

Warmer or cooler, faster wicking or additional air permeability, and now, possibly even shape-shifting, materials that adjust their properties to varying conditions are paving the way for the next generation of smart clothing.

Chain reaction

A textile would be genuinely smart if it were capable of adapting to changing conditions or needs in an active, as opposed to a passive, manner. The possibility of programming materials to modify their properties is far from widespread, but creative textile engineering has worked out a few solutions. Some materials generate heat when needed, while others speed up wicking processes or let more air through in a certain situation.

Developed in the early 1990s, Outlast claims to offer warmth or coolness on demand thanks to an encapsulated phase-change material (PCM) embedded in a fibre (viscose or polyester) or coating. The capsules are filled with paraffin that will melt in warm conditions, absorbing excess heat in the process, and will solidify when temperatures drop, a process that releases heat. "Outlast can be engineered to have different melting points," says Martin Bentz, Outlast Europe's managing director. These would be necessary to adjust to a user's own temperature differences, "as feet are usually colder and the head is the hottest part of the body," he says.

Outlast Xelerate, a new product launched this year, brings the technology to the next level, says Mr Bentz. A layer of conductive material is printed on the fabric and spreads heat throughout its surface following a grid pattern. "The Xelerate print spreads more heat, which is absorbed by the PCM over a larger area. This speeds up the melting and crystallisation process of the PCM, making it work more proactively and reducing hot spots in the garment," he says. The cool silver look of the grid gives the product a 'spacey' aesthetic. "In the laboratory, we have proven that with the help of Outlast Xelerate technology, thermal conductivity can be increased by up to 30%," Volker Schuster, in charge of R&D at Outlast Europe.

Sitip, an Italian fabric manufacturer based in Cene, Italy, has worked with Japanese fibre producer Asahi Kasei to create Behot, a fabric that it claims generates and retains heat when stretched. This kinetic function is due to Asahi Kasei's Roica elastane yarn that converts movement into energy. The fabric is said to produce "at least a 1°C difference" due to an exothermic reaction when stretched. Repeated expansion and contraction will generate and absorb heat, Asahi Kasei states.

Promoted as providing a permanent fresh effect, Polartec Delta has been featured in Salewa's collections.

Salewa

Thermal Booster, by insulation specialist Thermore, is another reactive material based on a temperature sensitive polymer that is coated on the wadding. The polymer expands in cold conditions to "boost" the product's thermal properties by up to 20% the company claims.

Now based in Tennessee, US, Polartec believes it has the best solution for active thermal insulation with its Polartec Alpha fabric. "We've created and dominated the active insulation category with Polartec Alpha," company CEO Gary Smith told *WSA*. The company's newest product, Polartec Power Fill, adds to the range with a filler that does not require a scrim layer, as opposed to most thermal insulations, thus shedding a few grammes off the weight of a garment and improving its ability to adjust its properties to the environment. Developed to broaden its offering beyond insulation, Polartec Delta can also be considered adaptive. The special knit construction holds and releases moisture when the wearer begins to sweat.

The c_change membrane used by Schoeller and Eschler in their collections is a smart, waterproof, windproof and breathable film that reacts to changing temperature and activity levels. Inspired by pine cones, the biomimetic material opens its pores when the temperature rises or physical activity increases, allowing excess heat to escape. When the wearer or outside conditions cool down, the pores close to keep warmth near the body. This helps to ensure optimum comfort in all situations, the company states.

Dynamic cooling

Textiles that activate wicking when sweat builds up rely on the effects of evaporative cooling, the closest the industry has come to reactive moisture management. As moisture evaporates off the skin it removes excess heat, resulting in a feeling of freshness. In that sense, these materials model their properties on human physiology.

One of the first novel finishes developed by Swiss chemicals company HeiQ, Smart Temp (formerly known as Adaptive), instigates a series of dynamic reactions in evaporation, fabric wetting and wicking. Combined, the company claims they reduce body heat in warm conditions and retain warmth when it gets chilly.

