IOCPS 2025 Conference

The 3rd International Online Conference on Polymer Science

19–21 November 2025 | Online

MDPI

Near-infrared-responsive dual cross-linked chitosan/hyaluronic acid/graphene oxide hydrogel microneedles for controlled transdermal curcumin delivery in cancer therapy

George Zervas (geperva@chem.duth.gr), Ioanna Koumentakou (ikoument@chem.duth.gr), Sofia Kavafaki (skavafak@chem.duth.gr), Ramonna I. Kosheleva (rkosheleva@chem.duth.gr), Georgios Maliaris (gmaliari@chem.duth.gr), George Z. Kyzas (kyzas@chem.duth.gr), *

1 Hephaestus Laboratory, School of Chemistry, Faculty of Sciences, Democritus University of Thrace, GR-65404, Kavala, Greece.

INTRODUCTION & AIM

Conventional drug delivery systems such as oral or injectable routes often result in pain, tissue damage, or poor drug bioavailability. Transdermal drug delivery systems (TDDS) offer a non-invasive alternative but are limited by the skin's barrier, which restricts the penetration of large or hydrophilic molecules. Microneedles (MNs) overcome this limitation by creating microchannels that allow localized and painless drug transport. Biodegradable polymers such as chitosan (CS) and hyaluronic acid (HA) are highly biocompatible and suitable for MN fabrication, while graphene oxide (GO) contributes mechanical reinforcement and responsiveness to near-infrared (NIR) light. This study aims to develop dual-crosslinked CS/HA/GO microneedle patches using thiol–ene "click" chemistry for controlled and NIR-triggered curcumin delivery in cancer therapy.

METHOD

- CS was functionalized into O-allyl-CS (CSOAL) to introduce reactive C=C groups.
- GO was modified with thiol groups (GO–SH) to enable covalent crosslinking.
- The hydrogel precursor was prepared by dispersing GO–SH in water, dissolving HA and CSOAL and adding Irgacure 2959 as a photoinitiator.
- The mixture was UV-irradiated to form a dual-crosslinked hydrogel.
- For drug-loaded samples, curcumin was incorporated after curing.
- PDMS MNsmolds were fabricated using 3D printing.
- Hydrogel formulations were cast, centrifuged, and dried to form MN patches.

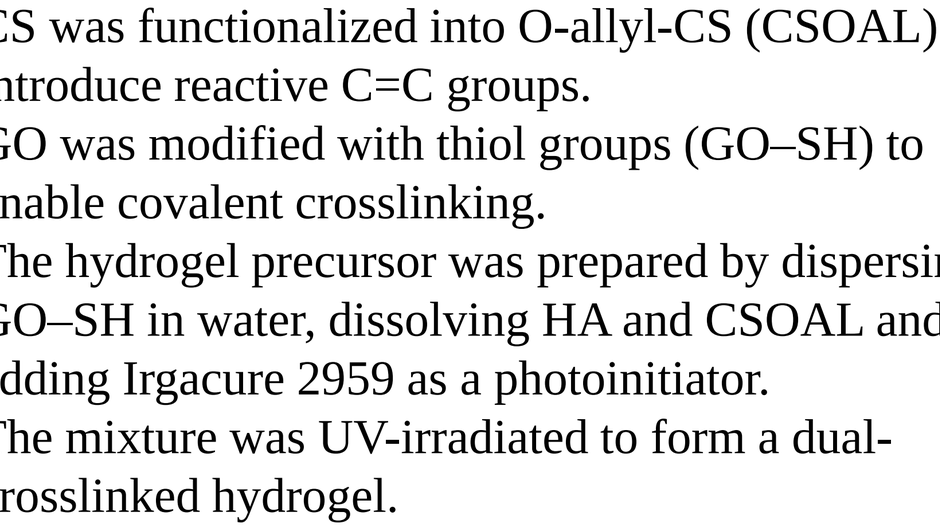


Fig 1. Schematic visualization of the method.

RESULTS & DISCUSSION

FTIR spectra verified the incorporation of functional groups and the consumption of C=C bonds during crosslinking, indicating the formation of a stable three-dimensional polymeric network.

XRD results revealed that the incorporation of GO and the chemical crosslinking enhanced the structural order and partially disrupted the crystallinity of curcumin, improving its solubility and bioavailability within the matrix.

