Mechanical and piezoresistive behavior of self-sensing MWCNT/UHMWPE nanocomposites processed via selective laser sintering (SLS)

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Introduction

- ✓ **Selective laser sintering (SLS)** exhibits various advantages such as relatively high strength of the printed parts, the absence of support structures, the ability to produce large batches and to recycle unfused powder [1].
- ✓ **Ultra-high molecular weight polyethylene (UHMWPE)** is a semi-crystalline thermoplastic polymer, possessing extraordinary characteristics such as good lubricity, high abrasion and impact resistance, chemical inertness, thermal stability and biocompatibility due to which it has found many practical applications in various fields particularly biomedical applications [2].
- ✓ **CNTs** have exceptional electrical as well as mechanical properties. Also, due to high aspect ratio of CNTs, the conductive paths between the fillers can be established efficiently even ***at low percolation thresholds*** [3].
- ✓ **In this study**, we experimentally evaluate the mechanical and piezoresistive performances of electrically conductive 3D printed MWCNT/UHMWPE nanocomposites and 2D lattice structures *with **self-sensing capabilities.***

Methodology

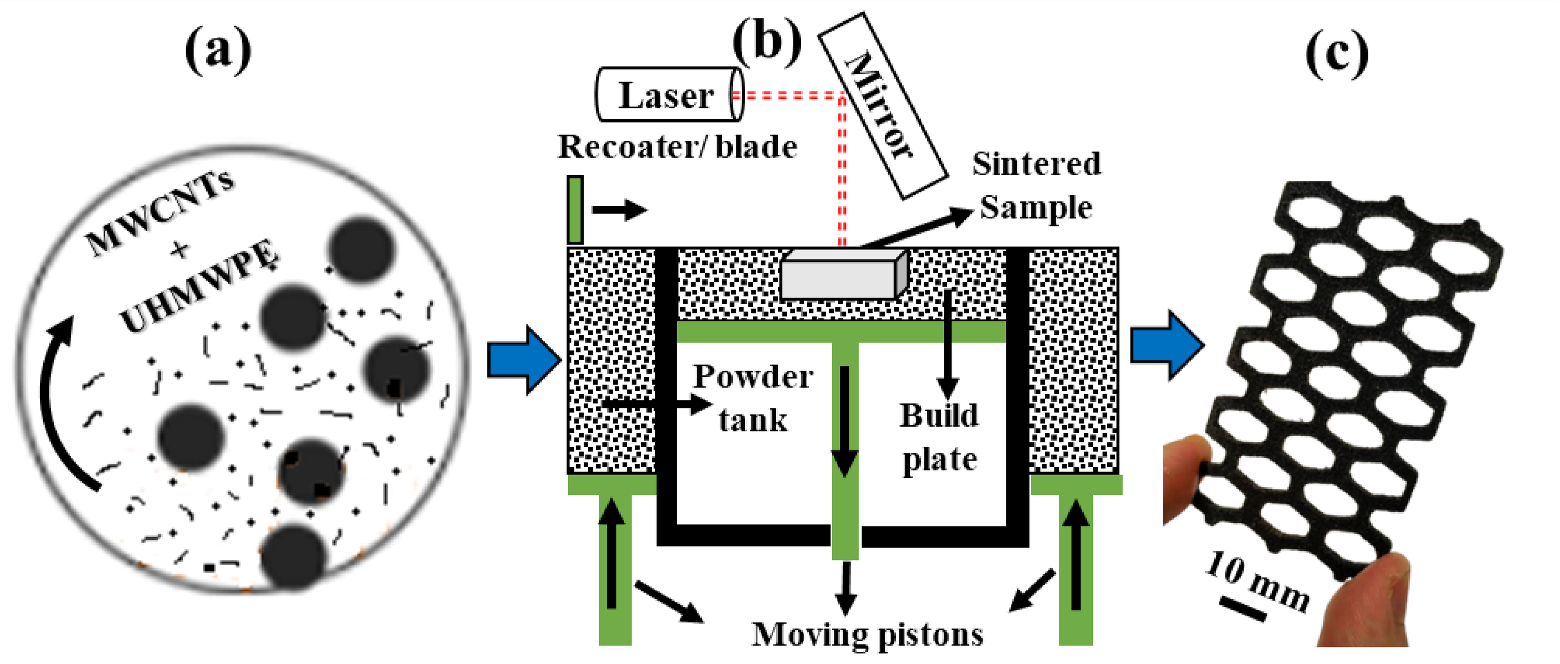

Fig.1 *Schematic of steps involved in processing of MWCNT/UHMWPE nanocomposites via SLS: (a) preparation of nanocomposite powders via ball milling, (b) 3D printing via SLS, (c) 3D printed structure.*

