Effects of electron beam irradiation crosslinking on microstructure and electrochemical performance of hybrid polyethylene separators for lithium-ion batteries

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Introduction & Background

Rechargeable lithium-ion batteries (LIBs) are one of the promising next-generation energy storage systems due to their high power density, high energy, ultra-fast charging, and no memory effect. As an important section of the LIBs, the separator is used to electrically insulate electrodes (anode and cathode) while guaranteeing ions migration between them. Ideal separators must have excellent chemical stability to electrolyte and electrode materials. Also, they must possess robust mechanical properties. Structurally, they should have adequate porosity to absorb the electrolyte and achieve excellent ionic conductivity. Herein, combining the industrialized biaxial stretching technique with E.B irradiation crosslinking, the nanocomposite separator with great commercialization potential is developed using UHMWPE and SiO_2 nanofillers.

Experimental Section

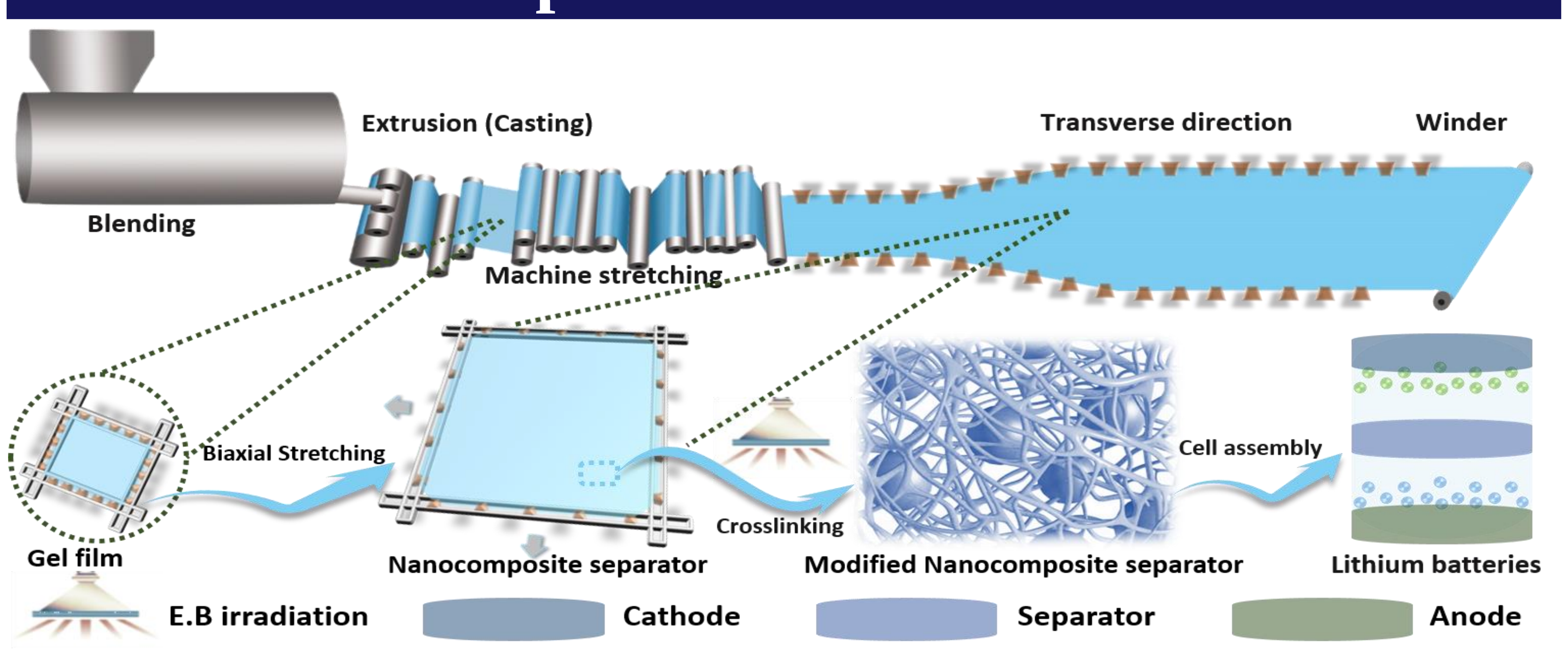

Fig. 1. Schematic representation of manufacturing and crosslinking of pure UHMWPE (M1) and nanocomposite UHMWPE-SiO_2 (M2) separators.

