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PNNL-32739

Durable Super-Repellant Materials for Stretchable and Flexible Personal Protective Equipment

March 2022

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Samuel Pennell

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Abstract

The goal of this report is to summarize findings from development of new flexible protective coatings with superhydrophobic properties. For many practical applications, the durability of such coatings must far exceed what it currently possible. We aimed to develop coatings that can be integrated into personal protective equipment to provide an additional barrier that can shed and reduce the spread of infectious liquids. The COVID-19 pandemic has revealed the importance of PPE for frontline healthcare workers. Developing durable protective coatings could have both immediate impacts during the pandemic and long-term benefits in multiple industries.

Acknowledgments

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1.0 Problem summary

First responders, healthcare workers, and soldiers risk contamination at the frontlines of an infectious disease epidemic, disaster response, or chemical or biological attack. Adequate personal protective equipment (PPE) can reduce but not eliminate this risk. When PPE contacts dangerous or infectious material it can become a vector for self-contamination. Many healthcare workers become infected when donning or doffing PPE because contaminated gloves transfer materials to the skin. Wet PPE can also reduce grip, dexterity, and comfort. Durable super-repellant PPE will prevent transfer of hazardous material and protect users.

2.0 Scientific Approach

The leaf of the lotus flower has a remarkable ability to shed water due to the micro and nanostructure of wax crystals that form on its surface. Materials that mimic this structure can replicate the super-repellent properties. Many manmade replicas of these structures suffer from poor durability, especially when applied to clothing that must be able to flex and stretch. At PNNL, we have recently developed a biomimetic coating with excellent water/liquid repulsion and shedding properties (Figure 1A). The coating can be integrated directly into latex and maintains repellent properties when stretched up to 300%. In fact, the unique composition allows it to exhibit *higher* hydrophobicity when stretched (Figure 1B). We employ a uniform layer of low cost hydrophobic silica fibers that are embedded in a layer of latex. As the latex stretches the surface layer of silica fibers spontaneously transitions from a uniform nano-coating to a hierarchical micro- and nanotextured surface. Embedding silica fibers in a flexible polymer matrix also improves durability, usually the bane of manmade superhydrophobic materials. In abrasion tests our hydrophobic latex material maintained its repellent properties until the underlying latex failed by tearing.

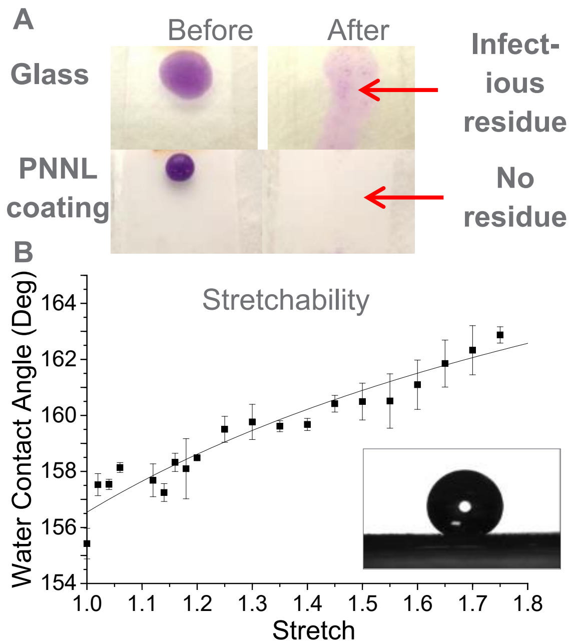
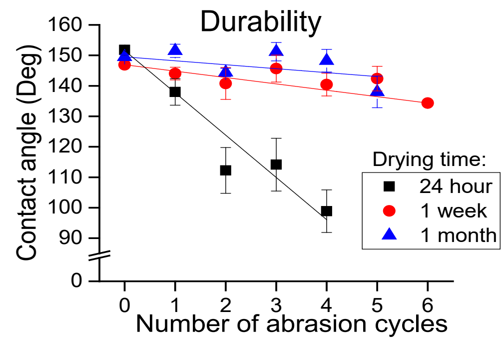
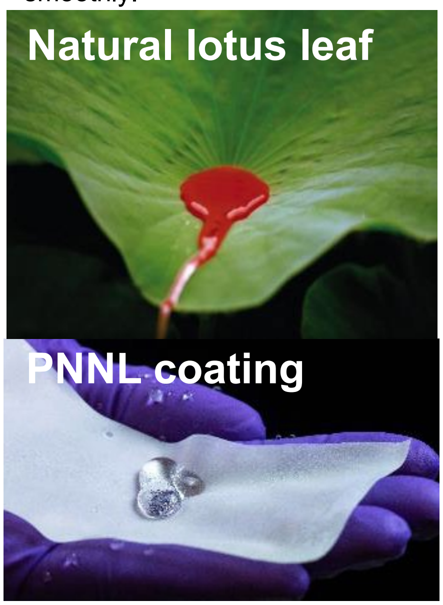


Figure 1: A) Novel water repellent PPE material prevents adhesion of infectious liquids (purple stained bacterial slurry) B) The latex based material exhibits higher hydrophobicity (contact angle) when stretched and causes liquids to bead up and roll off (inset). Bars show standard deviation (N=5).

