CONCEALMENT OF THE WARFIGHTER'S EQUIPMENT THROUGH ENHANCED POLYMER TECHNOLOGY

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ABSTRACT

One method to modify the Near Infrared (NIR) reflection signature of a base fabric is through the addition of nano and micro particle size additives to the polymer during fiber manufacturing. Different additives produce various effects in both the visual and near infrared spectrum. Work between INVISTA and the U.S. Army Natick Soldier Center has allowed for the development and commercialization of these fibers so that the warfighter's equipment can meet both the visual and near infrared requirements for enhanced concealment.

1. INTRODUCTION

The earth's earliest inhabitants used camouflage when hunting and hiding. It is well known that cave dwellers wore animal skins, antlers, feathers and vegetation to get close enough to kill their prey. The term camouflage itself comes from the French word *camoufler* meaning, "to disguise, concealment by means of disguise". Early camouflers were artists, theatrical make-up people or stage set designers. Camouflage conceals the warfighter from enemy's harm. For the military, camouflage has been important since the introduction of small-bore repeating rifles, machine guns, and rapid-fire artillery toward the end of the nineteenth century (Hartcup, 1980). The first *section de camouflage* in military history was established in 1915 by the French, under the command of an artist, and thereafter, comparable units were used by the British and Americans, and, to lesser extent, by the Germans, Italians, and Russians (R.R. Behrens, 2002).

Initially, it was suffice for camouflage to conceal the warfighter in the visual spectral region. However, as technology improved, the warfighter has been able to see in the night using image intensifier devices also known as night vision goggles. Image intensifier devices work by amplifying existing light in the near infrared region. Today, very little light at all is needed to effectively see in the night. Developed during WWII, one of the first night vision devices used by the military was the sniper scope (Generation 1) which sent out an IR beam that reflected back to the user and allowed the user to see in the near-infrared region. This device was useful; however would reveal the attacker if his enemy had similar equipment. As technology improved the NVGs were able to amplify the existing light without an active source. This technology allowed the user to separate the individual from its environment even on extremely dark nights. The latest version of passive NVGs (Generation 3) is extremely sensitive for wavelengths between 600 and 900 nm. The principals of camouflaging against passive NVGs are the same as standard camouflage. It is necessary to match your environment, avoid contrasts, and break up contours by means of effective patterns.

A major effort is under way in the military to seek ways of improving the camouflage protection of synthetic fiber-based garments and equipment in the near infrared (NIR) spectral region. This is possible today for dark colors (solid color olive drab) and prints (woodland), using selective pre-metalized dyes on Nylon 6,6. However, when these dyes are used on heavy denier fabrics like Nylon 6.6 Cordura® the dye levelness on the fabric can be poor. In addition, there is no mechanism to meet near infrared specifications for light colors such as solid tan or shades in the 3-color desert camouflage print. In the case of light colors and prints, the base Nylon 6,6 fabric has a very high reflectance in the NIR region and traditional dyes used to dye and print do little to mask the high reflectance when viewed through passive NVGs. This results in high reflectance properties in the 600 – 900 nm range, the region where passive night vision devices operate. Our objective is to develop a durable solution to correct this situation.

2. RESULTS

One method to modify the NIR signature of the

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base fabric is through the addition of nano and micro particle size additives to the polymer. Figure 1 shows a SEM photograph of the cross section of Nylon 6,6 Cordura® fiber containing nano and micro particles.

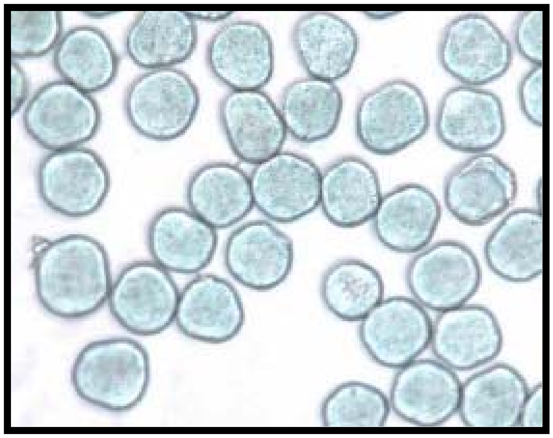

Figure 1. Cross section of Nylon 6,6 Cordura® round fiber containing nano and micro size particles (500X magnification)

The nano and mirco size particles can be observed in the SEM photograph by the dark spot inside the round fiber cross section. These particles modify both the visual and near infrared spectrum. The advantage of this technology is one can manufacture fibers containing proper color and NIR spectrums to improve camouflage.