Results & Discussion

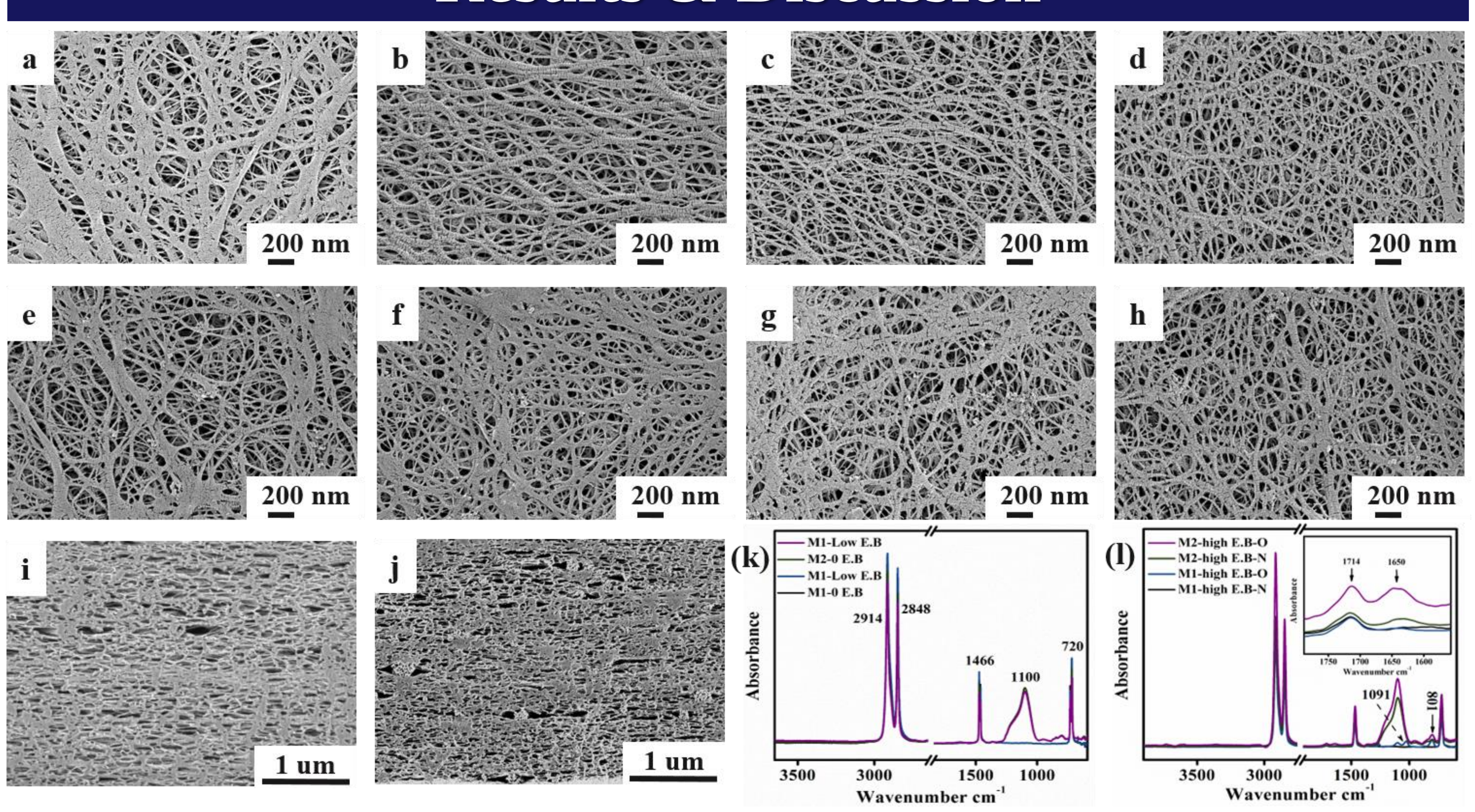

Fig. 2. SEM photographs of M1 and M2 irradiated using different E.B doses (a and e) 0 kGy, (b and f) 20 kGy, (c and g) 50 kGy and (d and h) 150 kGy. (i and j) the cross-section for M1-0 and M2-0. (k) ATR-FT-IR spectra of M1 and M2 before and after low dose E.B cross-linked, and (l) high doses under N_2 and O_2 atmospheres.

