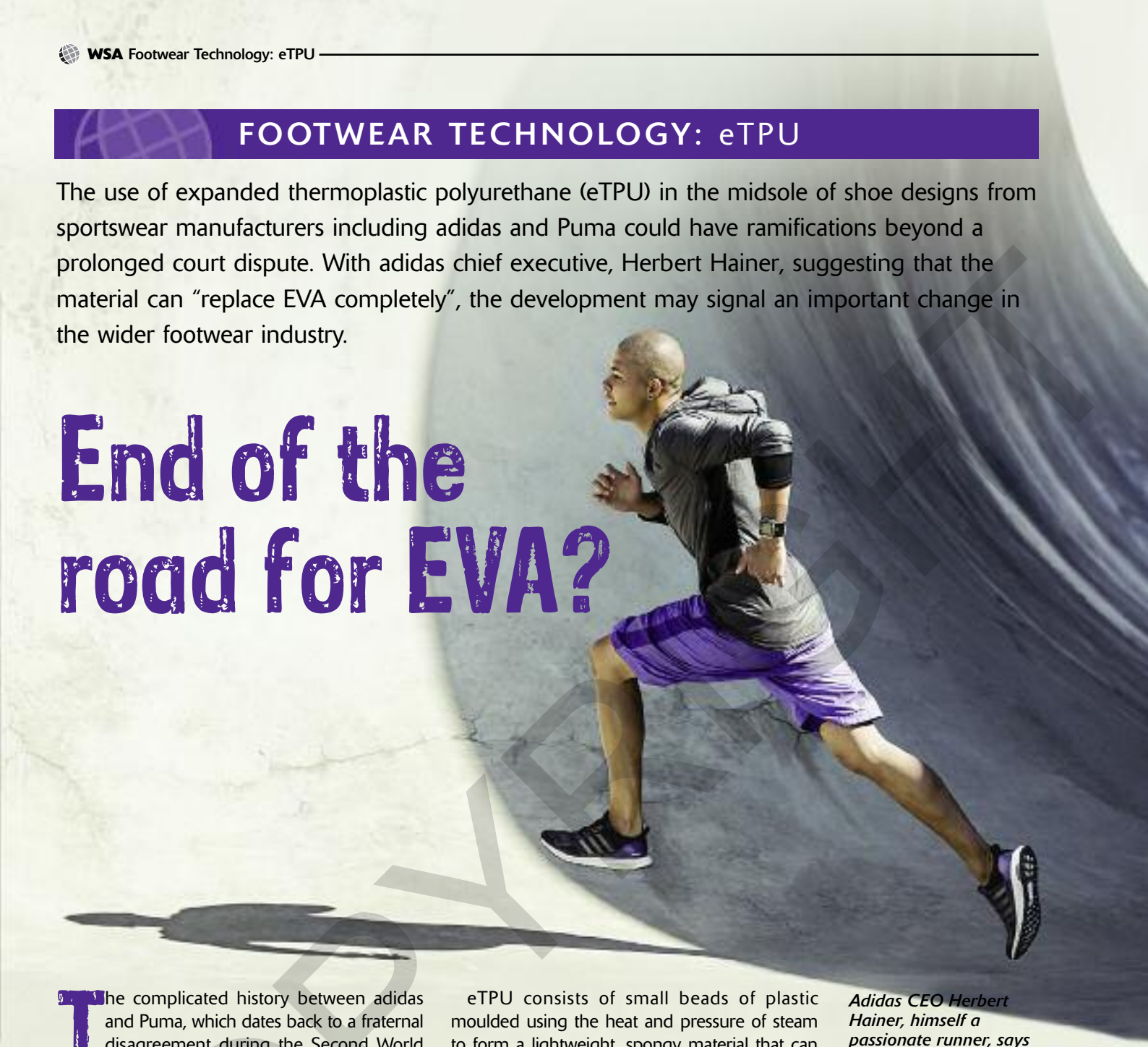
FOOTWEAR TECHNOLOGY: eTPU

The use of expanded thermoplastic polyurethane (eTPU) in the midsole of shoe designs from sportswear manufacturers including adidas and Puma could have ramifications beyond a prolonged court dispute. With adidas chief executive, Herbert Hainer, suggesting that the material can "replace EVA completely", the development may signal an important change in the wider footwear industry.

End of the road for EVA?



Adidas CEO Herbert Hainer, himself a passionate runner, says that eTPU could make EVA "obsolete". It has been the footwear industry's trusted synthetic material for over 30 years.

adidas

The complicated history between adidas and Puma, which dates back to a fraternal disagreement during the Second World War, has only served to intensify the competition between the brands. The running apparel and footwear market, just one sector in which the companies compete, is highly lucrative and industry projections suggest that it will continue to grow in the coming years. As a result, the two companies must continually strive to position themselves at the forefront of any technological advances.

