IOCN 2025 Conference

The 5th International Online Conference on Nanomaterials

22–24 September 2025 | Online

MDPI

Mechanically monitoring thermoset polymer materials using SWCNT thin films

Hassaan A. Butt*, Nikita E. Gordeev, Vladislav A. Kondrashov, Dmitry V. Krasnikov and Albert G. Nasibulin
Laboratory of Nanomaterials, Skolkovo Institute of Science and Technology

INTRODUCTION & AIM

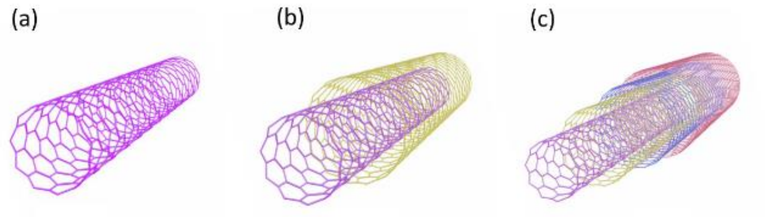

Fig. 1 (a) Single, (b) double, (c) multi-walled CNTs (SW-,DW-, MW-CNTs)

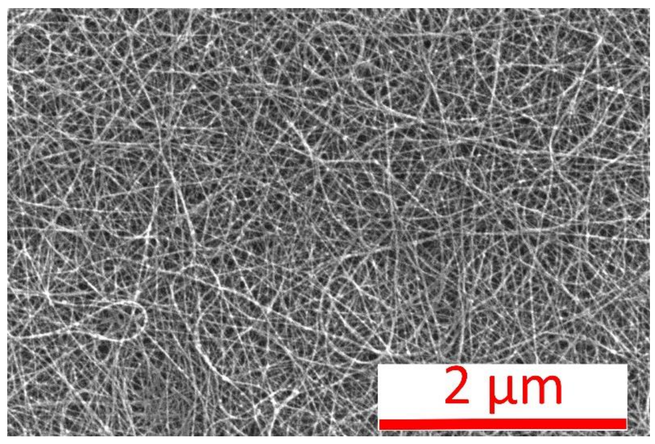

Fig 2. SWCNT thin films

- SWCNTs show exception properties: high modulus (~1TPa), ultimate tensile strength (≥ 200 GPa), and electrical and thermal conductivity (~10^8 S/m, ~3000 W/mK)
- Their thin films are highly porous, compatible with polymers and sensitive to physio-chemical changes

Can SWCNT thin films be used for the one-step integration, dual-stage (manufacturing and structural health) monitoring of thermoset materials?