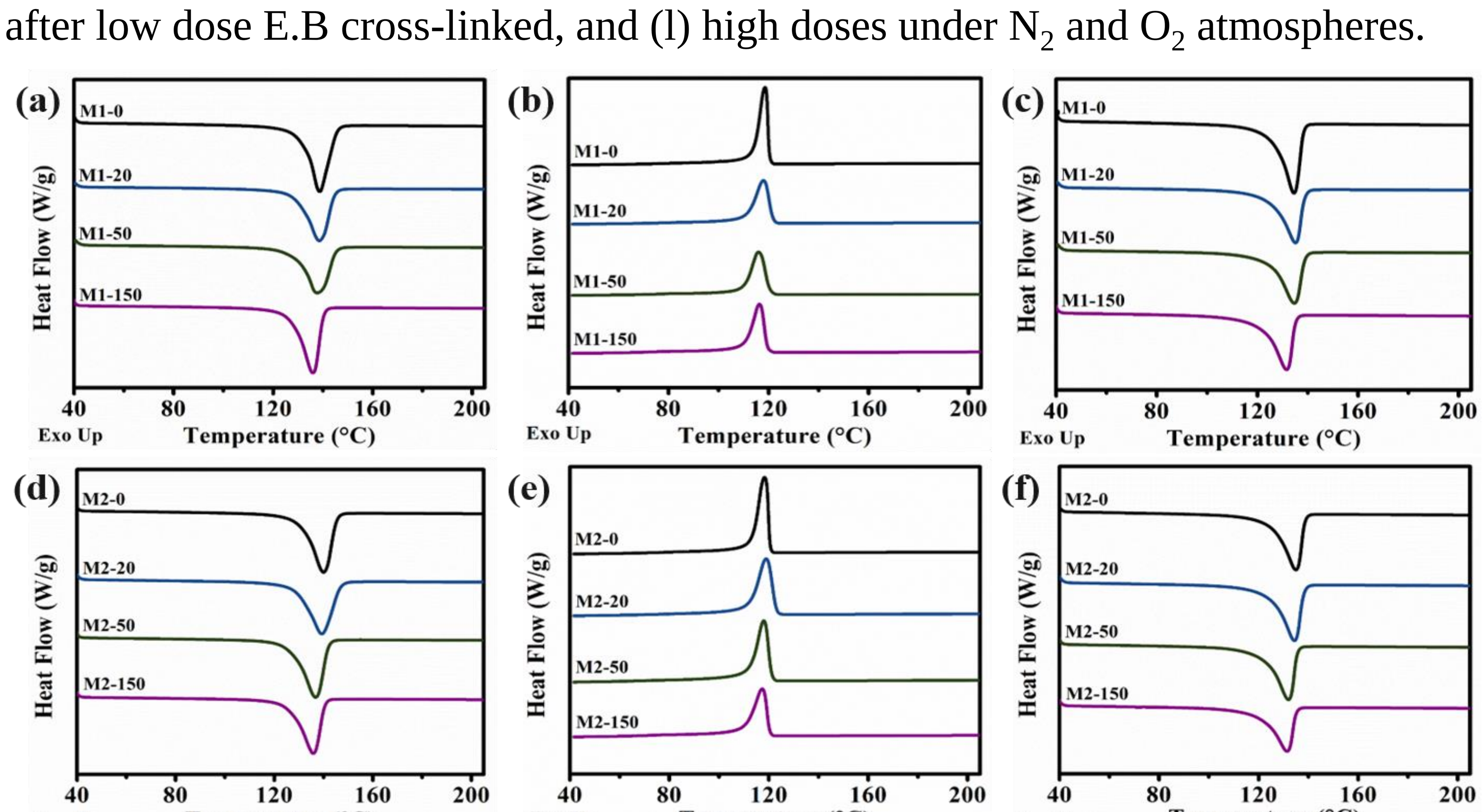

Fig. 3. DSC measurements: (a and d) first heating curves (b and e) cooling curves and (c and d) second heating curves for (a, b, and c) pure M1 and (d, e, and f) nanocomposites M2 separators cross-linked with different irradiation doses.