Virtually all running shoes produced globally in the last 30 years have contained an ethylene-vinyl acetate (EVA) midsole, which made it difficult for any brand to use materials to stand out from the competition. As a consequence, competing brands devote considerable resources to research and development in order to find an edge; expanded thermoplastic polyurethane (eTPU) is the latest fruit of this research and its invention could bring about a move away from across-the-board use of EVA.

eTPU consists of small beads of plastic moulded using the heat and pressure of steam to form a lightweight, spongy material that can be used for the midsole of a running shoe. To produce it, Dr Frank Prissok, a scientist at chemicals and materials manufacturer BASF, succeeded in expanding the thermoplastic polyurethane Elastollan using a procedure that allows the benefits of TPU to be retained whilst adding the typical properties of foams. A closed-cell, elastic foam, which BASF called Infinergy, was the result.

According to Martin Vallo, head of footwear sales at BASF Polyurethanes, Dr Prissok first presented the idea to him during a coffee break in 2009. He explained: "The standard presentation of TPU is in the form of fine granules. Frank exposed these granules to pressure and heat and created eTPU."

What followed was three years of testing and fine-tuning to enhance the foam's performance characteristics. It was evident to BASF from an early stage that it had discovered something of

In 2015 adidas sold 12 million pairs of shoes featuring the Boost technology, with 10 million in the running category alone.

adidas

potential significance to running shoe manufacturers. Puma and adidas were eager to be at the front of the queue to capitalise on the development. This eventually resulted in a high-profile court dispute which came to a conclusion, of sorts, on April 19 this year.

Tug of war

The origin of the recent dispute dates back to the time that the sports companies separately spent working with BASF on alternatives to EVA. Puma developed an interest during the initial development of its NRGY line of footwear. In 2011, however, the agreement between the organisations was terminated and BASF joined forces with adidas, with whom it signed an exclusivity agreement. Puma, meanwhile, partnered with another technology provider, Huntsman Polyurethanes, and launched its first NRGY products in 2014. Adidas, who had already unveiled its own range featuring an eTPU midsole, calling it Boost, applied to the courts to block the release of Puma's products, citing violation of its exclusivity agreement with BASF.

This objection was dismissed by the Düsseldorf Higher Regional Court in April and Puma was cleared to continue selling NRGY shoes. According to Neil Narriman, head of intellectual property, the company will now promote the range more aggressively having held back from launching a number of products due to the ongoing legal dispute. As expected, adidas disagreed with the decision and is considering its next move. A spokeswoman has said that the company "will continue to vigorously protect our rights and will continue to take action in case of infringements". At the same time Puma is to press ahead with proceedings of its own against adidas for what it deems use of its research with BASF dating back to 2009. It believes that "development results, tools and know-how have been transferred". Adidas denies this, saying it worked with BASF in parallel to Puma, but the case is expected to run until at least October.

Bouncing back

As Dr Uwe Keppeler, material and process developer at BASF, explains: "eTPU is manufactured by foaming the starting material, TPU granules. After pre-treatment with pressure and heat, the individual granules measuring up to five millimetres each are blown up like popcorn."

This increases the volume tenfold, creating foam beads that have small, closed gas bubbles inside. It is these sealed air cells that give eTPU its elastic properties. Inventor Dr Prissok compares the beads to "tiny footballs" and says that "the more air they contain, the better they bounce back".

After a court in Düsseldorf ruled in its favour, Puma says it will market the NRGY range more aggressively, including the release of held-back products.

Puma

Marketing for the Boost and NRGY ranges has been centred on the energy-returning cushioning that the eTPU midsole offers. According to BASF, it springs back into shape immediately after impact with the ground. This cushioning triggers an energy-return every time downward force is applied, increasing efficiency and allowing the wearer to expend less energy while running. The closed-cell structure of the foam gives it excellent recovery ability. Tests of the resilience of the eTPU material showed it has a rebound height of 55%. This is significantly more than EVA, which has a rebound height of 35%. It also comfortably outstrips expanded polystyrene (EPS) by 20%, and polypropylene (EPP), 30%. BASF describes it as "the most elastic particle foam currently available on the market".

