

Nano-membranes

Lighter and finer than conventional extruded films, non-woven membranes, made using a manufacturing technique called electrospinning, may be the next big thing in water resistant clothing and footwear. Being fabrics rather than films, their open pore structure allows them to breathe whilst also preventing external moisture penetration in much the same way as the PTFE and PU membranes that are in current widespread use. But, at down to only 3 nanometres thick and weighing a

mere 5 g/m², electrospun non-woven membranes could well be setting new standards for membranes in the future.

In the electrospinning process, a polymer is mixed with a solvent to make it liquid and forced through a nozzle or syringe into an electrical field. The resulting yarns are whipped or spun and fall onto a moving carrier as a tangled array of nano-filaments to produce a non-woven fabric. The actual yarns themselves measure only in the order of a hundred nanometres and so the resulting non-woven is

both ultra light and extremely fine.

Electrospinning is not a new technology. The process was in fact patented by JF Cooley and WJ Morton in the early 1900s. Its further development however, owes much to Anton Formhals, a German textile engineer who believed it could be used as a method of producing synthetic fibres and subsequently filed some 22 patents during the 1930s and 1940s. It has now been used in industrial applications for fifteen or so years, mostly for filtration purposes but also for breathable waterproof membranes.



CREDIT: D RAVANEL

BEGINNING IN SPORTSWEAR

2010 saw the first use of an electrospun membrane in performance sportswear when Polartec launched a triple-layer fabric called PowerShield Pro. At 5,000mm water penetration resistance and 2cfm (cubic feet per minute) air permeability, its performance was considered ideal for water resistant clothing. The following year, it introduced NeoShell, with water resistance penetration at 10,000mm and air permeability down to 0.5cfm based on an improved version of the non-woven the company describes as a 'discontinuous polyurethane membrane'. The minimal amount of air passing through the fabric means it is more windproof and therefore more comfortable in adverse conditions with zero cfm the absolute ideal. However, while that might not be so important for footwear, what it does show is that such a thin membrane can be produced with a range of highly effective and useful properties.

The membrane used in the NeoShell range is produced by Finetex, a Korean company that holds the patent for what it calls Technoweb Pro nanofibre technology and licenses the product exclusively to Polartec. Based in Seoul and founded in 2004, Finetex has been working on electrospinning since the 1990s and is one of the few companies producing the material on an industrial scale. The membrane is said to be predominantly made of polyurethane, although it would seem that the manufacturing process can accommodate combinations of multiple polymers in different layers so that a measure of non-hydrophobic polymer for instance could be included to round out the membrane's overall performance.

3D NANOWEB

A considerable number of research laboratories are now working on electrospinning and some European companies such as El Marco in the Czech Republic are producing machines. South Korean companies have nevertheless made remarkable progress and are considered front runners in the field. Bristex for instance, the maker of Sealon tapes, has been working on electrospinning for the past two to three years. The firm has patented the concept as an Electro-Nano Membrane and currently

sells it to Korean companies only. "It is essentially a nano-sized version of an interlining," says managing director Keun-Hun Chang.

The technology used is known as melt electrospinning. Chips of polymer material are melted and nano-sized fibres produced by extruding the melted polymer through nozzles after which they are subjected to high voltage and air that spins and scrambles them as they fall onto a slow moving carrier as described earlier. The speed of the carrier determines the thickness of the non-woven in exactly the same way as spun-bonded non-wovens such as Typar that are used for shoe upper reinforcement.

The resulting non-woven web is made of fibres measuring between 5 and 500 nanometres in a 3D open-pore structure with an average of 25 billion microscopic pores per centimetre. Although on its own, it weighs only 7 g/m², the company says it can in fact go down to 5 g/m². The polymer used is PVDF (polyvinylidene difluoride), a fluoropolymer with some very interesting properties. This means for example, that it is hydrophobic as opposed to PU (polyurethane) the dominant polymer used by Finetex, which is hydrophilic. PVDF also has a much lower elongation point than PU, although Bristex says that it is also working on a PU version.

Once laminated, the Bristex membrane is said to offer an initial waterproof barrier of 5,000 mm, water vapour permeability from 9,000 to 10,000 using a 'dynamic' test and 30,000 to 40,000 g/m²/24 hours with a 'static' test, and air permeability of 1cfm. In other words, it would appear to have a good all-round performance in terms of comfort. The company has high hopes of its new nano-membrane and Keun-Hun Chang says that work is also under way to develop a version for use in footwear, in particular for water-resistant running shoes where lightweight and flexibility are so important.

GREAT POTENTIAL

Prof. Paul Kiekens's team of researchers in the Textile Department at the University of Ghent in Belgium has been working on electrospinning for the past ten years and is installing a machine they have designed and built

themselves. "Our machine is quite flexible, we have tested many different types of polymers including the usual textile ones such as polyester, polyamide, polypropylene, etc.," says Prof Kiekens, who sees great potential in the technology: "The nanoweb has an enormous surface area. It is rather easy to add other components or active ingredients during the manufacturing process and these will have higher efficiency due to the material's high surface area."

Compared to conventional porous or non-porous films, the non-woven structure of electrospun fabrics means they generally have a fairly low mechanical resistance. While Prof. Kiekens sees their inherent fragility as a weakness, he nevertheless believes this problem should be resolved within the next few years. He says the real difficulty with this lies in identifying "the optimal resin and in the right concentrations" to laminate the fine membrane. This he believes will also be worked out by the end of the decade.

A remaining hurdle for electrospun membranes is addressing the risk factor of working with nano-materials. "Once stabilised in the non-woven, the nano-fibres do not pose a problem," says Prof Kiekens. "But you cannot exclude the element of risk during the manufacturing process because this is when the fibres can be volatile. There are concerns, which the European Union considers real, conducting numerous studies." Proper measures are recommended during production to ensure worker safety.

The Professor and his team have also carried out a considerable amount of research into electrospinning and have investigated its potential application to footwear. As a result, he strongly believes that the industry could benefit from the technology and in fact submitted a footwear-based project to the EC in 2012. For some reasons, it was rejected with the result that a wealth of technical knowledge and expertise, although potentially available, is not to be fully commercially exploited in Europe in the years to come. In the meantime, South Korea is pressing ahead and Europe may miss the chance to be world leader in what might well prove to be an extremely important new technology for both clothing and footwear. 