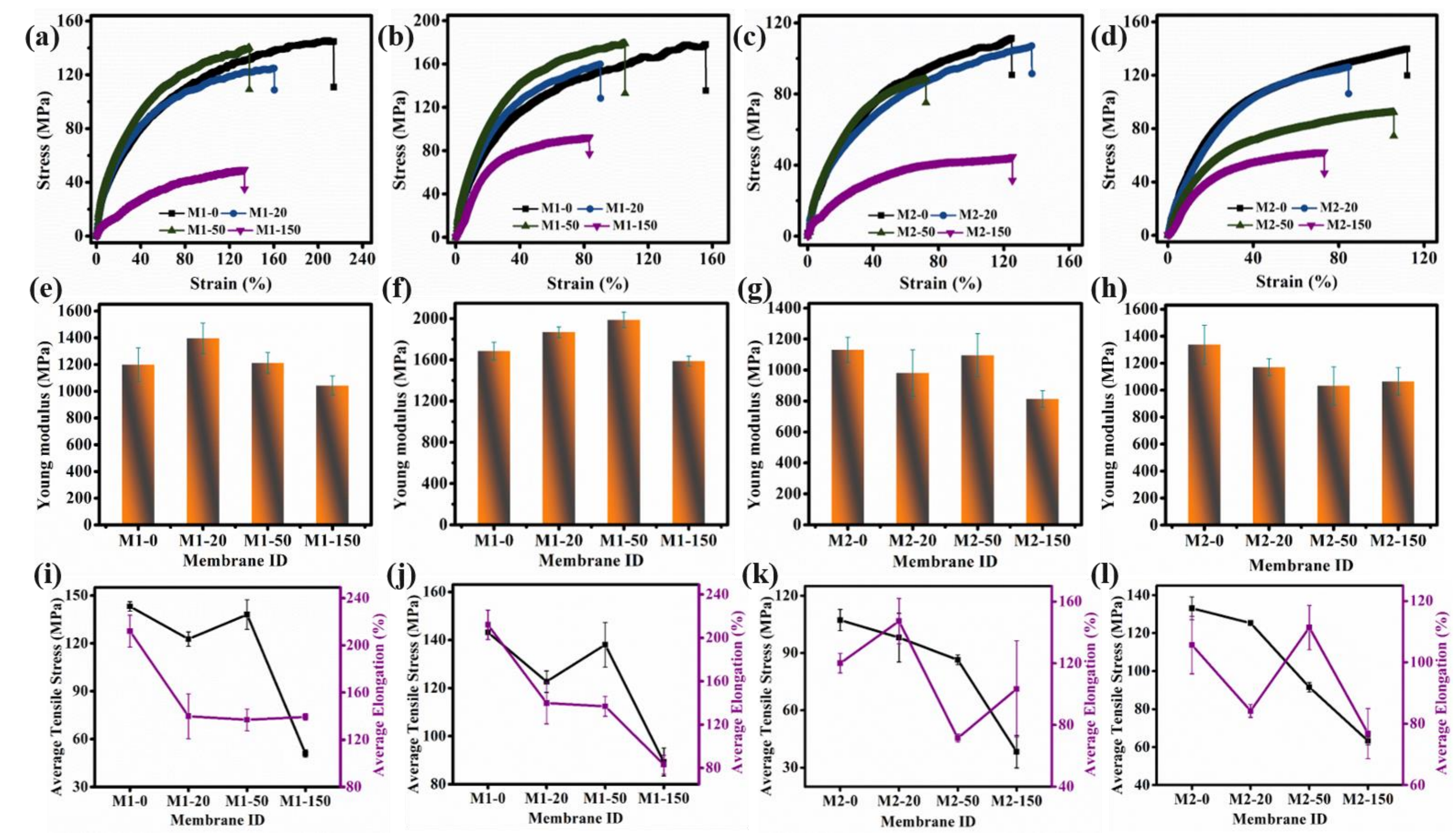

Fig. 4. Mechanical properties of M1 and M2 separators at different irradiation doses: (a-d) stress-strain curves, (e-h) Young modulus, and (i-l) summary of tensile strength and elongation at break; (a, e, and i) M1 in MD, (b, f, and j) M1 in TD, (c, g, k) M2 in MD, and (d, h, l) M2 in TD directions.

