Preview

The Future of Smart Textiles: User Interfaces and Health Monitors

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This issue of *Matter* shows the versatility of smart textiles as healthcare monitors and textile-based displays in a pair of research articles. By taking advantage of intrinsic fiber behaviors such as stretching, twisting, and knittability, the authors enhance device functionality while maintaining user comfort.

Whether in the form of clothing,. curtains, and upholstery, or landscape fabric, camping gear, and collapsible shelters, we continuously interact with textiles across various personal and professional aspects of our lives. Such ubiquity renders textiles useful as platforms for building either user interfaces for cloud computing systems or sensor arrays for longitudinal health monitoring. However, textiles—and particularly garments—are especially demanding technology platforms due to their complex and three-dimensional topologies and the large, varied mechanical stresses to which they are routinely subjected. This combination of features results in frequent and unavoidable delamination, abrasion damage, and/or cracking in any microelectronic devices or interconnects that are embedded into textiles. Further, aesthetics, tactile perception (or hand-feel), and practical concerns such as comfort, breathability, and launderability are often the major determiners that drive adoption of nascent textile-based technology, irrespective of device function and metrics.

The most successful examples of engineering design, as applied to smart textiles, are creative approaches that adapt mature textile manufacturing and garment assembly routines, such as yarning, knitting, weaving, and sewing for device fabrication. Notable research endeavors can be classified into two schools, which can be broadly considered as the textile equivalent of a "bottom-up" versus "top-down" approach. The bottom-up collection involves creating functional fabrics that are either woven or knit out of designer yarns or threads, whereas the top-down examples rely on creating rugged functional coatings on prewoven and/or preknit fabrics or garments. This issue of *Matter* contains two interesting entries from both of these two schools of practice.

Yang and Chen et al. present a textile-based pulse monitoring device capable of identifying obstructive sleep apnea in wearers.[1] Interestingly, the authors make use of an intrinsic property of textiles to enable their device function. Textiles microscopically stretch and twist at specific pulse points, such as the inside of one's wrist, as the pulse of blood travels through the wearer's body. The authors have found a way to record these stretches by placing metal yarn-based triboelectric devices at pulse points, which allows for pulse to be transduced as a contact- or tribo-electrification signal. This approach allows for continuous pulse monitoring without requiring tight or hard accessories, such as headbands or watches. By focusing on a yarn-based approach, the authors give themselves room to incorporate design and aesthetic considerations when assembling their device while also allowing for fine tuning of electrification within the triboelectric device using different yarning techniques.

From a practical perspective, health monitoring devices that take the form of everyday clothing, bedding, or upholstery have the promise of being readily adopted and frequently used in a user's natural environment, in sharp contrast to existing biomedical devices that require users to sacrifice personal comfort for medical precision. From a knowledge gathering point of view, smart garments can provide longitudinal datasets from which the intricate interrelationships between lifestyle and everyday habits and selected chronic illnesses can be systematically established.[2] Such detailed correlations are otherwise difficult to probe longitudinally across a large population with existing commercial technologies.[3]

Carmichael et al. present an interesting idea to take the top-down approach for creating dynamic textile-based displays.[4] Here, as in the previous case, the authors take clever advantage of the varying transmissivity that is intrinsic to different knit structures, particularly when stretched. By creating a conformal gold coating on a pre-knit textile, the authors create gold textile electrodes that are ultrasheer due to the open framework structure of the underlying knit. These gold textile electrodes can then be further elaborated upon to assemble stretchable

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https://doi.org/10.1016/j.matt.2020.03.011

electroluminescent textiles. The transmissivity of the gold textile electrodes and the luminance of the final electroluminescent devices can be tuned by varying the repeating loop structure of the knit pattern and also by stretching the knit textile substrate. Such dynamic, post-fabrication control over optical characteristics is difficult to achieve using traditional micro- and nano-fabrication approaches.

Commonly available, mass-produced textiles and premade garments can, in theory, be transformed into a plethora of dynamically responsive human-machine interfaces upon being coated with films of electronic materials, such as metals and conducting polymers. The definitive hurdle is that premade garments and fabrics have densely textured, three-dimensional surfaces that display roughness over a large range of length scales, from microns to millimeters. Tremendous variation in the surface morphology of metal- or polymer-coated fibers and fabrics can be observed with different coating or processing conditions.[5] In turn, the morphology of the metal or polymer layer determines device performance and, most importantly, ruggedness and lifetime. To date, reactive coating methods have been the most successful at creating electronic coatings directly on the surface of any premade garment or textile;[6] however, further processing innovations that increase coating speed and reduce toxic or solvent waste are always welcome. Ideally, new coating methods need to work without the need for specialized surface pretreatments, detergents, or fixing agents while also yielding uniform and conformal coatings that are notably wash-stable and withstand mechanically demanding textile manufacturing routines.

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Preview

Don't Sweat It: The Quest for Wearable Stress Sensors

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A nervous sweat may seem like an inconvenience, but your body could be releasing important signals. Herein, Gao and colleagues develop a wearable sensor with integrated microfluidics, immunoassays, and electronics for tracking cortisol in sweat—as a biomarker of stress.

Stress is an intense, natural, and universal reaction that guides both cognitive and physical processes with beneficial short-term consequences attributed to "fight-or-flight" responses and harmful long-term consequences to health. Recent studies show that chronic stress accumulated over time can lead to debilitating outcomes such as cancer, coronary heart disease, accidental injuries, lung disease, liver disease and suicide.[1] The World Health Organization estimates that stress-related disorders are one of the leading causes of disability globally and classifies stress as the "health epidemic of the 21st century".[2] According to the American Psychological Association, over 80% of workers in the United States suffer from work-related stress, costing businesses a staggering $300 billion annually.[3]

Although the underlying causes can vary widely, the frequency and intensity of stressful events are rising sharply, due in part to the increasing influence of social media on daily life.[4] Extensive research suggests that such stress can exacerbate or even cause serious medical conditions beyond those described

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https://doi.org/10.1016/j.matt.2020.03.004