Measurement of mechanical and piezoresistive responses

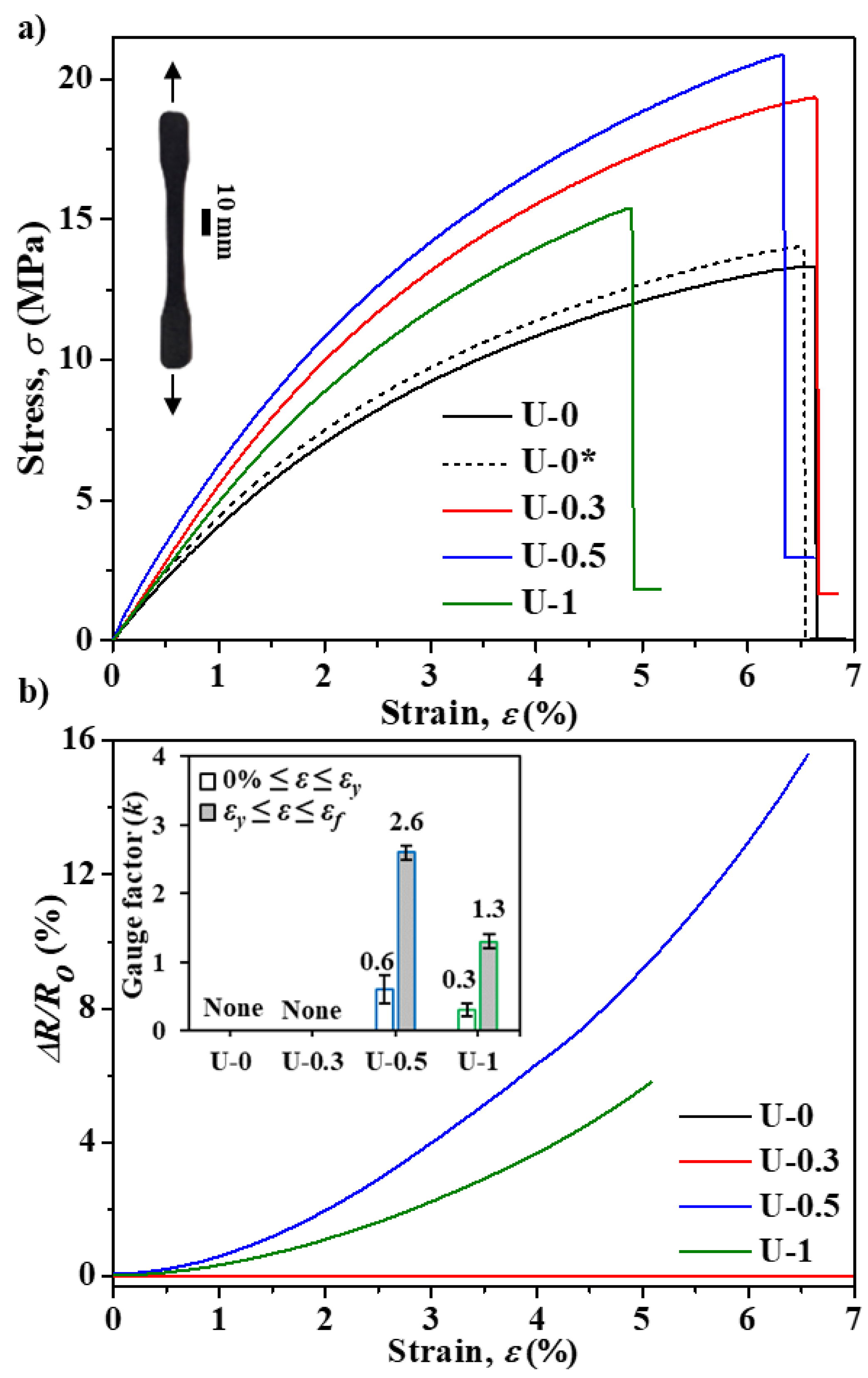

Fig. 2 *Mechanical and piezoresistive behavior of MWCNT/UHMWPE nanocomposites under uniaxial tension: (a) stress-strain response (b) piezoresistive response. Inset in (b) shows gauge factors calculated in elastic and inelastic regimes. Note: U represents the polymer matrix whereas numerals (0.3, 0.5, 1) are wt.% of MWCNT. U* represents the ballmilled pure polymer. ε_y is yield strain and ε_f is fracture strain.*