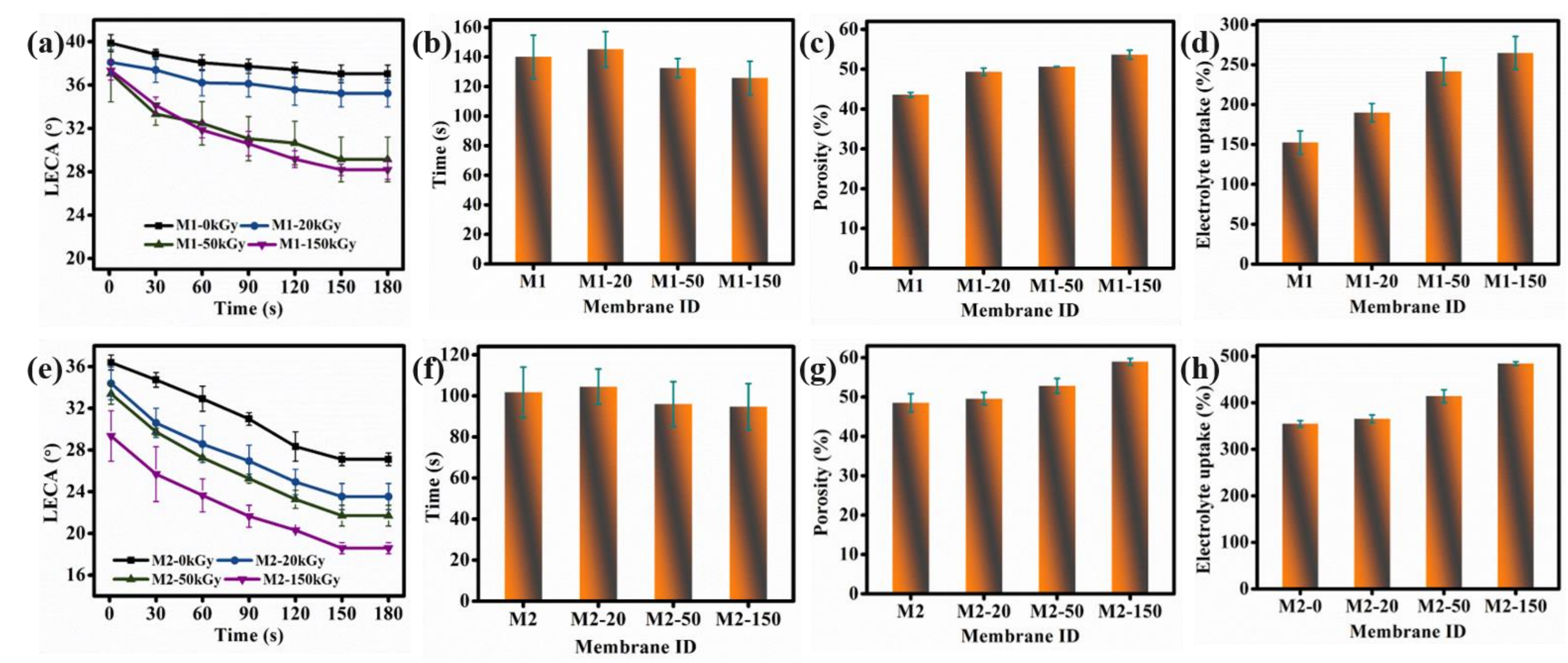

Fig. 5. (a and e) recorded liquid electrolyte contact angle “LECA”, (b and f) air permeability values, (c and g) porosities, and (d and h) electrolyte uptakes of pure M1 and nanocomposite M2 separators at different irradiation doses, respectively.

