The Sky is the Limit for a Treatment Developed by US Air Force

Courtesy of Technical Textiles International

Ever-rising technical and performance specifications demanded by the military constantly pose challenges to the textile industry. And, despite the current global eco-nomic problems, it seems there is to be no compromise, at least as far as the US military is concerned. Director of the Individual Protection Directorate at the US Army Natick Soldier System Centre, Robert Kinney, for instance, recently asserted that the next generation military battle dress uniform is expected to be:

- waterproof;
- flame-resistant;
- anti-bacterial
- repellent to mosquitoes; and
- have built-in odour suppression.

Add to this some additional preferences – such as being warmer in winter, cooler in summer and lighter in weight than existing uniforms – and the gauntlet is thrown firmly at the feet of suppliers.

Adding Multiple Functions

Fortunately, a crucial technology has emerged with the potential to fulfil such multi-functional demands. At a presentation given to the Fiber Society's Fall 2008 Annual Meeting and Technical Conference in Montreal, Quebec, Canada (1–3 October 2008), the US Air Force demonstrated the synthesis of a standard 50/50 cotton/polyamide fabric that was self-extinguishing when burned, superhydrophobic (contact angle greater than 150°, see box, page 23), oleophobic, reactive to chemical warfare agents and machine-washable. All this functionality was imparted to the fabric in a single treatment requiring only a 30 s cure in a conventional microwave oven operating at the 50% power setting.

Reactive Surface Technology (RST) is the culmination of several years of research by Dr Jeff Owens and his team at the US Air Force Research Laboratories, Tyndall, Florida, USA. Working as part of a research programme, the team's initial challenge was to develop a means to bond both antimicrobials and a selection of potentially life-saving chemical agent reactive compounds to soldiers' uniforms. These grafts had to be strong enough to maintain their integrity, even after repeated laundering and punishing treatment as a result of their use in a wide range of weather conditions and terrains.

Given the potential diversity of applications for military uniforms and equipment, any process employed had to be simple and scalable, and to be adaptable for use on textile products including uniforms, tents, sleeping bags and even high-efficiency particulate air (HEPA) filters.

Like many innovations, RST technology is the result of a union of two different scientific disciplines, in this case physics and chemistry. The basis of the process is silane chemistry, where organofunctional silanes contain both organic and inorganic reactivity in the same molecule. Initially, in the 1940s, silanes were used to improve the performance and durability of early fibre glass composites. Now, however, they are used extensively as coupling agents, adding functionality to thousands of products including textiles, tyres, paints and printing inks.

In the RST process, the reactivity of these silanes is achieved not by heat curing, but rather by the use of microwave radiation. This novel approach results in:

- a reaction producing a more stable graft of the function on the material; and
- the preservation of sensitive functional groups after the treatment.

The process has been tested extensively on almost every textile—ranging from wool, cotton, leather and cellulose fibres through to a wide range of synthetics, including aramids and polyester. It was essential for the team to understand the limits of the process and, over the past twelve months, Owens' laboratory has been steadily filling with the widest range of textiles received from all over the world, each for testing with the treatment.

Creating New Properties

With the initial focus on antimicrobial compounds, the technology was tested on most existing and developmental agents of this type, to check that the process did not inhibit their functionality. Extensive testing with these materials, both before and after treatment, threw up some interesting results. It was noticed that these materialsexhibited different physical and chemical properties when treated with the microwave, compared with ones that were attached using heat curing. This can result in better performance of the antimicrobial and in some cases even new functionality. Owens believes that this is due to the fact that the microwave reaction produces a more orderly molecular alignment, compared with those achieved by the application of other curing methods in use today.

Tests on textiles involved passive and persistent treatments. One antimicrobial group in particular, the chloramides, when attached with the RST technology, out-performed all existing and developmental antimicrobials. In extensive trials conducted at three separate military laboratories, chloramides were shown to be effective not only against gram positive and gram negative bacteria, but also viruses and, most importantly, anthrax spores.

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Grafting chloramides to textiles and subsequently chlorinating them with a dilute hypoclorite solution produced a reactive textile with broad spectrum antimicrobial properties that was particularly effective against spores. Even more interestingly, the chloramide-treated textiles could be peri- interestingly, the chloramide-treated textiles could be periodically and repeatedly regenerated by adding a tiny quantity of bleach during the final rinse in the laundry process.

That the technology lends itself to the grafting of multiple functions for demanding applications became even more apparent when Owens successfully demonstrated the ability to attach several types of chemical agents and antimicrobial compounds on the same surface simultaneously, and in a matter of just seconds, to create tailor-made solutions.

Development and Commercialization

The RST technology is now at the centre of three major US military development programmes headed by Owens and his team:

- the next generation chemical/biological uniform ensemble;
- a Department of Defense (DoD) initiative for the fire and emergency services; and
- a project to develop chemical agent resistant coatings (CARC), not only for textiles, but also for other surfaces such as coatings, paint and glass.

Global rights to the RST technology are now held by Alexium Ltd, which was formed specifically to commercialize the technology. The company's John Almond commented "When we saw the data showing the effectiveness of the chloramides, we knew that the technology had a central role to play in controlling the spread of infection in hospitals. We could find no other antimicrobial with such proven persistent effectiveness against such a wide range of spores and other pathogens."

Extensive toxicity trials in the USA have now been successfully completed for the chloramide-treated materials. Given that the RST technology can be used to apply this antimicrobial to bedding, hospital curtains, uniforms, patient gowns and even paint surfaces, it now offers prospects for clean, germ-free environments in hospitals around the world.