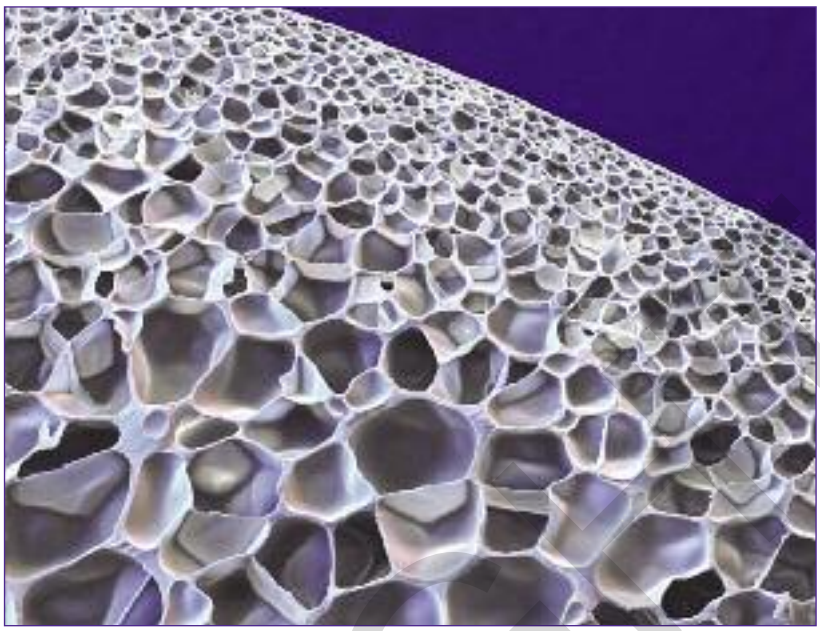
Soles made from eTPU are more durable as the material is able to maintain its shape for longer. Due to the nature of EVA expansion, the level of performance deteriorates more quickly. This material robustness reduces the need for the runner to rotate running shoes, a practice that has long been recommended by athletic shoe retailers and experts in order to prevent injuries.

High-frequency fatigue testing showed that it continues to be resilient under continuous load, performing 75% better than expanded polyethylene (EPE). An EPE test piece lost a considerable percentage of thickness during testing, whereas the eTPU sole lost less than 10%. This suggests that the new foam returns nearly all of the energy exerted on it.

Gerd Manz, senior innovation director for global brands at adidas, says that during testing "we compress the material 10,000 times to evaluate its resistance. Although the foam is softer than previous materials, the cell structure remains intact for much longer and the shoe retains its properties for hundreds of kilometres."

It also performs well across a range of temperatures. It was tested from -20ºC to 40ºC and the results showed that the sole underwent less hardening in cold temperatures and less softening when exposed to warmer conditions. This temperature resistance makes it ideal for an all-purpose running shoe. "We analysed the temperature stability in a climate chamber and found that the soling material offers three times greater temperature resistance compared to conventional foam," Mr Manz explains. It also absorbs less water, allowing it to function effectively in extreme weather conditions. Over a 24-hour testing period only 2% of water by volume was absorbed, which compares favourably to the recorded performance of EVA.

As a particle foam, eTPU benefits from a low bulk weight. With a density of 110kg/m³ (resulting in a moulded part weight of 200-320 kg/m³), it is slightly heavier than EPS and EPP but lighter than elastomeric polyurethane foams.



Foam beads with closed gas bubbles inside give eTPU its ability to bounce back. BASF says Infinergy "can be used anywhere where customers require a combination of low weight, excellent mechanical properties and good durability across a wide temperature range."

BASF SE

Regular TPU is heavier than EVA and was unfavoured in athletic shoes for this reason. The expanded material is much lighter in weight which, when combined with its good flexibility, makes it suitable for use in all kinds of sports.

Several of the positive characteristics of TPU are retained during the expansion process including high breaking elongation (between 100% and 150% depending on the density), high tensile strength (approximately 600 kilopascals) and good abrasion resistance. It also has good chemical resistance.

With the help of crack splitting and pressure filling, eTPU is suitable for large-scale manufacturing as it can be processed on conventional thermoplastic injection machines used for EPP, PVC or TPR. Splitting machines, punches and water jet cutting machines, which are already used in the production of other soling materials, can also be used, as can processing techniques such as adhesive bonding and foam sealing.

Before this advance, EVA was already at a disadvantage compared to TPU because a sole made from the latter can be directly injection-moulded on to the upper of a shoe. A sole made from EVA needs to be attached using adhesive, resulting in increased labour and material costs.

BASF has been quick to stress that its hopes for eTPU are broader than midsoles for running shoes. Having already developed a range of Padel bats containing the material alongside racket maker Dunlop, the company sees the potential for its use in other sporting settings, including as a cover for athletic tracks or to create puncture-resistant bicycle tyres.

Whilst it's not yet time to write a eulogy for EVA, early signs suggest that eTPU could be the immediate future of the running shoe midsole. The ferocity of the battle between adidas and Puma over its use only serves to strengthen this hypothesis.