

Figure S1. SEM images of MnO₂-MXene at different magnifications and the corresponding elemental mapping images of C, O, Ti, and Mn.

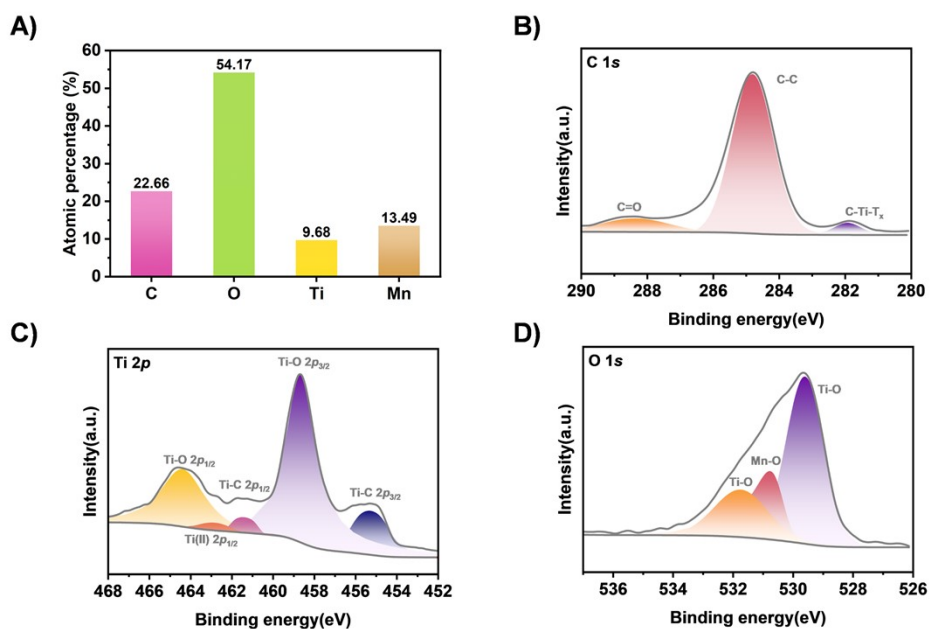


Figure S2 Synthesis and physicochemical characterization of MnO₂-MXene.

(A) Atomic composition of MnO₂-MXene determined by EDS analysis.

(B-D) High-resolution C 1s, Ti 2p and O 1s XPS spectra of the MnO₂-MXene sample.

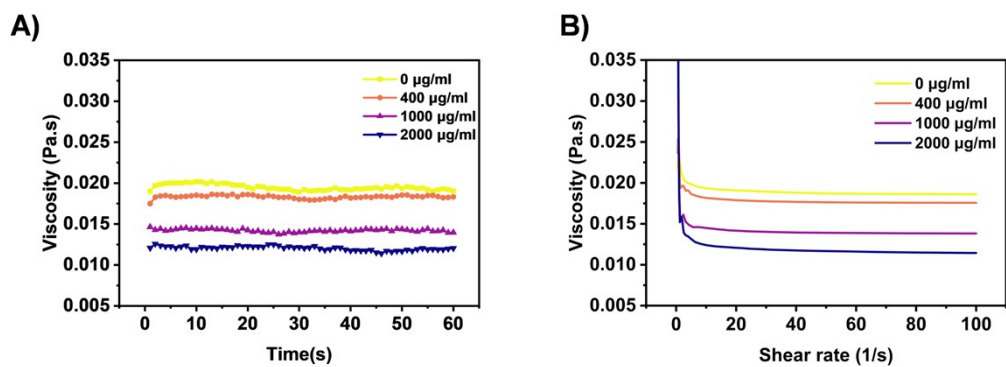


Figure S3 Rheological properties of MMG hydrogel precursor solutions.

(A) Time-dependent viscosity of GelMA and MMG hydrogel precursor solutions.

(B) Shear rate-dependent viscosity of MMG hydrogel precursor solutions.