Over the past twelve months, Alexium and the US Air Force Research Laboratories have demonstrated the technology on a wide range of both natural and synthetic textiles. As the Alexium process involves the use of microwave radiation, as opposed to heat, it can be used with delicate textiles and more complicated synthetics such as aramids.

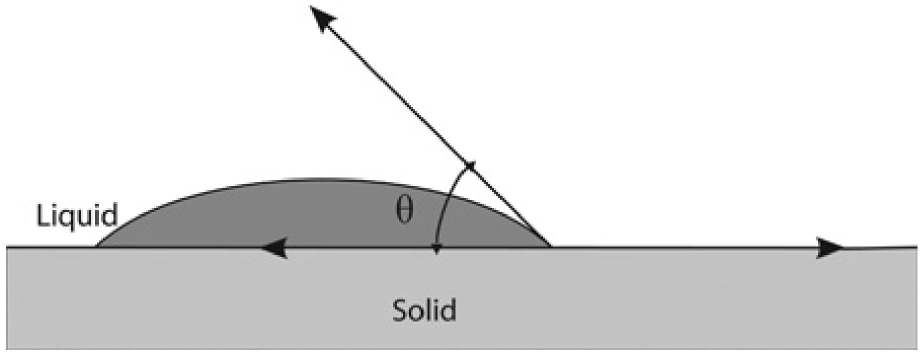
Grafting additional, multiple functions on performance tex- tiles such as meta-aramids (m-aramid) can further extend their applications. Tests recently conducted by the US Air Force have demonstrated, for instance, that the technology can graft a superhydrophobic, (almost super-) oleophobic and a flame retardant function to a fabric made from DuPont's m-aramid (Nomex) to produce a material that significantly outperforms an identical untreated textile in the event of a free-flowing fuel fire. With the combined flame retardant and oleophobic treatment, a 50/50 polyamide/cotton (NyCo)fabric, such as used for battle dress uniforms, exhibits the same rapid self-extinguishing performance when doused with fuel and then immediately subjected to a flame test.

Alexium has identified specialist textile applications – ranging from wound dressings to upholstery, apparel, technical textiles and high performance filters – where multiple func- tions can now be grafted either directly to the fabric or on nanoparticles that are simultaneously grafted to the fibres. The ability to select multiple functions and match them to the requirements of their intended uses has implications for so-called "intelligent textiles" too: functionalities can now be added to the fabric and programmed to react under the appropriate conditions.

The RST technology is ready for commercial applications. The US Air Force is checking that the technology is scalable and capable of treating textiles on a continuous process at commercial speeds. By the second quarter of 2009, reel-to-reel batches of cloth will be produced as part of a demon-strator programme at the US Air Force Research Laboratories in Tyndall.

Alexium has recently installed a commercial microwave generator at the Laboratories, which is currently being used to treat pre-production quantities. The modified generator resembles one of thousands used extensively in dozens of other industrial applications around the world. Consequently, the capital costs for the process are modest compared with other finishing technologies.

The company's Steve Ribich, who has previous experience developing microwave technologies with the US National Research Laboratories said "The process is extremely flexible in that materials can be treated either as a batch or a continuous linear process. However, for most high-volume textile applications we envisage a continuous reel-to-reel process, which can be easily integrated into most textile finishing processes."



Contact angles and surface tension

The contact angle is the angle at which a liquid (or vapour) interface meets the solid surface. If it is greater than 150°, the material is said to be superhydrophobic.

If the volume of the water drop being measured is increased without altering the interfacial surface area between it and the solid the contact angle increases to a maximum value known as the advancing angle. Similarly, if the volume of the water drop being measured is decreased without altering the interfacial surface area between it and the solid the contact angle decreases to a minimum value known as the receding angle. The contact angle hysteresis is the difference between the advancing and receding angles.

He added "We have been optimizing the process over the past few months, with the result that the treatment time has now been reduced from 30 s to 5 s for most applications. This reduces the energy and raw material consumption even further, allowing faster run speeds and lower unit costs."
Almond emphasizes that RST is not a plasma technology: "It is usually the first question that potential customers ask when we introduce the technology. There are significant dif- ferences between the two technologies, we prefer to focus on providing unique functions to our clients. The means to graft multiple value-added functions including epoxides and active enzymes onto textiles by a simple cost-effective process provides immense appeal."

Alexium is in the process of producing samples for testing as well as addressing the many technical questions raised. One of the key concerns is the ability to repeatedly wash the textiles before any degradation of performance. "For most applications, such as hydrophobic and oleophobic, we can achieve 50−60 wash cycles although, when cross-linking a flame retardant, it is currently restricted to 15−20 cycles" Almond noted.

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However, the flame-retardant treatment programme is only a few months old and, with extensive efforts underway in the USA, Alexium is certain it will significantly increase the number of wash cycles. "They succeeded with all the other applications to date and we are confident that the same can be achieved with the flame retardant function over the next few months" said Almond.

With the technology at the centre of a number of US military programmes for both paint and textile applications, the challenge for Alexium is to facilitate the rollout of the technology. To this end, the company has been active in developing strategic relationships with commercial and industrial partners around the world.

Adding Functionality, Saving Costs

Almond believes the timing is good: "We are aware of no other technology where textile materials can be modified in such a simple cost-effective manner. As the world economy has slowed over recent months, we have seen a corresponding increase in interest in our technology. More than ever textile producers are seeking ways to add multiple value-added features to their offerings, as well as a means to save energy and reduce production costs. We believe that our technology has a significant role to play in both."