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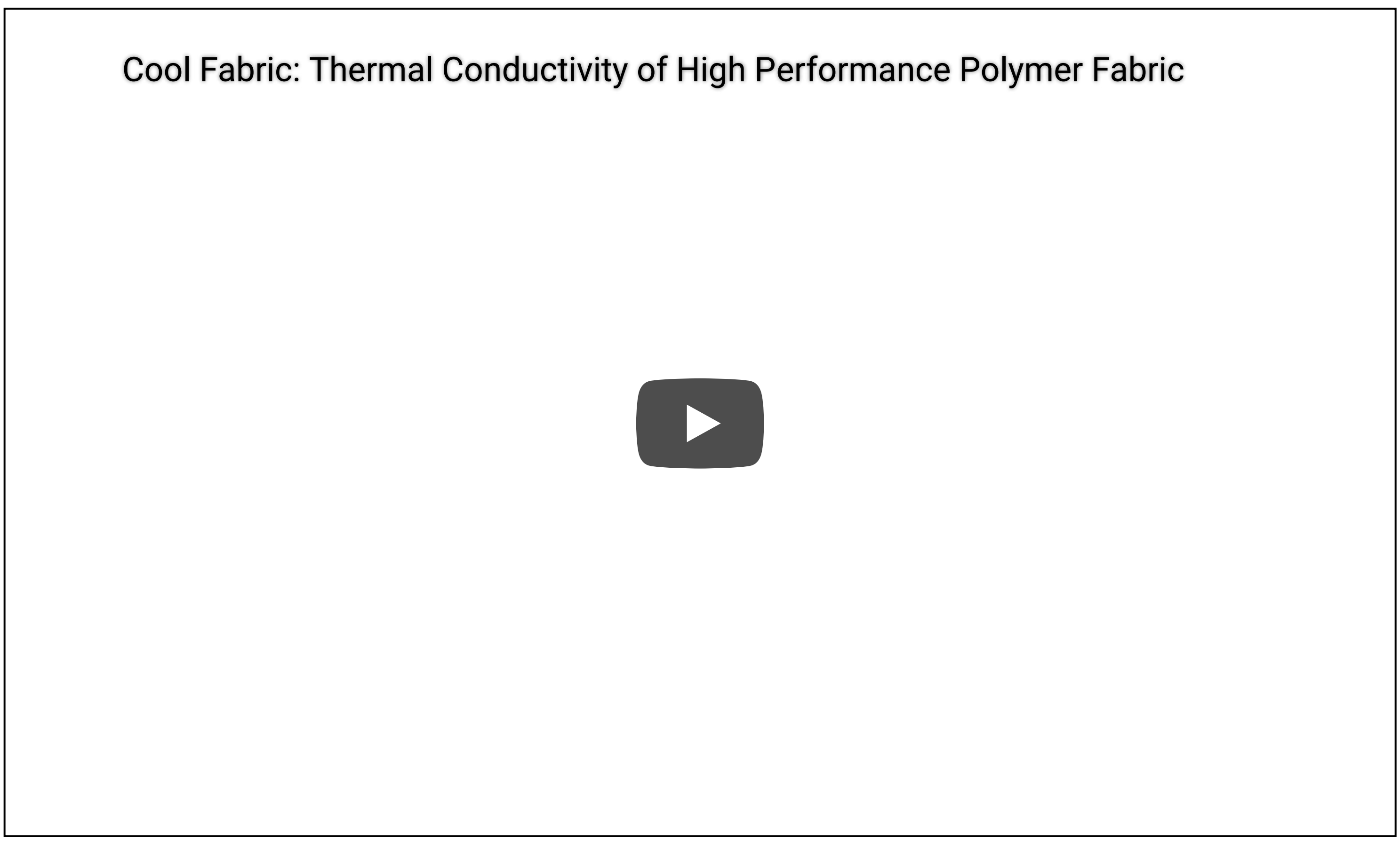
Hiking gear fabric has cooling effect that may make your next smartwatch more comfortable