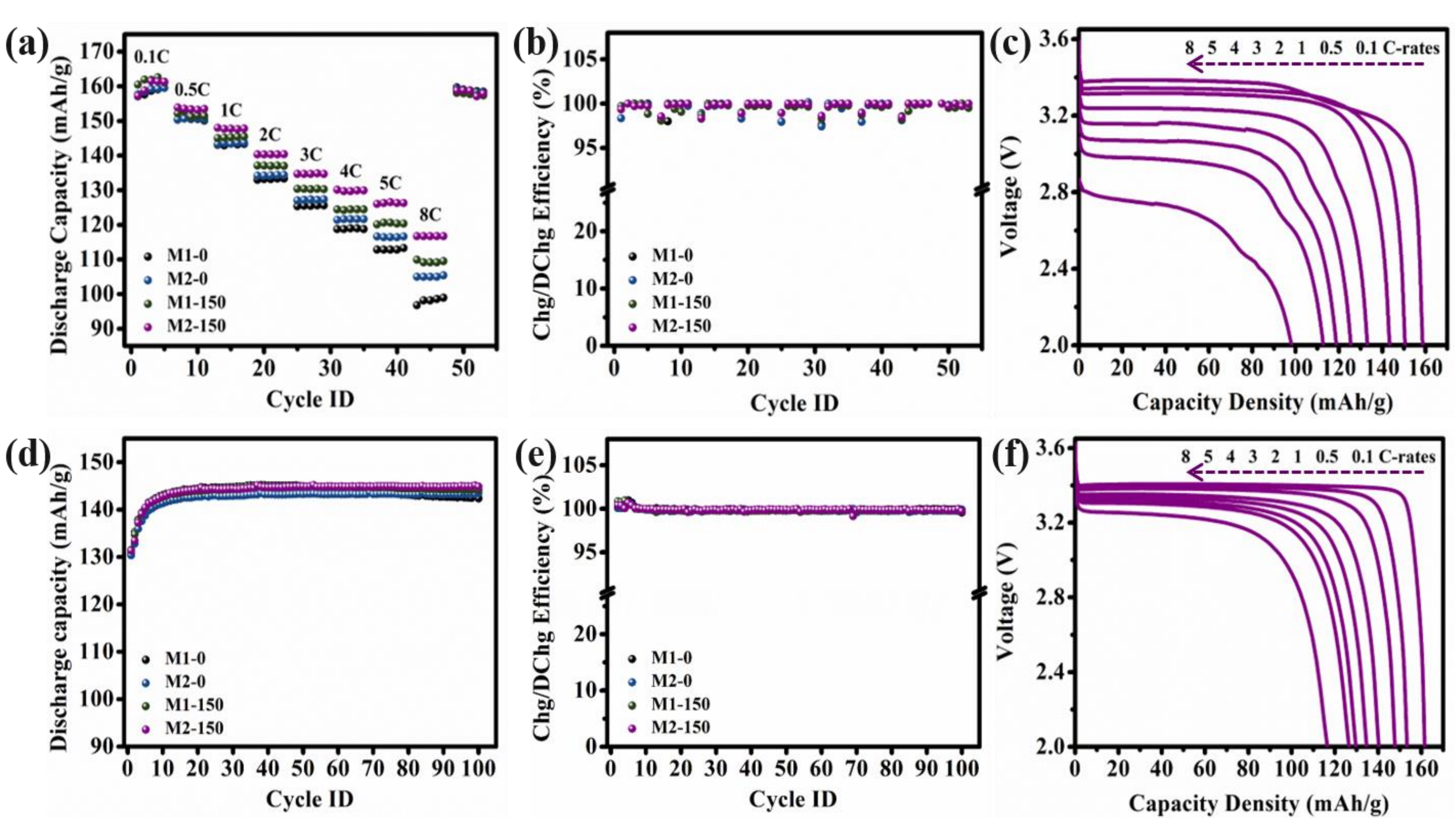

Fig. 6. Electrochemical performance of cells: (a) comparison of discharge C-rate capability of cells at different C-rates, and (b) the corresponding coulombic (CE). The cyclic performance of cells using different separators (d) specific discharge capacities of cells and (e) the corresponding CE of cells. Discharge profiles of cells at different C-rates with: M1-0 (c) and M2-150 separators (f).

Summary

A straightforward commercial process was demonstrated to prepare an advanced nanocomposite separator between UHMWPE and inorganic SiO_2, followed by E. Beam crosslinking without post-treatments. The influence of inorganic nanofillers and high energy E.B irradiation crosslinking on the structure, surface morphologies, mechanical and thermal properties and electrochemical performance of nanocomposite M2 separators cross-linked by various E.B irradiation doses (0, 20, 50, and 150) kGy were investigated and compared to that of pure (M1).

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