Stretch Your Imagination: Durable and Stretchable Superhydrophobic Coatings Resist and Repel Dangerous Liquids

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We have developed a new class of superhydrophobic materials that are built into soft stretchy latex and nitrile glove materials. Like the sacred plant that inspired them, superhydrophobic materials defy our expectations of the physical world by repelling water in curious, unexpected, and seemingly unnatural ways. Personal protective equipment (PPE) can, unfortunately, become a vector for transport of and exposure to hazardous materials. Durable and flexible materials with superhydrophobic wetting behavior could reduce the risks faced by the armed forces, first responders, and healthcare providers by dramatically lowering the adhesion of dangerous liquids on their gloves, clothing, equipment, and other surfaces. The coatings and materials we developed have a flexible base that contributes to improved durability and ability to withstand abrasion. Surprisingly, these materials also exhibit improved water repellency as they are stretched. Liquid droplets that land on these materials don't form the regular raindrop shape; instead the droplets roll up into balls and slide effortlessly around the surface. Prior attempts to make durable synthetic materials have failed because textures modeled on the lotus leaf are typically no more durable than the delicate flower that grows from the same plant. Light abrasion against fine textures typically breaks their fragile structure and inhibits water-repellent behavior. The benefits of fragile superhydrophobic materials are temporary and practical applications have been limited. We designed stretchable superhydrophobic materials to overcome these limitations. A key feature of our materials is their ability to transform their surface microstructure as they are deformed by stretching or abrasion. The surface was designed to start with a uniform nanotextured surface and to break apart into micro-sized surface agglomerates during stretching or abrasion. Transition from a uniform nanostructure to a multi-scale hierarchical structure led to an increase in water repellency as measured by water contact angle. We tested the materials for water repellency in stretching conditions and after numerous abrasion cycles. Our stretchable coatings maintained superhydrophobic behavior even as the underlying latex and nitrile ripped or tore due to excessive abrasion. Partial embedding of the surface agglomerates in a flexible polymer substrate allowed the material to bend and yield rather than being sheared or abraded off. The results also suggested new mathematical models for surface wetting that build on the standard Wenzel and Cassie-Baxter theories. In particular, moderate stretching resulted in a sharp increase in contact angle that we propose results from a previously unknown hybrid Wenzel/Cassie-Baxter state. Improved fundamental knowledge of wetting behavior could improve the rational design of materials used in PPE and provide an improved ability to resist and repel dangerous liquids in real world conditions. The ability of the material to shed infectious material (bacteria, spores, and viruses) and toxic chemicals (organic solvents, strong acids, strong bases, etc.) was also tested. PPE has a high 'return on investment' because a low-cost article like a latex glove can easily prevent a serious injury or illness. Stretchable superhydrophobic materials made from low-cost non-toxic components may further extend the benefits and capabilities of PPE by preventing adhesion of hazardous materials.

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