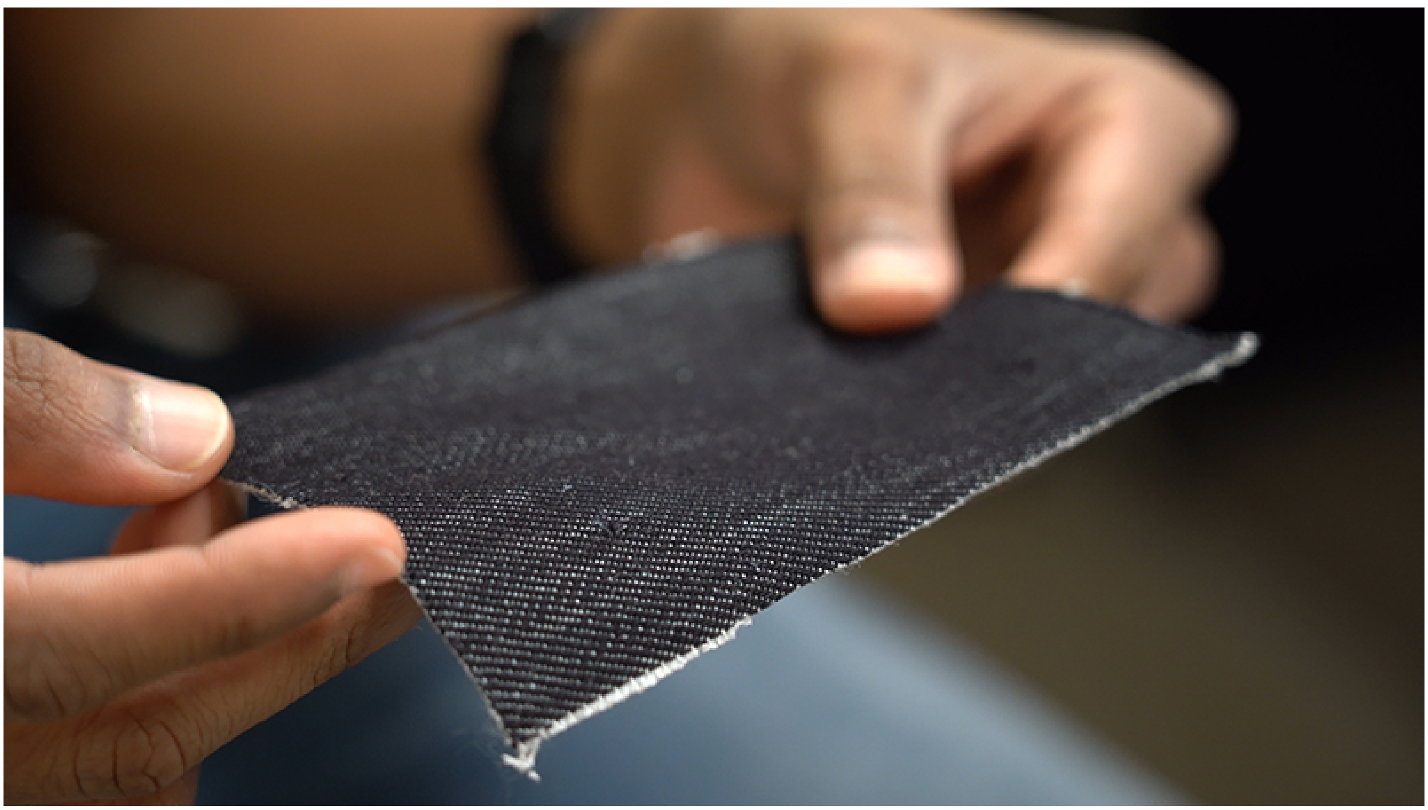
Note to journalists: A video about this research is available on **YouTube (https://www.youtube.com/watch?v=TT_KbU4y5iM)**. The research paper is available online open-access on the **journal's website (https://www.nature.com/articles/s41598-021-87957-7)**. Photo and video of the researchers testing the fabric are available via **Google Drive (https://drive.google.com/drive/folders/1jSabmRfEQkJjPKQYZYHW96VKqQz96w23?usp=sharing)**. Journalists visiting campus should follow **visitor health guidelines (https://www.purdue.edu/newsroom/media/media-visit-protocols.html)**.



WEST LAFAYETTE, Ind. — As smartwatches become more powerful, they will generate more heat. To prevent burns or rashes, what if a material touching the skin could feel as cool as metal, but also be flexible enough to be worn on the wrist?

A team of Purdue University engineers has discovered that a type of fabric typically used for hiking gear has remarkable heat-conducting properties on par with stainless steel, potentially leading to wearable electronics that successfully cool both the device and the wearer's skin.

The material is made of ultra-high molecular weight polyethylene fibers, which are sold commercially under the brand name **Dyneema (https://www.dsm.com/dyneema)**. These polymer-based fabrics are marketed for their high strength, durability and abrasion resistance, and are often used to create body armor, specialty sports gear, ropes and nets.



Researchers have discovered that a commercial fabric typically used for hiking gear has the heat-conducting properties of stainless steel, allowing the material to dissipate heat more effectively than other fabrics. (Purdue University photo/Jared Pike) ***Download image (https://www.purdue.edu/uns/images/2021/weibel-fabricLO.jpg)***

Purdue heat transfer researchers recently investigated other uses for the fabric, namely as a cooling interface between human skin and wearable electronics (see a video about this research on **YouTube (https://www.youtube.com/watch?v=TT_KbU4y5iM)**). Their research is published in **Scientific Reports (https://doi.org/10.1038/s41598-021-87957-7)**.