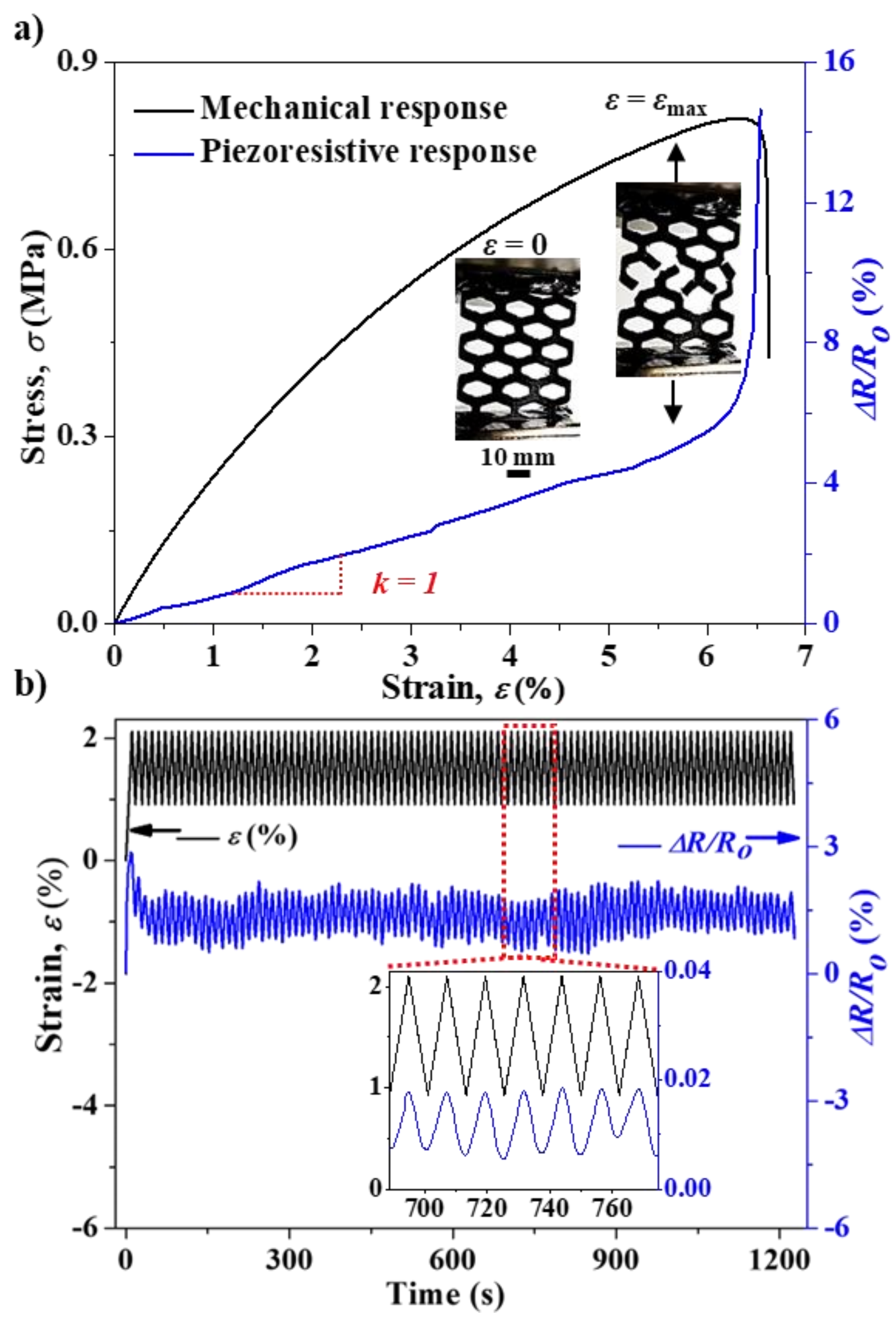

Fig. 3 *Mechanical and piezoresistive responses of MWCNT/UHMWPE 2D hexagonal lattice structures (0.5 wt.% MWCNTs) under: (a) quasi-static uniaxial tension; (b) constant cyclic loading in tension (100 cycles).*