SEM analysis demonstrated that CSOAL-GOSH/HA MNs possessed well-defined conical tips and uniform geometry, showing superior structural integrity and mechanical robustness.

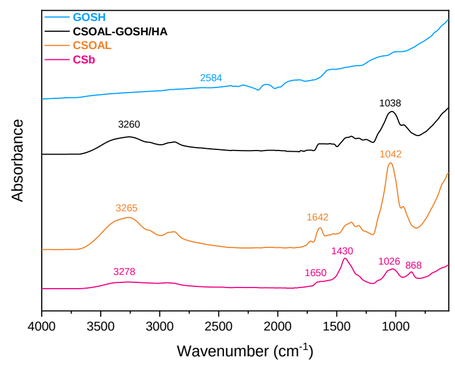


Fig. 2. FTIR results of the functionalized materials.

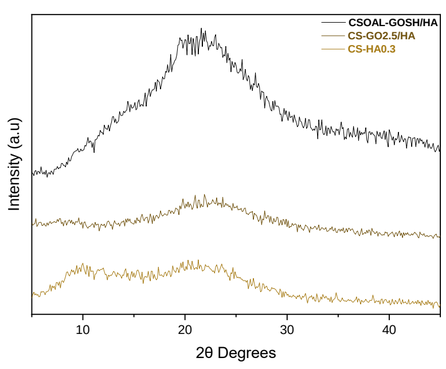
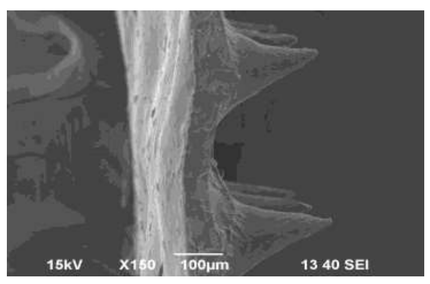


Fig. 3. XRD results



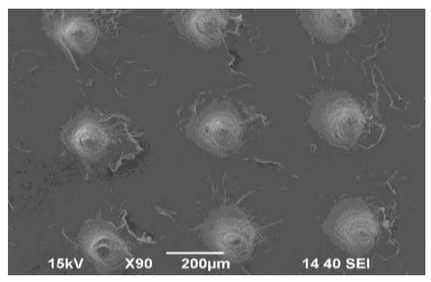


Fig. 4. SEM image of CSOAL-GOSH/HA microneedles.

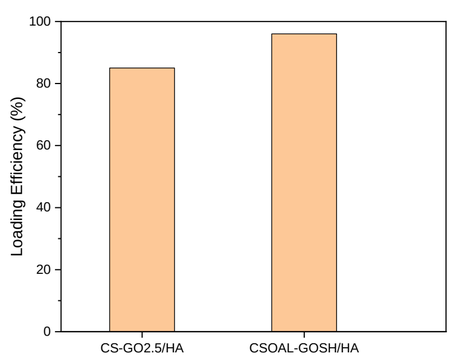


Fig. 5. Loading efficiency of CM

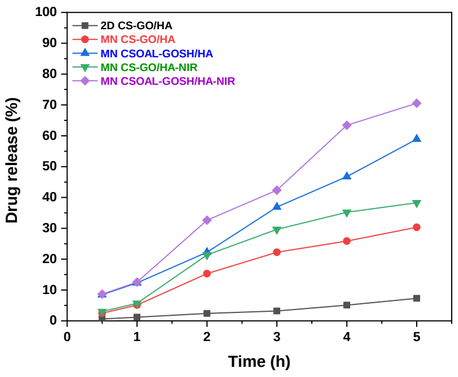


Fig. 6. Drug release of CM

The curcumin loading efficiency was 96% and **drug release experiments** confirmed sustained delivery of curcumin for up to 5 hours, with NIR irradiation providing a controllable "on-demand" release profile due to the photothermal responsiveness of GO.

CONCLUSION

A novel dual-crosslinked CS/HA/GO hydrogel microneedle system was successfully developed using thiol–ene click chemistry. The resulting MNs combined high mechanical strength, optimal swelling behavior, and exceptional curcumin loading capacity. The incorporation of GO provided NIR responsiveness, allowing for externally controlled, sustained drug release.