2.1 UNDERSTANDING THE ENVIRONMENT

Figure 2 shows a scenic photograph from Crofton, Maryland taken by Mr. J. A. Wrotniak.

Figure 2. Image of pond in Crofton, Maryland. *Photograph being used under the permission of J. A.Wrotniak.*

The photograph was taken using a straight shot, no filter, EFL=35mm, program at 1/400 second at an f-stop of 5.6. The photograph is of a pond in Crofton, Maryland. The importance of the photograph is that it contains some of the key components of our environment: bark, foliage, grass, rocks, and water. Figure 3 shows the same scene now converted to a monochrome photograph.

Figure 3. Monochrome image of pond in Crofton, Maryland. *Photograph being used under the permission of J. A.Wrotniak.*

Figure 4 shows the same scene using infrared film with the picture being converted to monochrome.

Figure 4. Near infrared image of pond in Crofton, Maryland. *Photograph being used under the permission of J. A.Wrotniak.*

Figure 4 shows the same scene in the near infrared region using a Hoya R72 (#89B) filter, 1 second at an f-stop of 2.0. A comparison of figures 3 and 4 shows the foliage on the trees and the grass changes from a dark image (non-reflective) in the visual range to a bright image (reflective) in the NIR range. This is because in the wavelengths between 720 and 900 nm of foliage and grass have a high reflectance in the NIR while a low reflectance in the visual. Further examination shows how the white rocks become gray in the NIR. This is because in the NIR spectrum rocks and gravel (and sand which is not shown) have a very low reflectance in the NIR. Last, figures 3 and 4 show how water adsorbs almost all the NIR spectrum and becomes very dark.

Figure 5 shows the reflectance curves of various terrain elements using a standard UV-VIS-NIR spectrometer.

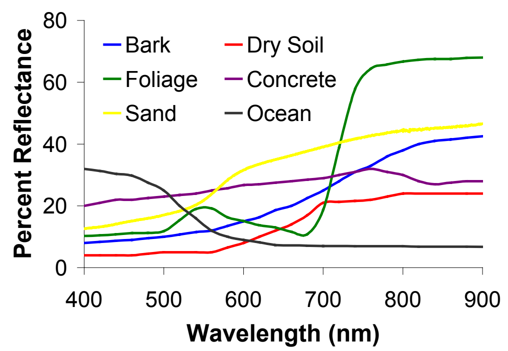

Figure 5. NIR signature of various terrain elements

Figure 5 shows the percent reflection of six different terrain elements: bark, concrete, dry soil, foliage, ocean and sand. Each terrain element has a different reflective signature based on its chemical make-up. For example, foliage adsorbs most of the visual wavelength and reflects much of the near infrared wavelength. Due to this visual and NIR signature, foliage looks dark under visible light and bright under NIR. It is also shown above why in the previous photographs the foliage was brighter that its surroundings in the near infrared images versus the standard images. Figure 5 illustrates that between 720 – 900 nm foliage has a significantly higher NIR reflectance than other terrain elements.

2.2 SOLUTION DYE CORDURA® COYOTE FABRIC FOR US MARINES

The US Marine Corps developed a new common color, Coyote, for the Interceptor Vest. The objective of the new Coyote color was to develop a color that works well in both arid and woodland environments. From a visual camouflage, Coyote, a brown color, makes sense since it is a common color in both desert and woodland prints. For the Coyote color to blend in well in the NIR it needs to have a reflectance that is in between the arid and woodland environments. Near infrared reflectance requirements were governed by this need.

Figure 6 shows that acid-leveling dyes used to dye the vest fabric could not meet the NIR requirements. When using acid leveling dyes, the base Nylon 6,6 fiber is too reflective. This causes the fiber to appear very bright in contrast to its surroundings when viewed through NVGs.

