A Sustainable Alternative to Performance Plastics Makes a Debut

Our world is awash in plastics. Once considered "miracle materials," they are found in everything from food wrappers to handbags to car seats. One application in which plastic plays a huge role is in mimicking leather (so-called pleather), with a global projected market size of nearly $78 billion in 2025. The problem with plastic-based materials, however, is that their production process is highly polluting and contributes to greenhouse gas emissions. More serious is their disposal, because plastics do not readily break down under natural conditions, and thus they make their way into our lands, waterways, and oceans as microplastics. Furthermore, additives that make plastics water-repellent often contain highly fluorinated substances (*e.g.,* PFAS) or "forever chemicals" that can jeopardize health even at parts-per-trillion levels. Thus, there is a strong desire to replace petroleum-based, non-renewable, and harmful polymers.

Replacing pleather with a sustainable material would not only solve a vexing environmental problem, it would also present a huge business opportunity. While several attempts have been made by researchers to achieve that objective, most have come up short because those technologies must use petroleum-based inputs to meet performance targets or have inferior performance compared to leather.

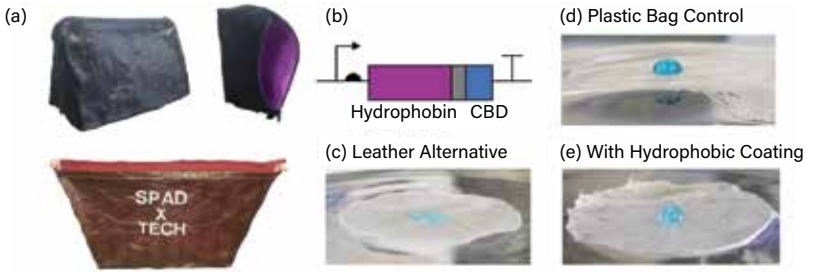
With funding from the U.S. National Science Foundation (NSF), SpadXTech, a Worcester, MA-based biotech start-up, has created a breakthrough high-performance leather alternative.

Their technology is based on bacterial cellulose sheets that are secreted by genetically modified strains of *Gluconacetobacter xylinus*. These sheets have a set of unique characteristics rendering them suitable for attaining the desired material properties. After processing to make them supple, individual sheets of the material appear translucent and resemble plastic. Stacking multiple sheets creates a strong material (with a Young's modulus of ~130 MPa) that has the look and feel of leather. The material can be colored with natural pigments, sewn, and embroidered without tearing. SpadXTech's cellulose sheets are also compostable, breaking down in a cold compost bin within five weeks; it would take centuries for plastics to break down under similar conditions.

However, cellulose is naturally hydrophilic, limiting its applications as compared to traditional plastics. To make its material water-repellent, SpadXTech has developed an innovative coating based on naturally occurring hydrophobins. By attaching a suitable cellulose-binding domain (CBD) to a hydrophobin, the team was able to bind the hydrophobin to the surface of the cellulose. "Our CBD plus hydrophobin coating will not only serve SpadXTech for its leather alternative, but also the approach has the potential for making other cellulose-based materials like cotton and blown-in insulation water-repellent. With further modifications, making other kinds of fabrics water-repellent may be possible," says Lina González, cofounder and CTO of SpadXTech.

SpadXTech is currently working on ways to scale the production of its leather alternative and its coating. For its leather alternative, it plans to go from producing a few square feet per week to thousands of square feet per week and to reduce costs. For example, the company has engineered its strain of the cellulose-secreting bacterium to grow faster, decreasing its doubling time from ~5.5 hr (wild type) to ~0.9 hr. The team also has used natural, commercially available components to optimize their media, reduce its cost, and produce a thicker mat of cellulose. Indeed, there is a strong market pull. "Companies are desperate for these leather-alternative materials," says Jessica Kruger, Founder and CEO of Luxtra London, a leader in the industry.

With its technical demonstrations based on genetic engineering, SpadXTech is well on the way to matching the performance of plastics for diverse applications, improving a wide range of materials in an environmentally sustainable way, and advancing material science, energy conservation, and the bioeconomy in the U.S. CEP



▲ (a) SpadXTech is making leather-alternative bags from cellulose, which can be sewn and embroidered. (b) To impart hydrophobic qualities to the leather-alternative material, the company created a gene circuit of a cellulose-binding domain (CBD) linked to a hydrophobin. (c) The cellulose leather alternative is naturally hydrophilic, as shown here with water spreading. (d) Shown as a control, water beads on a plastic bag. (e) The hydrophobic coating provides water resistance to the leather-alternative material.

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