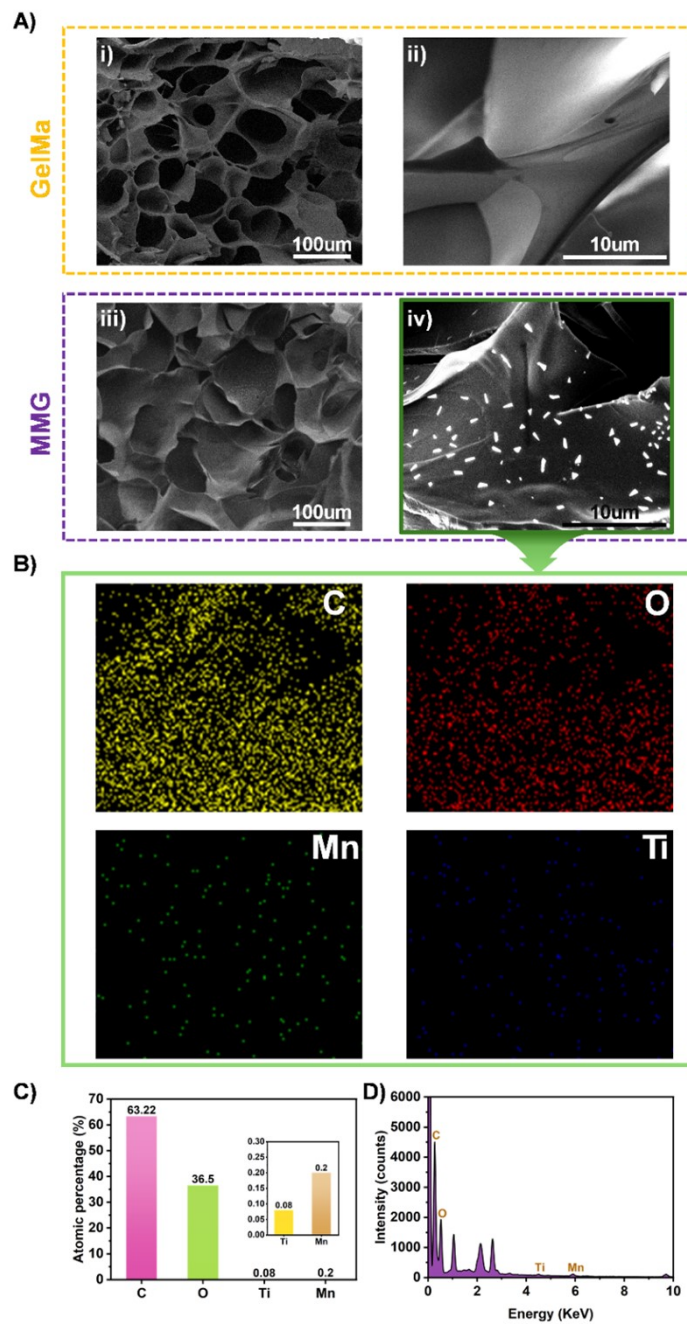


Figure S4. Microstructure and elemental characterization of GelMA and MMG hydrogels. (A) SEM images of GelMA and MMG hydrogels at different magnifications. (B) Elemental mapping images of MMG hydrogels showing the distribution of C, O, Mn, and Ti. (C-D) EDS spectrum and corresponding atomic percentage analysis of MMG hydrogels.

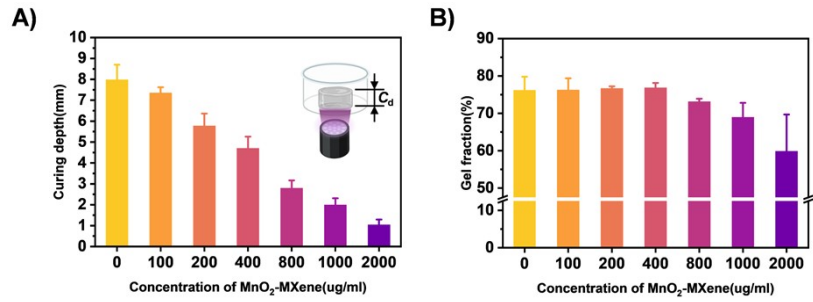


Figure S5 Photopolymerization characteristics of MMG hydrogel.

(A) Curing depth of MMG hydrogels as a function of MnO₂-MXene concentration. Samples were exposed to UV irradiation (405 nm, 40 mW cm⁻²) for 300 s.

(B) Gel fraction of photocrosslinked MMG hydrogels.

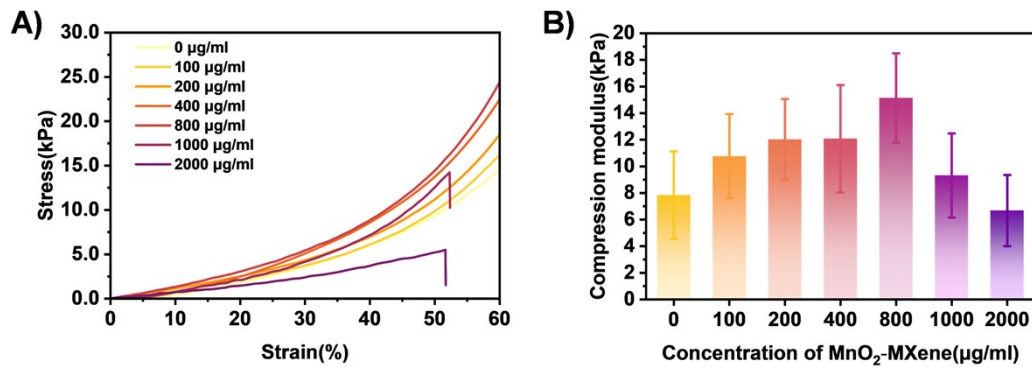


Figure S6 Compressive mechanical properties of MMG hydrogel.