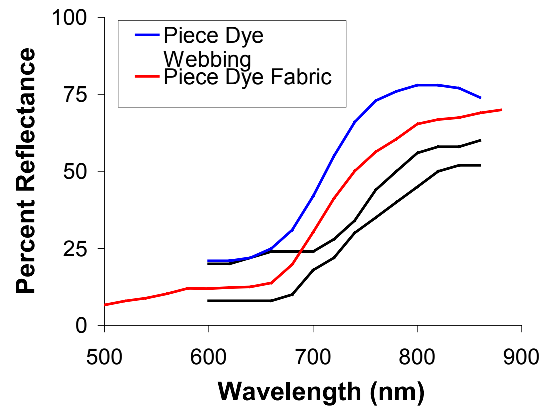

Figure 6. NIR signature of piece dyed coyote fabric and webbing. *Solid black lines are the minimum and maximum reflectance requirements*

Figure 6 shows two curves representing pieced dyed Coyote fabric and webbing versus the military specification described in Purchase Description 03-22A. In both cases standard Nylon fibers were dyed using commercially available acid leveling dyes. Although these dyes gave excellent color match, the dyes were unable to modify the NIR signature enough to match its surroundings. Figure 6 shows that the piece dyed goods reflect too much of the wavelength between 600 – 860 nm thus allowing the observer to see an illuminated object when using NVGs.

Figure 7 illustrates how adding nano and micro size particles can lower the NIR reflectance signature. The nano and micro size particles are added prior to extrusion in the fiber making process. Thus the color and the near infrared signature is contained in the fiber. No further processing is necessary to get the color and NIR signature.

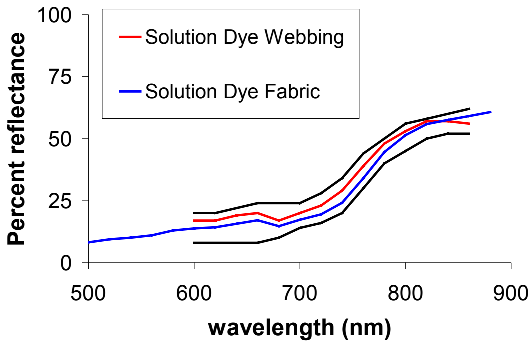

Figure 7. NIR signature of solution dyed coyote fabric and webbing. *Solid black lines are the minimum and maximum reflectance requirements*

The lower signature makes the fiber/fabric appear less bright when observed through night visions goggles lessening the contrast between the item and its surroundings. In addition since the fabric and the webbing are essentially identical the webbing strips can not been seen on the vest. In the case of Coyote the additives not only modify the NIR signature but also make up the color of the fiber/fabric. Thus there is no dyeing done by the finisher. By modifying both color and NIR signature in the fiber form it is possible to have excellent matching of both fabric and webbing.

2.3 DYEABLE CORDURA® EP FABRIC FOR U.S. ARMY

During Operation Iraqi Freedom the warfighter's equipment was changed from the woodland camouflage print to the 3-day desert camouflage print so that the warfighter's equipment matched its environment. As shown earlier, although sand is a light color in the visual spectrum it adsorbs most of the light/photons in the NIR region. Unfortunately, when light colors are dyed on standard Nylon 6,6 fabric the reflectance is very high. This creates a contrast between the warfighter's equipment and his surroundings making it difficult to conceal the warfighter. Figure 8 shows the NIR reflectance curve when the 3-day desert pattern is printed on standard Nylon 6,6 Cordura®.

