyestuffs do not interact with finishing products and complexation reactions or other kinds of interactions between them have to be excluded. Finally, mechanical characteristics of the fabric are not significantly altered by finishing treatments.

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