METHOD

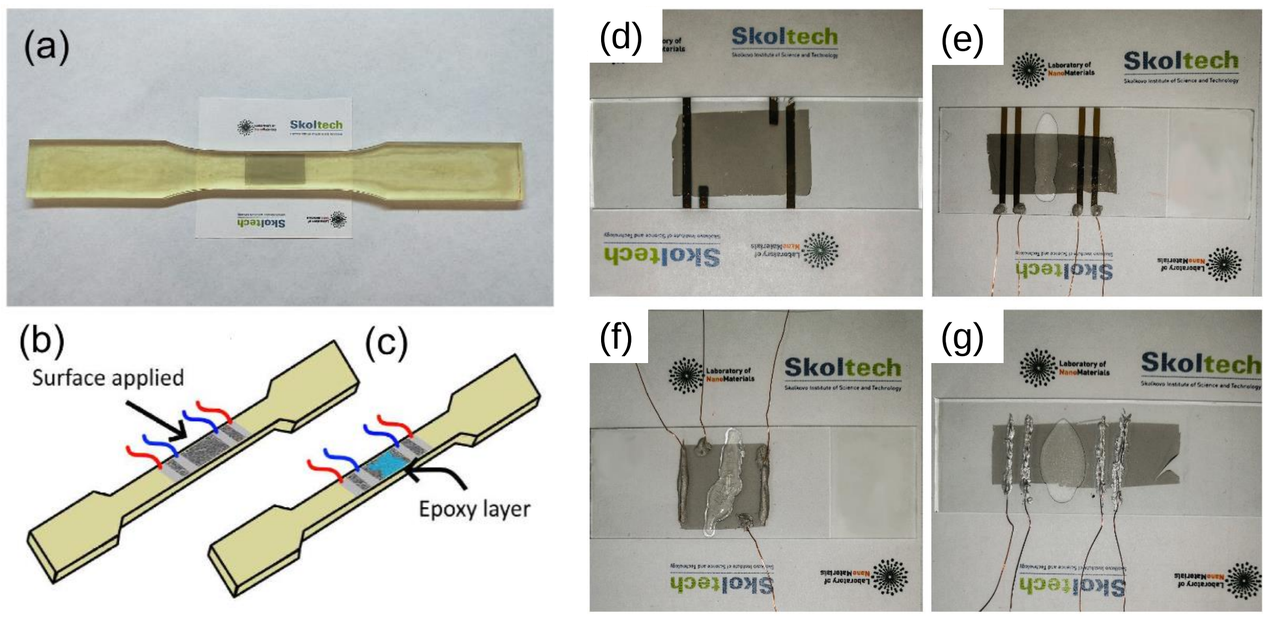

Fig 3. (a,b) surface applied and embedded films. (d-g) Different schemes and electrical contacts

Surface applied sensing films:

- Mold polymeric substrates (ASTM 638)
- Dry transfer films of various thickness onto the surface
- Conduct simultaneous tensile characterization and electrical measurements
- Determine effects of films on mechanical properties
- Determine sensitivity of films to mechanical deformation

Embedded sensing films:

- Embed films into substrates during molding process
- Monitor electrical changes during the polymerization process
- Conduct simultaneous tensile characterization and electrical measurements after curing of substrates
- Determine effects of films and film thickness on mechanical properties
- Determine sensitivity of the various films to mechanical deformation

Purpose:

What should be kept in mind when employing thin films as mechanical sensors (thickness, electrode configuration)?