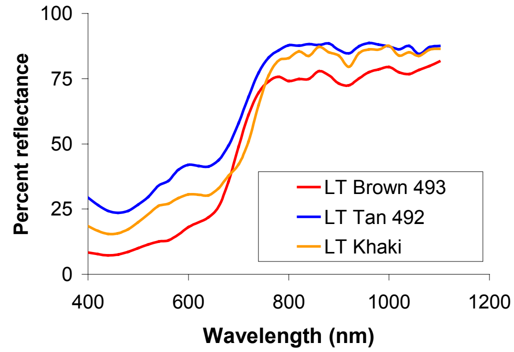

Figure 8. NIR signature for 3-Day desert fabric printed on standard Nylon 6,6

Figure 8 shows that the NIR signature of the 3-Day Desert printed on standard Nylon 6,6 Cordura® fabric has a very high reflectance in the critical 700 – 900 nm range. This high reflectance causes contrast between the warfighter's equipment and the warfighter's surroundings. To confirm this, Figure 9 compares the base fabric light tan 492 dyed on standard Nylon 6,6 Cordura® to the new military specification for light tan 492 defined in CO/PD 00-02D.

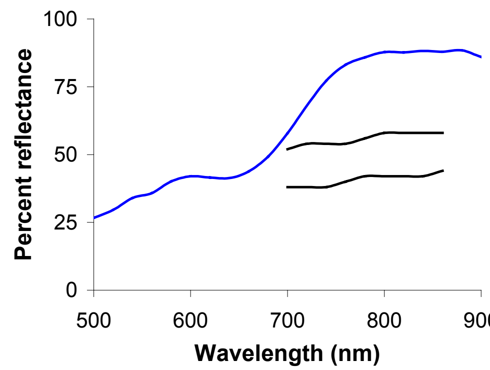

Figure 9. Light tan 492 (base color of 3-Day Desert Print) using standard Nylon 6,6 fabric versus the U.S. Army specification. *Solid black lines are the minimum and maximum reflectance requirements.*

Figure 9 shows the near infrared reflectance curves for the Standard Nylon 6,6 Cordura® dyed in the Light Tan 492 ground shade for the U.S. Army 3-Color Desert Camouflage Print. Figure 9 shows that the NIR reflectance is very high and outside the specification limits designed to properly conceal the warfighter.

Figure 10 illustrates a new technology developed by INVISTA that adds nanoparticles to the standard Cordura® fiber. The addition of these nanoparticles to the fiber lowers the reflectance of the base fabric.

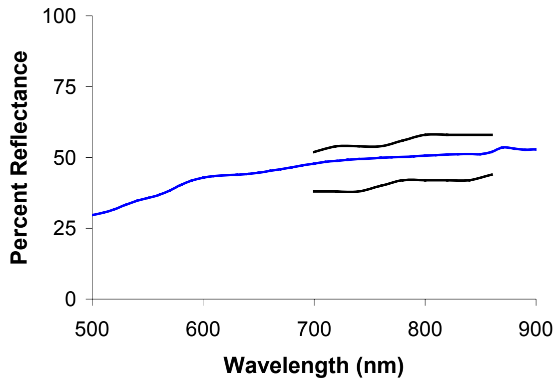

Figure 10. Light tan 492 (base color of 3-Day desert print) using Cordura® EP (Enhanced Polymer) fabric versus the U.S. Army specification. *Solid black lines are the minimum and maximum reflectance requirements.*

The inclusion of nanoparticles to Cordura® EP lowers the NIR signature thus making it is possible for the dye houses to piece dye and print the 3-day desert fabric matching the color and NIR requirements of the environment. Figure 10 shows that the base color, light tan 492 dyed on Cordura® EP, has a much lower reflectance in the 600 – 900 nm than when standard Nylon 6,6 Cordura® fabric is dyed to light tan 492. In addition, the light khaki 494 and brown 493 colors (not shown) also meet the U.S. Army NIR reflectance specifications described in CO/PD 00-2D. The lower NIR signature will lower the warfighter's reflectance signature from both his synthetic based clothing and equipment fabric improving his concealment at night in arid environments, and protect against enemy detection through passive NVGs.

CONCLUSIONS

Through the inclusion of nano and micro particle size additives to the intrinsic body of the constituent yarns it is possible to modify the NIR signature of the base fabric. Various effects can be achieved in both the visual and near infrared spectrum by the use of different additives. Work between INVISTA and the U.S. Army Natick Soldier Center has allowed for the development and commercialization of fibers produced with appropriate additives such that the warfighter's equipment can meet both the visual and near infrared requirements for enhanced concealment.

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