MEDICAL TEXTILES FOR UNIFORM BACTERIA MITIGATION

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1.0 SUMMARY OF CURRENT EFFORT

1.1 Background

Skin infections, body odor, and wound infections during battlefield activities are of great concern for individual soldiers. Triton Systems, Inc. under a Small Business Innovative Research (SBIR) contract with Natick Soldier Center developed a textile finishing process to produce advanced bio-textiles that will incorporate both broad-spectrum "leaching" and "bound" anti-microbial agents as skin/wound infection barriers for the Future Force Warrior. As seen in **Figure 1**, the approach uses both silver containing fibers and fibers coated with organic antimicrobial- compounds such as polyhexamethylene biguanide and quaternary ammonium silane in a synergistic manner to produce anti-microbial bio-textiles from woven, braided, stitched, or knit configurations. Triton's biocidal textile is aimed at producing fabric utilizing the nylon and cotton fibers currently used for military uniforms and equipage. The effort yield high kill rate durable organic antimicrobial agent to soldiers' apparel, such as Battle Dress Uniforms (BDU's), t-shirts, and socks.

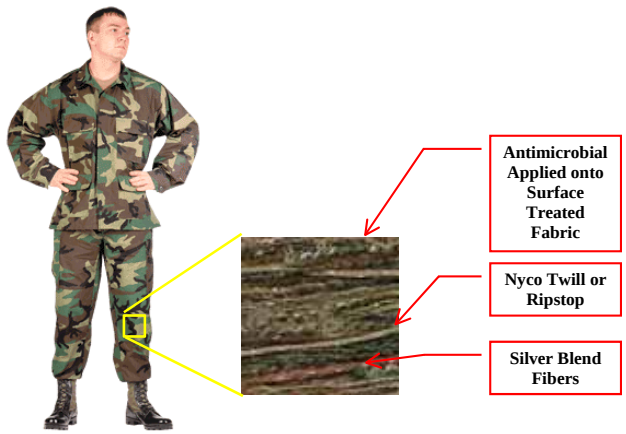

Figure 1. Triton's approach to antimicrobial textiles

Antimicrobial agents primarily work in two ways. The conventional "leaching" antimicrobials, separate from the textile upon contact, and chemically interact with the microorganism. The result of the interaction leads to the destabilization of the microorganism, eventually killing it. The "bound" antimicrobial, on the other hand, remains affixed to the textile, and, on a molecular scale, physically penetrates the bacteria membrane and complexes the biochemicals in the microorganism on contact to kill it. While there are many commercial antimicrobial agents available, the choice of antimicrobial agents for use on fibers is limited to those who have the correct chemistry for bonding, are safe for human exposure, stable to environmental conditions, and have high broad-spectrum activity.

Silver is known to have a very broad spectrum of antimicrobial activity at very low concentrations, while also being safe for human contact. The metal coating also has good fiber adhesion, thus yields a highly durable fiber system. The metal clad fibers can be integrated into the cotton/nylon blend during the spinning process.

1.2 Approach

The research effort utilized:

- Off-the-shelf materials;
- Triton's proven and proprietary fiber functionalization and coating process, Triton's Treat and Bind (TTB) process; and
- Methods for durable (10's of laundry cycles with high temperature (140º F) and high pH [>10]) attachment of the antimicrobial agents to both cotton and nylon.

1.3 Results

This method was successfully demonstrated utilizing both a 100% nylon cloth and a nylon/cotton 50/50% blend ("Nyco") BDU cloth. In addition to a clear zone of inhibition shown by the AATCC-147 test methodology, durability was shown by laundrometer washing at Natick Soldier Center, followed by microbial assay testing using both gram-positive and gram-negative bacteria. The research addresses the need for antimicrobial textiles that

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utilize the broad-spectrum activities of both silver and bound organic biocidal compounds in an easy to apply manner, and which limits the development of antimicrobial resistant strains of organisms.

Polyhexamethylene biguanide or the quaternary ammonium silane organic-based anti-microbial compounds were directly bound to the surface of textile fibers to yield antibacterial bio-textiles with both high activity and broad-spectrum protection to both gram-negative and gram-positive bacteria.

During the research program, several objectives were accomplished. In summary, we were successful in binding polyhexamethylene biguanide and quaternary ammonium silane organic antimicrobial agents to the surface of nylon-based fibers and fabrics. Through the use of both qualitative and quantitative testing, the bound antimicrobial agents were shown to still be active. In fact, the antimicrobials were found to be bound and active after the equivalent of five Army laundry cycles using zone-of-inhibition and kill rate tests. Preliminary testing of the difference in antimicrobial activity for electroless and electroplated silver was also accomplished. Most importantly, quantitative kill rate tests performed by Army personnel demonstrated 100% effectiveness after 24 hrs against gram-positive bacteria. These tests clearly demonstrated the efficacy of our approach in eliminating microbial activity on both nylon-based fabrics. **Table 1** shows quantitative results obtained for samples tested.

1.4 Experimental Summary

The durable attachment of the antimicrobial agents to the fabrics is summarized in two brief steps. The first step involved the functionalization of the fabric surface to allow attachment of the agents. There are a few chemical methods to accomplish the functionalization. These include acids, bases, and plasmas. The second step involves the durable attachment of the organic antimicrobial to the fabric surface. This step is accomplished through utilizing pendant functional groups of the antimicrobial agents that will not inhibit the antimicrobial activity of the agent.

2.0 FUTURE WORK

Under a Phase II SBIR contract , the team is working on optimizing the fabric treatment conditions to provide durable attachment of the organic antimicrobials without significant degradation to fabric properties or increase in weight. We are also working on scaling up the batch process from swatch to suitable fabric widths for fabrication of military apparel incorporating our antimicrobial technology. From this material we will fabricate appropriate apparel for the Army to perform an initial field wear evaluation. Furthermore, we are designing a continuous process that can be incorporated into the current textile finishing processes.

Table 1. Quantitative Kill Rate Results for Triton's Functionalized Fabric

Sample	Fabric Type	*Staph. aureus*		Effectiveness, % killed
		0 hrs	24 hrs	
1	Nylon	54,000,000	0	100
2	Nylon	41,500,000	0	100
3	Nylon	64,000,000	22,300	99.97
4	Nylon	40,000,000	0	100
5*	Nylon	40,500,000	5,850,000	85.56
6	Nylon	52,500,000	0	100
7	Nyco	9,600,000	0	100
8	Nyco	13,300,000	0	100
9	Nyco	2,490,000	0	100
10	Nyco	400,000	615	99.85

* - Control sample no organic antimicrobial present