Materials Today • Volume 20, Number 8 • October 2017

Uncovered

2D metal carbides (MXenes) in fibers

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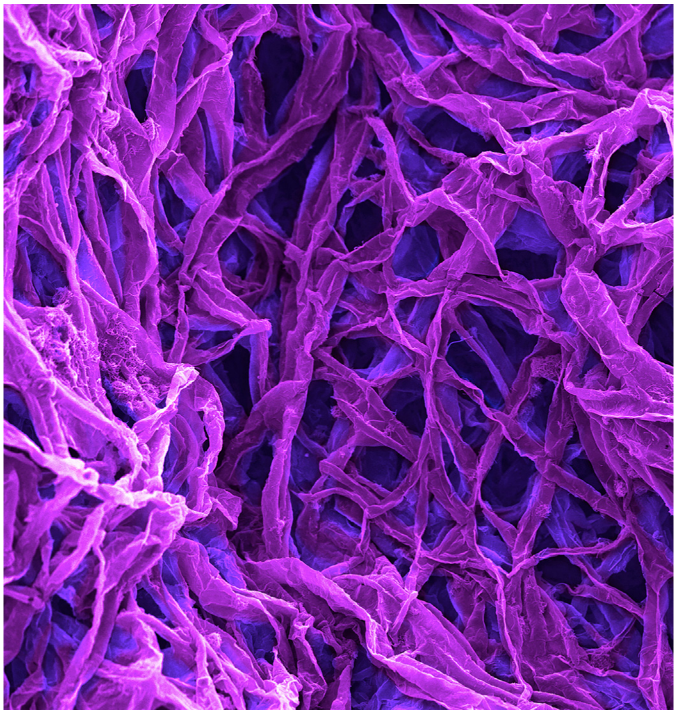

As technology advances, our expectations from wearable and portable electronics increase. Our active lifestyle dictates a need for materials that can harvest and store energy, store data, communicate with other devices, and at the same time be convenient and easy-to-wear. Wearable sensors and antennas, radio-frequency identification (RFID) tags, flexible roll-up touch screens, and implanted medical devices are emerging fields that create more awareness about our bodies and encourage a healthier lifestyle. Fabricating flexible and small-size energy storage is another research area that is attracting tremendous attention. However, it is still a great challenge to make thin and flexible electronic devices. One of the main steps toward this goal is to produce reliable thin and light materials that combine superior electronic conductivity, energy storage capability and mechanical integrity and flexibility.

Two-dimensional (2D) materials are among the most promising materials for portable devices due to the high level of control of their properties at the atomic scale and large surface area [1]. 2D materials can be integrated into fibers to fabricate wearable and flexible electronics [2]. However, these hybrid structures usually suffer from low electronic conductivity and mechanical integrity.

A large family of 2D metal carbides and nitrides, called MXenes, has emerged with more than 20 different compositions already synthesized (for example, Ti_2C, V_2C, Nb_2C, Mo_2C, Mo_2TiC_2, Nb_4C_3, etc.), and many more theoretically predicted (for example, Sc_2C, Ti_2N, Mo_2VC_2, etc.) [3]. MXenes have a general formula of $M_{n+1}X_n$, where M represents a transition metal (for example, Sc, Ti, Zr, Hf, V, Nb, Ta, Cr, Mo), X is carbon and/or nitrogen, and $n = 1$–3. Because of the top-down synthesis by selective etching, all MXenes reported to date have surface terminations, such as oxygen, fluorine, or hydroxyl, shown as T_x in the $M_{n+1}X_nT_x$ formula. MXenes have a high electronic conductivity (up to 10,000 S/cm in multilayer films) and hydrophilicity which make them promising for a variety of application such as in energy storage [4,5], electromagnetic interference (EMI) shielding [6], biosensors [7], water purification [8], medicine [9] and gas sensing [10]. When used as electrodes in energy storage devices, MXenes can act as a current collector, conducting agent and electrochemically active material at the same time [3]. Due to their 2D morphology, MXenes can be easily processed into films [11], which can be used in flexible devices. MXenes' high surface area and reactivity, high

1369-7021/ http://dx.doi.org/10.1016/j.mattod.2017.08.001

conductivity, useful optical properties, hydrophilicity and biocompatibility, can all be retained in fibrous architectures designed for flexible electronic devices.

On this issue's cover, we present a fibrous MXene architecture fabricated by dip coating of $Ti_3C_2T_x$ MXene from aqueous colloidal solution onto an electrospun polymer fiber mat from polycaprolactone (PCL), a widely studied polymer for electrospinning. Dip-coating was done by immersing a branch polyethylenimine (bPEI) modified PCL electrospun mat, rending the mat positively charged, into a negatively charged $Ti_3C_2T_x$ solution. Due to the black color of $Ti_3C_2T_x$, the mat color changed from white to black after MXene deposition. bPEI modified carbon nanotubes (CNT) dispersed in an aqueous solution were then dip coated on the MXene layer as spacers to prevent stacking of 2D MXene flakes in the next cycle of dip coating. The layer-by-layer assembly led to a mass loading of $Ti_3C_2T_x$ (vs. PCL) up to 10 wt%. We annealed the CNT-MXene-PCL composite at 400 °C under argon flow for 4 h to decompose the polymer. Interestingly, the ultra thin CNT-MXene composite kept the shape of the original fibers, forming an open fibrous scaffold. The hollow CNT-MXene fibers may find applications in catalysis, water desalination, or hydrogen evolution due to its high surface area. Hollow 2D fibers will have much improved accessibility of active sites for these applications. The cover image (40 μm in width) was taken from these fibers using a scanning electron microscope (Zeiss Supra 50VP, Germany).

The dip coating method presented here is only an example of several ways to shape 2D MXenes into fibers. Other methods include wet or melt spinning [12] and spray-coating of MXene solutions onto polymeric templates. The possibility to obtain conductive fibrous structures from MXenes is a first step toward making efficient and convenient wearable electronics. Multifunctionality and versatile chemistry of MXenes allow us to build various devices, such as transistors, electromagnetic interference shields, antennas, or supercapacitors, all from the same material.

Acknowledgements

We acknowledge the use of SEM of the Core Research Facilities (CRF) at Drexel University.

Further reading

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