(A) Compression curve.

(B) Compression modulus.

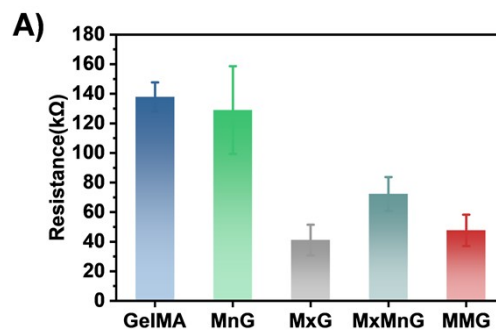


Figure S7. Electrical resistance of crosslinked GelMA, MnG, MxG, MxMnG and MMG hydrogels.

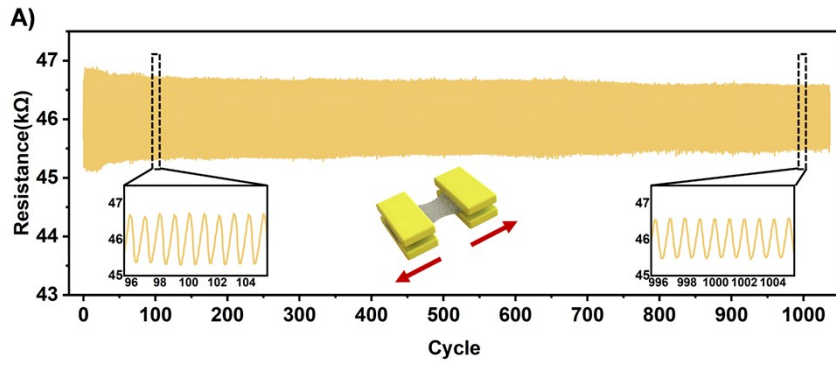


Figure S8. Electrical resistance evolution of solid MMG hydrogel subjected to 20% tensile strain over 1000 cycles.

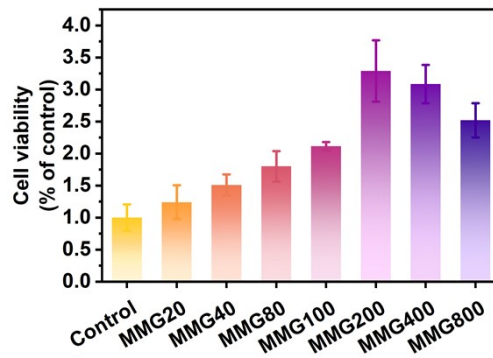


Figure S9. Cytotoxicity evaluation of MMG hydrogels at different concentrations using H9C2 cells.

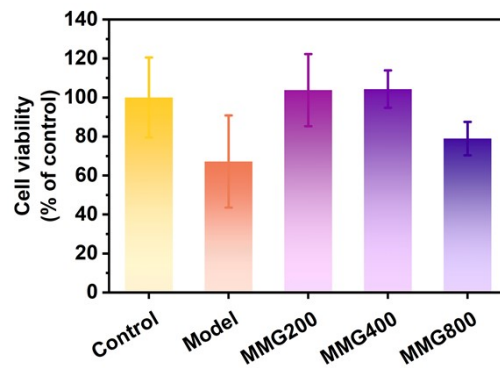


Figure S10. Cell viability of H9C2 cells under H_2O_2 -induced oxidative stress with MMG treatment at different concentrations.

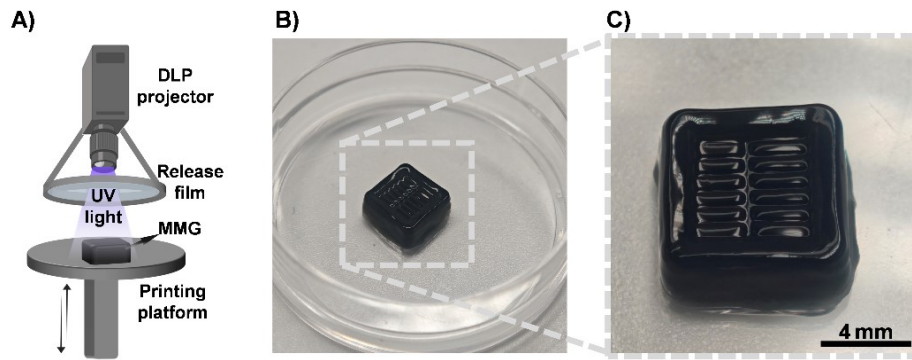


Figure S11. DLP 3D printing of structured MMG cardiac patches.

(A) Schematic illustration of DLP-based photo-crosslinking process for MMG hydrogel printing.

(B) Photograph of a 3D-printed MMG cardiac patch.

(C) Enlarged view of the printed MMG cardiac patch showing a grooved microstructure.