Two-dimensional (2D) materials have many useful properties, which are very attractive for applications in smart textiles. However, only graphene and graphene oxide have been successfully manufactured into fibers without additive/binders so far. In a pioneering study by Zhang et al., an international multidisciplinary team developed, for the first time, a multifunctional additive-free MXene fiber with the 2D sheets aligned along the fiber axis. MXenes constitute a large family (30+ members) of 2D early transition metal (e.g., Ti, V, Nb, Mo) carbides and nitrides discovered in 2011. In addition to the large number of possible MXenes based on transition metal and C/N, MXene surfaces are terminated with O, OH, F, or Cl, leading to a very wide compositional space. The compositional versatility and tunability of properties, including excellent electrical conductivity, hydrophilicity, intercalation ability, have qualified MXenes to be excellent candidates for many applications.

The overwhelming majority of MXenes manufacturing studies have focused on using either powders of multilayered MXene or free-standing films of restacked MXene sheets prepared from aqueous colloidal solutions of 2D sheets of delaminated MXene. The former does not utilize the entire surface area of MXene, as layers are strongly bonded together by hydrogen bonds and van der Waals forces. On the other hand, for the free-standing films of restacked MXene, the way the layers stack on each other hinders the ions/liquid diffusion through the film, which can limit some applications such as electrochemical energy storage. Also, increasing the areal mass loading (mg/cm²) for MXene films can be problematic using filtration or spray-coating, which poses a scalability issue.

While the synthesis of MXene liquid crystal (LC) using surfactants was reported previously, Zhang et al. took advantage of MXenes’ hydrophilicity and their highly negative zeta potential in water to make liquid crystals without adding any stabilizing agents. Ti₃C₂ MXene was used as the main material in their study. Interestingly, they found that changing the lateral dimension of MXene flakes from ~3 μm (labeled L-Ti₃C₂) to ~0.3 μm (labeled S-Ti₃C₂), with the aid of probe sonication, resulted in a significant shift in the transition concentration from isotropic to nematic for MXene LC, and Schlieren textures were observed at concentrations of 13.2 mg/mL and 66.3 mg/mL for L-Ti₃C₂ and S-Ti₃C₂ respectively. Pure MXene fibers were manufactured by wet-spinning MXene LC in various coagulation baths using a syringe pump as shown in Figure 1a.

The potential applications of pure MXene fibers extend beyond what was reported by Zhang et al. and include water purification and smart textiles where MXene can be used for sensing, energy storage, triboelectric energy generation, electromagnetic interference shielding, antennas, and temperature regulation in clothes.
Depending on the content of a coagulation bath, MXene fibers with different characteristics can be achieved. Acetic acid or chitosan coagulation baths yield strong fibers that can be transferred onto a spool as shown in Figure 1b, producing a 5 m long pure MXene fiber. Investigating the newly made pure MXene fiber shows that 2D sheets are aligned along the fiber axis (Figure 1c). An acetic acid coagulation bath resulted in a porous fiber with a density of 1.7 g/cm³, while chitosan coagulated MXene fiber with a density of 3.6 g/cm³. The difference in densities was attributed to the speed of the coagulation (Figure 1d,e). Figure 1f shows that the denser MXene fibers had a higher tensile strength than that of lower density. Considering that the single layer of MXene has a tensile strength more than 2 orders of magnitude higher than that of MXene fiber, it is reasonable to expect that the strength of the fibers can be increased significantly by further increasing the lateral size of MXene sheets and changing the bonding between them. Similar to tensile strength, electrical conductivity was found to be the highest in L-Ti₃C₂ coagulated in chitosan, at \( \sim 7750 \) S/cm, which exceeds the conductivity of graphene fibers.¹ Spinning other MXenes, viz. Ti₂C and Mo₂TiC₂, was successfully achieved, proving that the procedure developed in this study is universal for the MXenes family.

In an effort to explore the functionality of these pure MXene fibers, Zhang et al.² studied them as electrode materials for supercapacitors in the acidic electrolyte and found that the best performance was achieved for S-Ti₃C₂ coagulated in chitosan (Figure 1g) with a stable performance (Figure 1h) which is comparable to what was reported for free-standing MXene films with a thickness of a few microns. They also showed that the fibers can be used as joule heating elements (Figure 1i,j) and exhibit a heating rate of 600 °C/s, which is higher than that reported for graphene.⁹

The potential applications of pure MXene fibers extend beyond what was reported by Zhang et al.² and include water purification and smart textiles where MXene can be used for sensing, energy storage, triboelectric energy generation, electromagnetic interference shielding, antennas, and temperature regulation in clothes. The liquid crystalline state of MXenes can be used in many manufacturing processes to shape a variety of products and control orientation of flakes in films or 3D structures. It is worth noting that the fiber diameter can be controlled by changing the spinning nozzle size. One can imagine slicing a large diameter MXene fiber or bundle of small diameter fibers to make discs of MXene with edge-on MXene ribbons (like slicing an onion into onion rings) allowing for extremely fast access of ions and electrolytes to the electrochemically active surface area of MXene while maintaining the high packing density of the pure fiber.

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Notes
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