Characterization

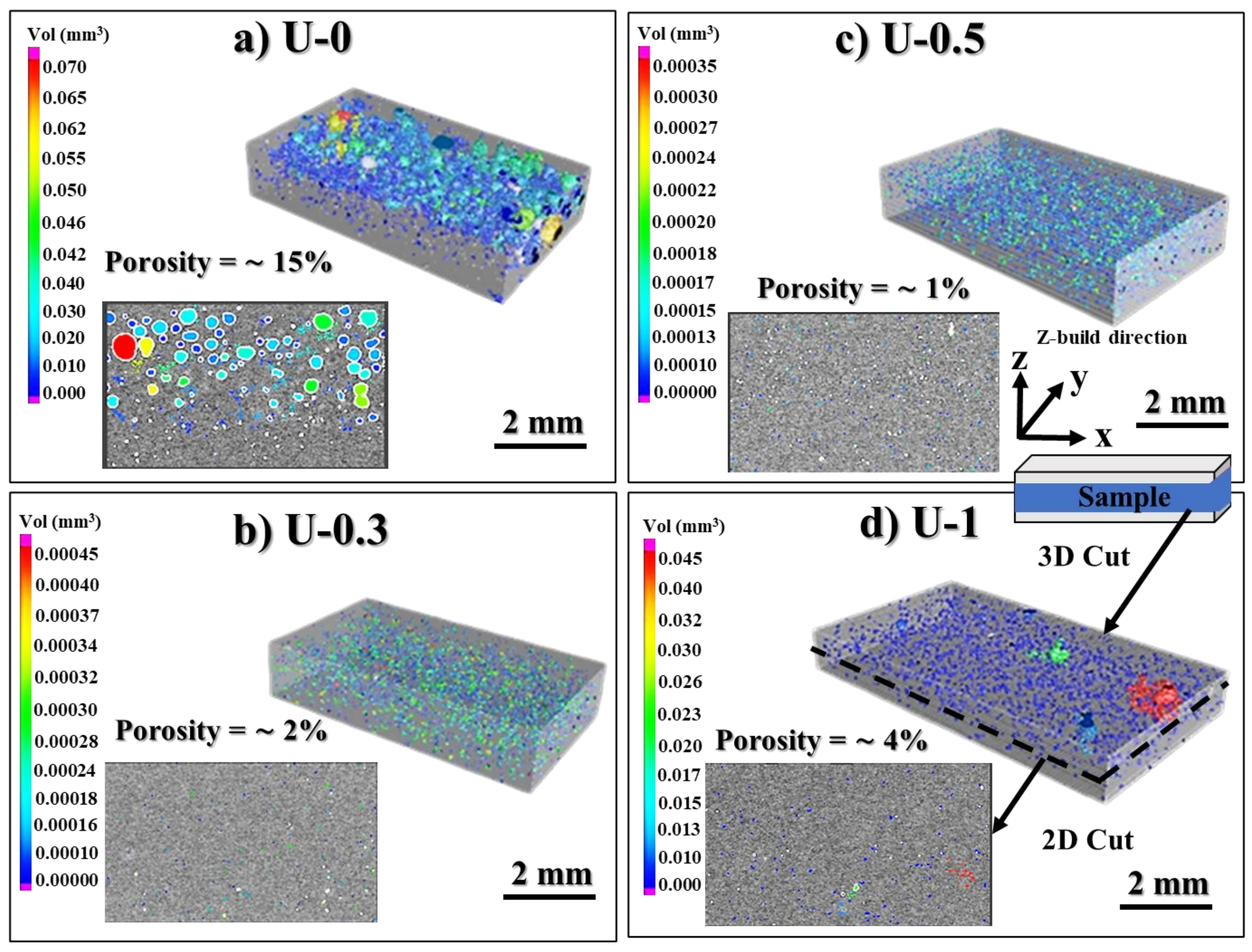

Fig. 4 *µCT analysis of (a) pure UHMWPE (b-d) MWCNT/UHMWPE nanocomposites.*

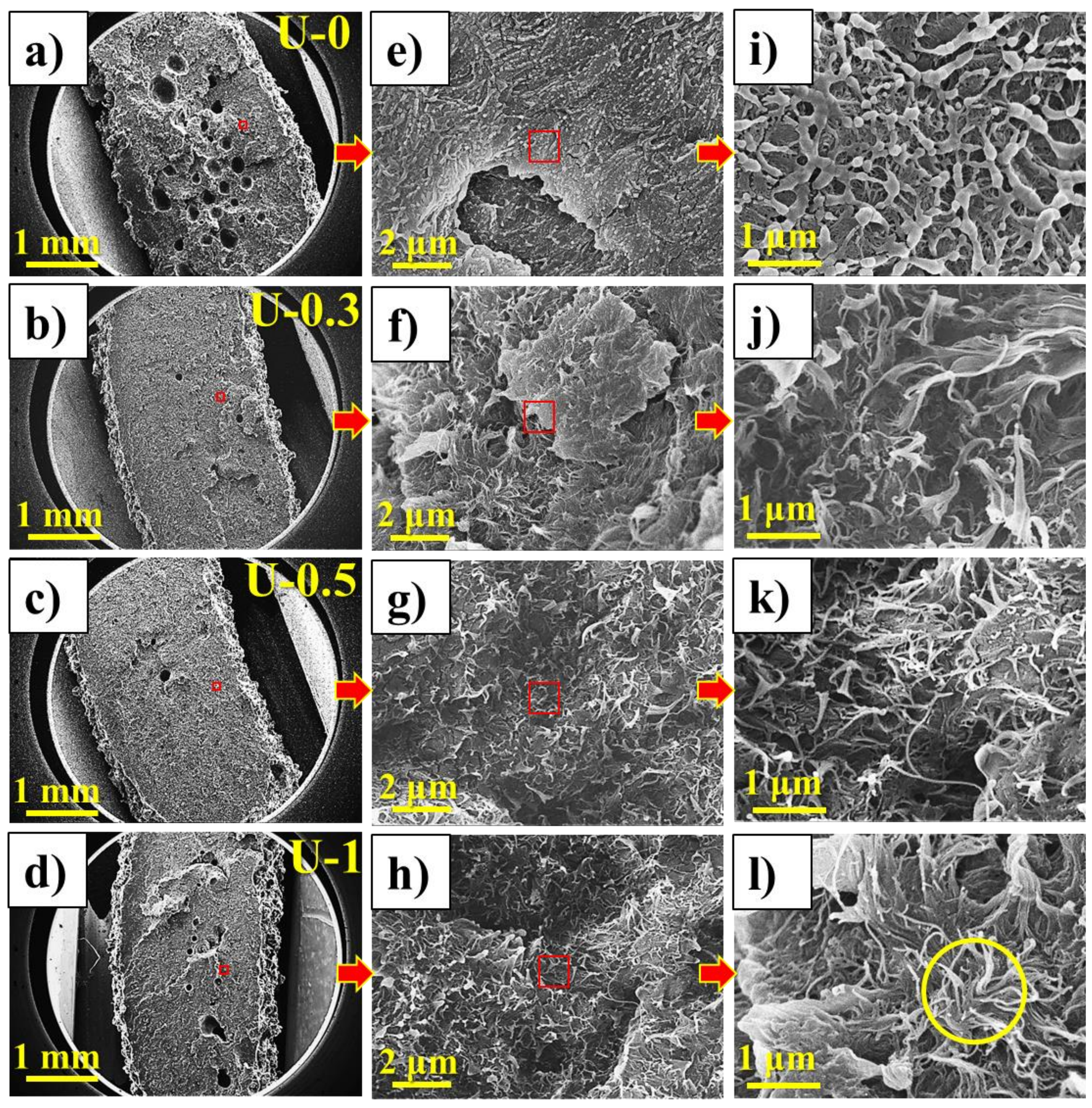

Fig. 5 *SEM images of fracture surfaces corresponding to 3D printed pure UHMWPE (top row) and MWCNT/UHMWPE nanocomposites (bottom and middle rows); the circle in (l) shows agglomerates of MWCNTs.*

Discussion and Conclusions

- ✓ **This study is the first** to report the successful fabrication of MWCNT incorporated UHMWPE nanocomposites via **SLS 3D printing**.
- ✓ The MWCNT/UHMWPE composite with **0.5 wt.% MWCNT** had the lowest porosity (~ 1%) and therefore exhibited superior ***mechanical properties***, reporting a tensile strength of 20.3 MPa which was **~ 45% higher** than the highest tensile strength reported in the current literature for SLS.
- ✓ The 0.5 wt.% MWCNT/UHMWPE nanocomposite showed highest sensitivity showing a gauge factor of **0.6** and **2.6** in the elastic and inelastic regimes, respectively.
- ✓ The results (**stable strain sensing capability**) demonstrate the potential of MWCNT/UHMWPE nanocomposites for the development of **smart biomedical devices.**

References

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