RESULTS & DISCUSSION

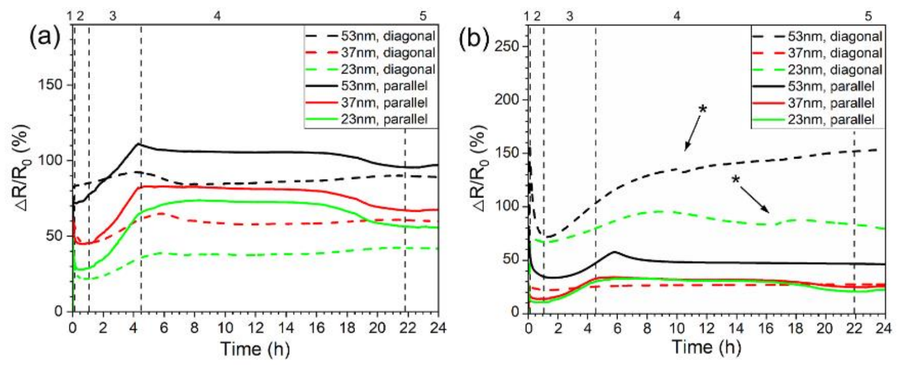

Fig. 4 Polymerization detection using (a) gold and (b) silver-glue electrodes

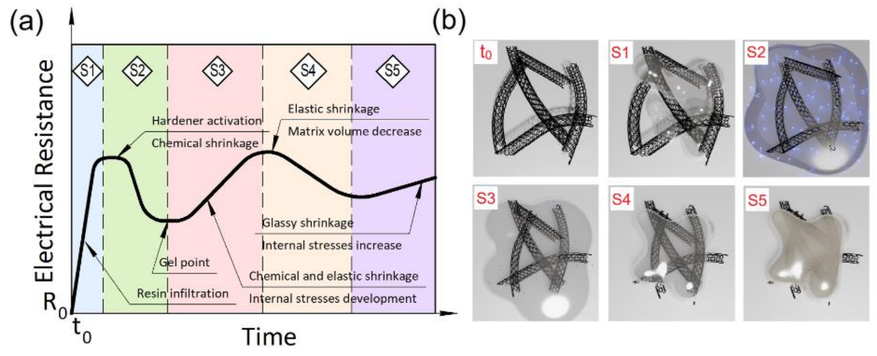

Fig. 5 (a) Detected polymerization stages and (b) changes occurring in the films

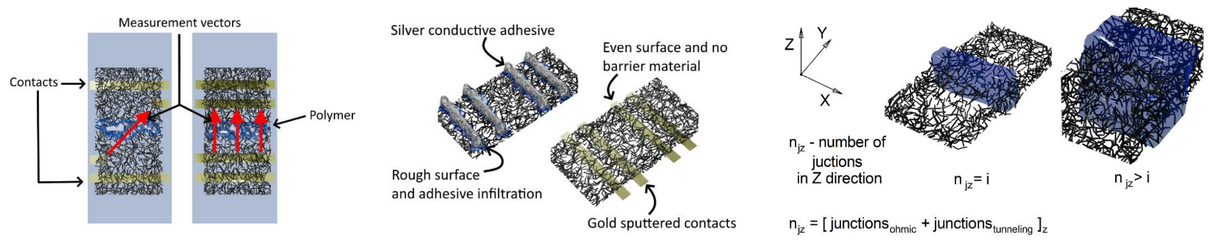

Fig. 6 Causes of different polymerization detection behavior

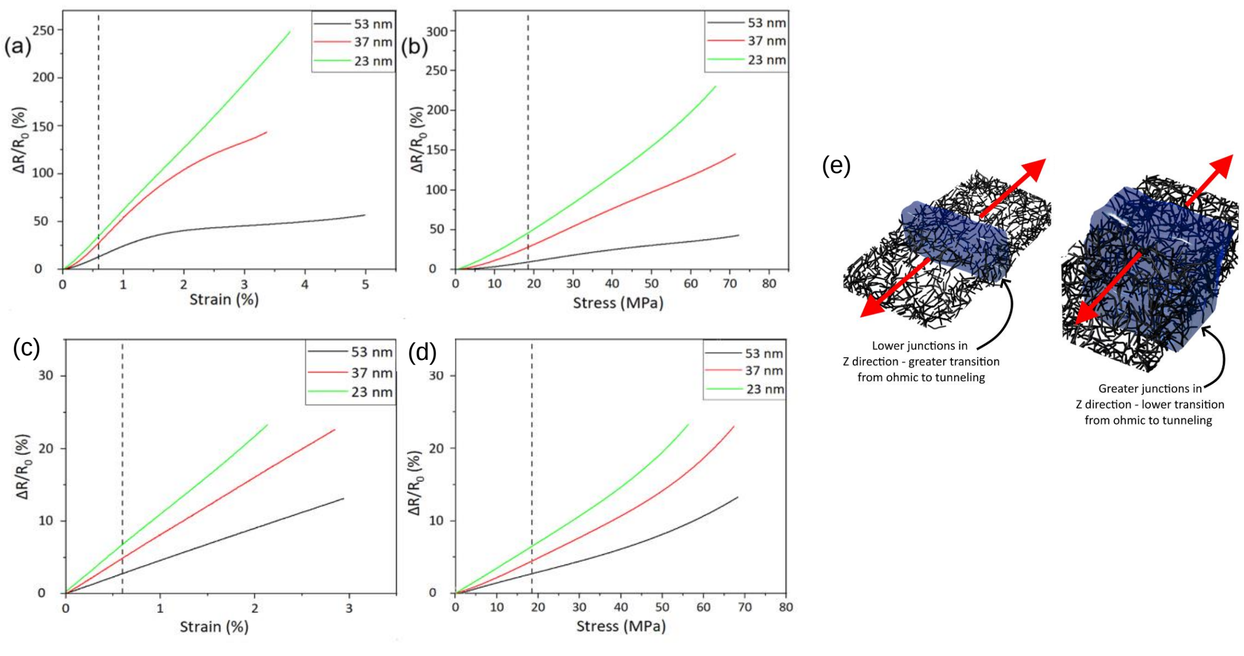

Fig. 7. Piezoresistive response of (a,b) embedded and (c,d) surface applied films. (e) displays cause of behavior

CONCLUSION

1. SWCNT thin films can measure polymerization stages
2. Thicker films are more sensitive and suitable for polymerization monitoring
3. Electrode scheme and materials have an effect on measurement sensitivity
4. Thinner films are more suitable for structural health monitoring
5. Embedded films provide greater sensitivity for lifecycle monitoring
6. Neither cause any mechanical performance loss

FUTURE WORK / REFERENCES

Study available at: 10.1016/j.carbon.2024.119603