"This fabric has great flexibility and thermal properties. If you stitch it differently, weave it differently or start blending the polymers with different materials, you could tailor the fabric's properties to different applications," said **Justin Weibel (https://engineering.purdue.edu/ME/People/ptProfile?resource_id=78578)**, a research associate professor in Purdue's **School of Mechanical Engineering (https://engineering.purdue.edu/ME)**.

If a material has a high thermal conductivity, that means heat dissipates through the material more easily. There are many heat-dissipation methods for fabrics, from the simple (moisture-wicking); to the intricate (conventional fabrics with heat-conducting strands woven in); to the very complex (liquid-cooled garments worn by astronauts).

"Your next smartwatch or virtual reality headset could be more powerful than your current smartphone, so we need to dissipate heat away from the electronic components to keep the wearer comfortable," said Aaditya Candadai, who recently completed his Ph.D. at Purdue doing research on this project. "These polymer fabrics have amazing thermal properties that can keep these devices cooler and avoid low-degree skin burns."

The team discovered these properties by benchmarking Dyneema against conventional cotton fabrics, as well as polyethylene sheets in rigid non-woven form. They obtained several different commercially manufactured fabric samples and even wove their own samples from raw Dyneema fibers.

The researchers tested the fabric samples at the **Birck Nanotechnology Center (https://www.purdue.edu/discoverypark/birck/)** in Purdue's **Discovery Park (https://www.purdue.edu/discoverypark/)**. The samples went into a small vacuum chamber, with a metal wire laid across the surface as a heat source.

Using an infrared microscope, they could generate detailed data about how much heat was being conducted through the fabric's surface, and in which direction. They found that the Dyneema fabric has 20-30 times higher thermal conductivity than other fabrics, comparable with steel.

The team also tested the fabric's flexibility, which is important for wearable electronics.

"There's a balance; we don't want to make thermally conductive materials that are so stiff, people won't be comfortable wearing them," Candadai said. "These polymer fabrics are in that sweet spot of having good conductivity and good flexibility."

The fabric naturally has these properties with no additional circuity or other equipment, but the researchers also have plans to test how weaving in different materials affects the fabric.

"We could integrate other types of fibers – carbon fibers, metal fibers – to achieve different combinations of properties," said **Amy Marconnet (https://engineering.purdue.edu/ME/People/ptProfile?resource_id=86360)**, an associate professor of mechanical engineering.

As part of his work investigating the **heat-conducting properties of fabrics (https://pubs.acs.org/doi/10.1021/acsapm.9b00900)**, Candadai won an **Art-In-Science award (https://engineering.purdue.edu/ME/News/2019/cool-denim-artwork-one-of-purdues-itherm-awards)** in 2019 for an infrared camera image showing how the fabrics transfer heat. The team's research was performed within **Purdue's Cooling Technologies Research Center (https://engineering.purdue.edu/CTRC/research/index.php)**, a graduated National Science Foundation Industry/University Cooperative Research Center with support from industry leaders in thermal materials and electronics.

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Media contact: Kayla Wiles, 765-494-2432, **wiles5@purdue.edu (mailto:wiles5@purdue.edu)**

Writer: Jared Pike

Sources: Justin Weibel, **jaweibel@purdue.edu (mailto:jaweibel@purdue.edu)**

Amy Marconnet, **marconnet@purdue.edu (mailto:marconnet@purdue.edu)**

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ABSTRACT

Thermal and mechanical characterization of high performance polymer fabrics for applications in wearable devices

Aaditya A. Candadai, Emily J. Nadler, Jack S. Burke, Justin A. Weibel, Amy M. Marconnet

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With advances in flexible and wearable device technology, thermal regulation will become increasingly important. Fabrics and substrates used for such applications will be required to effectively spread any heat generated in the devices to ensure user comfort and safety, while also preventing overheating of the electronic components. Commercial fabrics consisting of ultra-high molecular weight polyethylene (UHMW-PE) fibers are currently used in personal body armor and sports gear owing to their high strength, durability, and abrasion resistance. In addition to superior mechanical properties, UHMW-PE fibers exhibit very high axial thermal conductivity due to a high degree of polymer chain orientation. However, these materials have not been widely explored for thermal management applications in flexible and wearable devices. Assessment of their suitability for such applications requires characterization of the thermal and mechanical properties of UHMW-PE in the fabric form that will ultimately be used to construct heat spreading materials. Here, we use advanced techniques to characterize the thermal and mechanical properties of UHMW-PE fabrics, as well as other conventional flexible materials and fabrics. An infrared microscopy-based approach measures the effective in-plane thermal conductivity, while an ASTM-based bend testing method quantifies the bending stiffness. We also characterize the effective thermal behavior of fabrics when subjected to creasing and thermal annealing to assess their reliability for relevant practical engineering applications. Fabrics consisting of UHMW-PE fibers have significantly higher thermal

conductivities than the benchmark conventional materials while possessing good mechanical flexibility, thereby showcasing great potential as substrates for flexible and wearable heat spreading application.

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