By E&T editorial staff

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Scientists from California Institute of technology and Nanyang Technology University (NTU) Singapore have developed a new type of fabric with all the flexibility of cloth, but which stiffens on demand, becoming more like chain-mail armour or Batman’s cape.

The soft, lightweight fabric is 2D printed from nylon plastic polymers and is comprised of hollow, interlocking octahedrons. It is normally as flexible as any other cloth, but when wrapped within a flexible plastic envelope and vacuum-packed, it turns into a rigid structure 25 times stiffer than when in its ‘relaxed’ state.

Known as “wearable structured fabric”, its inventors hope it could lead to the creation of new smart fabrics which can harden to protect the wearer against an impact (such as in bulletproof vests or kits for high-impact sports) or to provide support when additional load-bearing capacity is needed (such as on construction sites or in configurable medical support).

“With an engineered fabric that is lightweight and tuneable, easily changeable from soft to rigid, we can use it to address the needs of patients and the ageing population, for instance, to create exoskeletons that can help them stand, carry loads and assist them with their daily tasks,” said Professor Wang Yifan, lead author of the *Nature* study.

“Inspired by ancient chain-mail armour, we used plastic hollow particles that are interlocked to enhance our tuneable fabrics’ stiffness. To further increase the material’s stiffness and strength, we are now working on fabrics made from various metals including aluminium, which could be used for larger-scale industrial applications requiring higher load capacity, such as bridges or buildings.”

The switch between soft and rigid is thanks to a principle called the “jamming transition”, which is similar to the behaviour of vacuum-packed bags of rice or beans. During this transition, aggregates of particles switch from a fluid-like soft state to a solid-like rigid state with a slight increase in packing density.

Typically, solid particles are too heavy and do not provide sufficient tensile resistance for wearable applications incorporating this transition. For this fabric, the researchers designed structured particles in the shape of rings, ovals, square, cubes, pyramids and octahedrons, which locked together (topologically interlocked structures). These can be 3D printed as a single piece.

To add some means of controlling the stiffness of the fabric, the researchers encapsulated the fabric in a flexible plastic envelope and compacted the fabric with a vacuum which applies external pressure. Under pressure, each particle has more contact with its neighbours, resulting in a structure many times more rigid.

When formed into a flat, table-like structure and vacuum-locked, the fabric can sustain a load of 1.5kg (more than 50 times the mass of the fabric). The fabric also resisted impact more effectively in its rigid state by a factor of six: dropping a steel ball deformed the fabric by up to 26mm when relaxed, but by only 3mm when stiffened.

The researchers tried 3D printing the fabric in aluminium and demonstrated that it has the same qualities as nylon when relaxed, but can stiffen into armour-like structures. This could be wrapped in an envelope of Kevlar to incorporate into more comfortable body armour, such as bulletproof vests.