The flexible coating can be easily applied to PPE surfaces making water bead and shed smoothly.

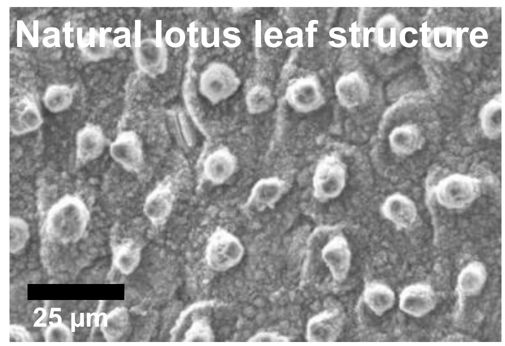


Durability was tested by abrading samples with a known weight (150 g) over sand paper (1000 grit). Coatings given ample time to dry (1 week or more) remained hydrophobic until the underlying latex tore.

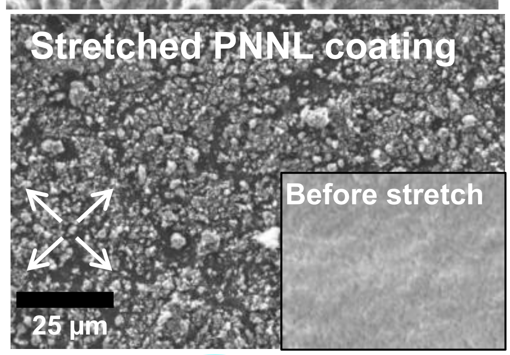


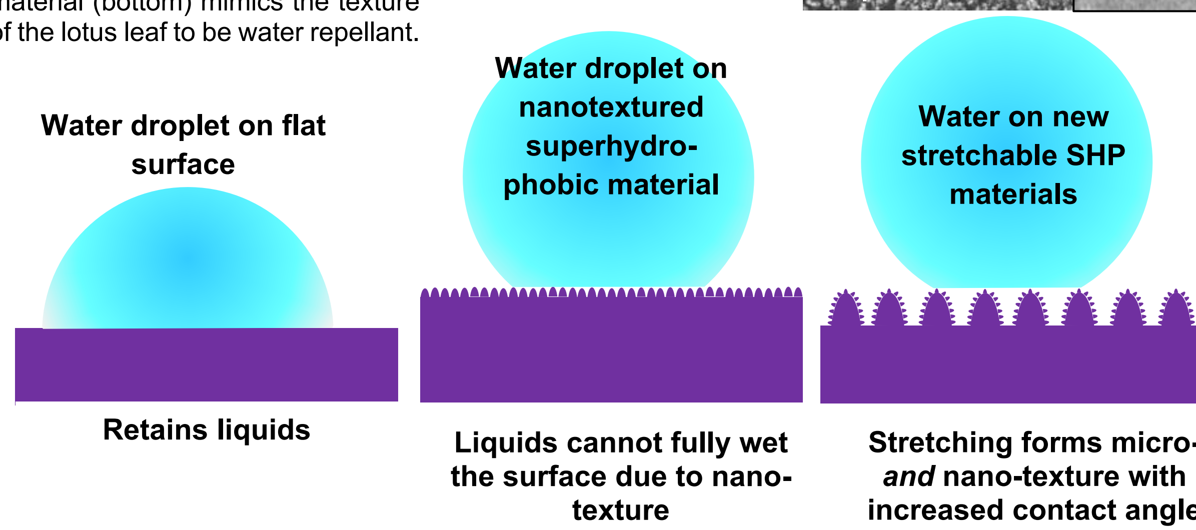
The lotus leaf (top) is naturally superhydrophobic (SHP) and sheds water without residue. A recently PNNL-developed superhydrophobic material (bottom) mimics the texture of the lotus leaf to be water repellant.

The natural lotus leaf has a hierarchical structure of micro-protrusions with nano-hairs that lead to superhydrophobicity.



Our material starts as a uniform coating with a nanofiber surface (inset). As it is stretched the surface spontaneously breaks up into microscale agglomerates. Transition from nano to hierarchical texture increases contact angle.





3.0 Outcomes

- Improved protection for first responders and healthcare workers for epidemic and bio-threat response
- Demonstrated benefits for high risk environments involving infectious fluids
- Matured technology ready for tech transfer via commercialization with external partners
- Greater understanding of science of durable superhydrophobic materials

4.0 Next Steps

- Demonstrate reduced residual bacteria and viruses and reduced transfer of the bacteria and viruses
- Test compatibility with commonly used disinfectants and chemicals
- Improve material formula and application method for industrial production
- Modify for application to various types of PPE (masks, face shields, gowns, etc.)
- Fundamental science to understands failure mechanisms and improve performance

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