A possible answer for protection against chemical/biological agents, fuel leaks, and coffee stains

January 31 2013

A recent discovery funded by the Air Force Office of Scientific Research (AFOSR) may very well lead to a process that not only benefits every uniformed service member of the Department of Defense, but everyone else as well: protection from chemical/biological agents, to self-cleaning apparel, to effortless thermal management, to fuel purification as well as enhanced control of leaks—especially oil and fuels.

In 2006, AFOSR Program Manager Dr. Charles Lee funded Professor Gareth McKinley at the Massachusetts Institute of Technology exploring nanocomposite technology for Defense applications. Anish Tuteja, an MIT doctoral student at the time, was exploiting the unusual surface properties of a nanocomposite with fluorinated nanoparticles, to create a superoleophobic surface. After graduation, Tuteja moved to University of Michigan in Ann Arbor, where he is currently an assistant professor of materials science and engineering, specializing in chemical engineering and macromolecular science and engineering. He was awarded a Young Investigator Program grant from AFOSR in 2011, and continued to conduct the same line of research begun at MIT. His team also included doctoral student Shuaijun Pan and postdoctoral researcher Arun Kota, as well as collaboration with Dr. Joseph Mabry, from the Rocket Propulsion Division of the Air Force Research Laboratory, at Edwards AFB, California.

In their latest paper, "Superomniphobic Surfaces for Effective Chemical

Shielding," in the current issue of the Journal of the American Chemical Society, Tuteja and his team have demonstrated surfaces that effectively perform as "chemical shields against virtually all liquids."

To make this possible, surfaces are prepared using a nanoscale coating that is approximately 95 percent air, which in turn, repels liquids of any material in its class, causing them to literally bounce off the treated surface. The surfaces "possess hierarchical scales of re-entrant texture that significantly reduce the solid–liquid contact area." It all comes down to controlling how much contact the liquid ultimately has with the treated surface. To accomplish that the researchers apply the nanoscale coating using a process called electrospinning—using an electric charge to create fine particles of solid derived from a liquid solution.

The coating is a mixture of cross-linked "polydimethylsiloxane," or PDMS, and liquid-resisting nanoscale cubes developed by the Air Force that contain carbon, fluorine, silicon and oxygen. While the material's chemistry is important, so is its texture, because it hugs the pore structure of whatever surface it is applied to, and creates a fine web of air pockets within those pores, so any liquid that comes in contact with the coating is barely touching a solid surface.

According to Dr. Tuteja, when an untreated surface and a liquid get in close proximity, "they imbue a small positive or negative charge on each other, and as soon as the liquid comes in contact with the solid surface, it will start to spread….we've drastically reduced the interaction between the surface and the droplet." By effectively eliminating the contact between the treated surface and the liquid, there is almost no incentive for the liquid to spread, as such, the droplets stay intact, interacting only with molecules of themselves, and maintaining their spherical shape.

The research team has tested more than 100 liquids and found only two that were able to penetrate the coating: they were both chlorofluorocarbons—chemicals used in refrigerators and air conditioners. In Tuteja's lab demonstrations the surface repelled coffee, soy sauce and vegetable oil, as well as toxic hydrochloric and sulfuric acids, and the surfaces are also resistant to gasoline and various alcohols.

This program is of particular interest to the Air Force and the Department of Defense, as it can be useful for self-cleaning surfaces (in particular, integral breathable protective Chemical/Biological Warfare defense in uniform clothing and sensor systems), improvement of thermal management efficiency in phase change cooling systems, fuel purification and the control of oil and fuel leakages in rockets and airplanes. Not to mention, protection against the everyday coffee spill.

Provided by Air Force Office of Scientific Research