Protective garment

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Military personnel, chemical workers, and others could benefit from a new synthetic rubber material tailored with liquid crystals. The material might be used to make body suits to protect chemical-industry employees from skin exposure to toxic vapors and aerosols, as well as providing protection for military personnel and civilians in the event of a chemical-weapons attack. The new composite is lightweight and breathable, but still blocks the passage of toxic chemicals, reducing the risk of heat exhaustion in anyone wearing it.

Writing in issue 24 of *Advanced Materials*, Douglas Gin of the University of Colorado, Brian Elliott at TDA Research Inc. (Wheat Ridge, Colorado), and colleagues, explain that effective personal protection against exposure to toxic vapors is a major concern in industry and in defense.

At present, the only certain way to protect people from all chemical vapors to which they might be exposed is to use a hermetically sealed body suit and fully enclosed breathing apparatus. An alternative used by the military is a heavy overgarment lined with activated carbon that can adsorb vapors for a limited time. Such equipment, while safeguarding personnel, is cumbersome, costly, and unwieldy to use in an emergency, as well as coming with health risks if used in hot environments.

To solve this problem, the researchers have turned to a highly effective garment material—butyl rubber (BR)—used in protective clothing, and have adapted it to a modern application. Butyl rubber, or more formally, linear poly(methylpropene-co-2-methyl-1,3-butadiene) can be chemically modified so that the polymer strands become crosslinked to one another. These crosslinks make synthetic rubber resistant to many corrosive chemicals and give it very low permeability, so that most toxic chemical agents, whether vapor or liquid, cannot penetrate.

However, it is this same lack of permeability that is a major drawback to using butyl rubber. Water vapor is also prevented from passing through crosslinked butyl rubber, so that under even moderate workload individuals wearing a synthetic rubber protective garment can become very uncomfortable and in extreme cases suffer heat stress, heat stroke, and even death from overheating. Because of these problems, most of the world's military currently rely on the heavier overgarments lined with activated carbon - but would prefer a lighter option that could be used for longer and is more easier to wear.

The ideal protective garment should be lightweight and selectively block toxic vapors, but be “breathable”, allowing water vapor to pass outward, thereby maintaining personal comfort and safety. Gin, Elliott, and their colleagues have now developed just such a material based on modified butyl rubber. The material is breathable but also rejects chemical agents.

To make their breathable rubber, the researchers originally blended the synthetic rubber with a liquid-crystal molecule that could also be crosslinked like the rubber itself. During preparation of the breathable rubber, the liquid crystals organize themselves into cylinders around water molecules in the reaction mixture. This causes tiny water-filled nanopores just 1.2 nanometers in diameter to form. Only the smallest of molecules can pass through these pores, including water. Many toxic molecules, nerve agents, and other chemicals are too big to enter the pores. Moreover, the pores are water-loving, or hydrophilic, whereas most chemical warfare agents and many toxic compounds are hydrophobic, or water repellent, so even if they could fit, they would be repelled by the pores.

The team carried out initial tests with their breathable liquid crystal rubber and found it to have a very high selectivity for water vapor compared to so-called “half mustard” gas, 2-chloroethyl ethyl sulfide (CEES). However, the rate of water vapor transport in the original test material was lower than that widely viewed as the target valued needed by the military. Also, penetration by CEES vapor was slightly above that measured for pure crosslinked butyl rubber.

In order to improve on this prototype, the researchers tried a different liquid crystal in their new composite. This second-generation material does not contain isolated water pores spread across its surface but instead has a manifold network of tiny conduits. The new material is more than ten times as effective at transporting water vapor compared to the original material. It also blocks the passage of CEES much more effectively than pure butyl rubber.

The team is now refining the material to make it thinner but just as effective. They are also testing how effective it is at keeping out phosphorus ester-based chemical-warfare agents.

While a breathable rubber is likely to appeal to the military and emergency services, the researchers might also find a secondary market for such a material. “It may be possible to use these nanoporous liquid crystal–polymer materials for performing molecular-level separations of liquid mixtures, or even removing toxic molecules and dissolved salts from contaminated water or seawater,” the researchers say. Gin, Elliott, and colleagues are already looking into these possibilities.

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