Multifunctional MXene-PAA microgel hybrids for high-performance conductive 3D printing inks and aerogels

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This work presents a novel approach for designing a multifunctional MXene-based ink with record-low solid content for 3D printing applications. By leveraging the unique properties of $Ti_3C_2T_x$ MXene nanosheets and polyacrylic acid-based microgels, we engineer a hybrid ink that exhibits a combination of high elasticity, high electrical conductivity, and low solid content. The ink formulation process involves a thermodynamically guided assembly approach, where MXene nanosheets are spatially confined within the jammed microgel network. This confinement prevents uncontrolled aggregation of MXene while simultaneously imparting favorable rheological properties for extrusion-based 3D printing.

The resulting MXene-microgel hybrid ink demonstrates remarkable printability, enabling the fabrication of high-fidelity 3D structures with excellent shape retention. Printed structures can be transformed into free-standing hydrogels and subsequently freeze-dried to yield highly porous, electrically conductive aerogels. This enhanced performance stems from the percolated conductive network formed by aligned MXene nanosheets, even at low concentrations. The aerogels exhibit an excellent electrical conductivity of 360 S/m and electromagnetic interference shielding (EMI) effectiveness of 57 dB.

The engineered MXene-microgel system exhibits excellent mechanical properties, with the aerogels demonstrating resilience to over 5000 times their own weight without structural collapse. This approach opens up new avenues for the development of 3D printable, multifunctional soft materials with potential applications spanning EMI shielding, energy storage, and wearable electronics.