Omni-Shade Sun Deflector, a new technology introduced by Columbia Sportswear in its S/S'18 collection, also takes a smart approach to excess heat and sun exposure. The fabric is coated with sun-reflecting titanium dioxide dots on the outside, and in its trail range, now branded Columbia Montrail, the company has applied its proprietary Omnifreeze Zero rings to the inside. This doubles the fresh effect of the fabric, which also has a special construction, says Christelle Bretaudeau, the company's spokesperson for Europe.





(Top) Outlast's climate-regulating PCM absorbs, stores and releases excess body heat to adapt its properties to changes in its surrounding conditions. The recently launched Outlast Xelerate optimises heat management to speed up the phase-change process.

Outlast

(Bottom) This denim-print laminate by Eschler, the knit division of Swiss textile manufacturer Schoeller, is made with a "bionic" c_change membrane that adapts breathability to activity.

Schoeller Textil AG

Biomorphic properties

A number of research labs are working on creating other types of responsive materials. One focus of these programmes is to combine materials that react differently to changes in humidity or temperature.

A team at MIT's Tangible Media Group has designed a prototype moisture-responsive material. The smart ingredient in the BioLogic workout suit is a layer of living microbes embedded on latex that is then coated onto a fabric. The cells shrink or expand with varying humidity levels, opening and closing small flaps cut in the garment. They can therefore be said to act as micro sensors and actuators. The cells chosen (E. Coli) are safe to touch and even consume, the lab has said. "The cell solution is extruded through a printer and deposited on a sheet of latex measuring 200 microns. After drying, the cell layer is about 5 microns. We

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This breathable shape-shifting workout suit prototype is coated with E. Coli cells that shrink or expand with varying humidity levels, opening and closing the ventilating flaps in response to an athlete's body heat and sweat. The photo on the left was taken before exercise when ventilation flaps are flat; after exercise (right), the ventilation flaps have curved.

Hannah Cohen

created the flaps by using latex sheet with coated cells on both sides. It opens up when we sweat, which provides air ventilation through the opened flaps," Dr Wen Wang, a former research scientist in MIT's Media Lab and Department of Chemical Engineering told *WSA*. The current prototype has been subjected to 100 dry/wet washing cycles without experiencing any serious degradation in either its cell layer or its overall performance.

The research team believes that, thanks to the genetic engineering tools available today, the cells could be made to express other functionalities, such as changing colour or emitting a scent. "The current prototype responds to humidity change by alternating shape and fluorescence. At different humidity levels, it shows different bending curvatures and fluorescent intensities. We are working towards changing the odour, but it is still in progress," says Dr Wang.

The BioLogic project was conducted in collaboration with sportswear brand New Balance, whose headquarters are in Boston, Mass. "New Balance supported our research in 2014-2015. We worked closely when developing the prototype. They provided the industrial insights and equipment. Two of them are also the co-authors of the paper published in *Science Advances*," says Dr Wang. No specific launch date has been announced, but he hopes BioLogic will be commercialised in about five years.

Otherlab, an innovation lab based in San Francisco, is also investigating biomorphic principles to create a thermo-adaptive textile that adapts to varying climate conditions. Founded by two MIT PhDs, Brent Ridley and Saul Griffith, Otherlab is studying various combinations of materials that react differently to temperature changes, expanding or retracting to adapt their insulating properties to the environment. "As temperature changes, the lengths of the two materials change differently, inducing a bend in the pair that, in a textile structure, can bring about a change in thickness," Brent Ridley has stated in an interview for *The Smithsonian*.

Combining fibres and yarns that behave differently in certain conditions is common in textile processing to obtain special colourings that change with the angle of vision or light. Expanding this notion to temperature and humidity levels could lead to tomorrow's non-electronic smart clothing.



Introduced in the Columbia Montrail trail running collection, titanium-dioxide based Omni-Shade Sun Deflector protects wearers from the sun, while a layer of Omnifreeze Zero rings on the back of the fabric offers an additional injection of on-demand freshness.

Columbia Sportswear

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