Portable Smart Bandage for Noninvasive Wound Monitoring in Prolonged Field Care

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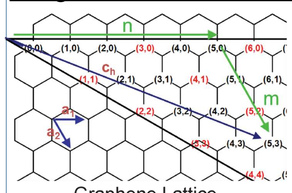
Abstract

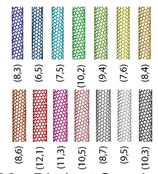
Monitoring warfighter health status during prolonged field care remains challenging because laboratory diagnostics are often unavailable. To address this need, we developed a patented platform (**U.S. Patent No. 12,446,804**) that integrates single-walled carbon nanotubes (**CNTs**) into a solid, biocompatible form via an electrospinning process (**CNT-Tape**). A particular example of this diagnostic platform is the creation of a polymeric **'smart bandage'** for the in situ noninvasive monitoring of hydrogen peroxide, a biomarker of wound inflammation. This addresses the need to reduce repeated dressing removals that can delay healing and increase infection risk. CNT-Tape has shown significant promise as practical optical biosensors due to the sensitivity and photostability of their intrinsic, tissue-transmissive near-infrared (**NIR-II**) fluorescence. Previous studies have demonstrated stable sensor retention, optical sensing through commercial bandages, and sensitivity to biologically relevant biomarker levels. Current work integrates the 'smart bandage' with a low-cost portable optical detection system using LED excitation and photodiodes, eliminating the need for bulky laboratory equipment. This integrated platform is being developed to provide rapid biomarker assessment during combat casualty care and prolonged field care, while offering dual-use applications for civilian point-of-care diagnostics (e.g., chronic wound management in diabetic patients). Current developmental status: **TRL 4 —** targeting **TRL 5–6** via field demonstration with DoD partner support.

Background

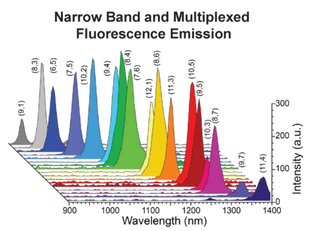
Single-Walled Carbon Nanotubes

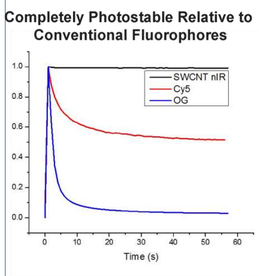


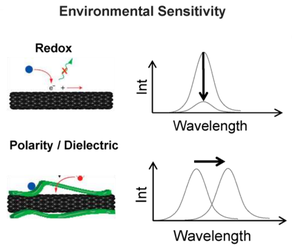
Graphene Lattice

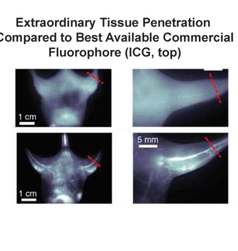


20+ Distinct Species (Chiralities)



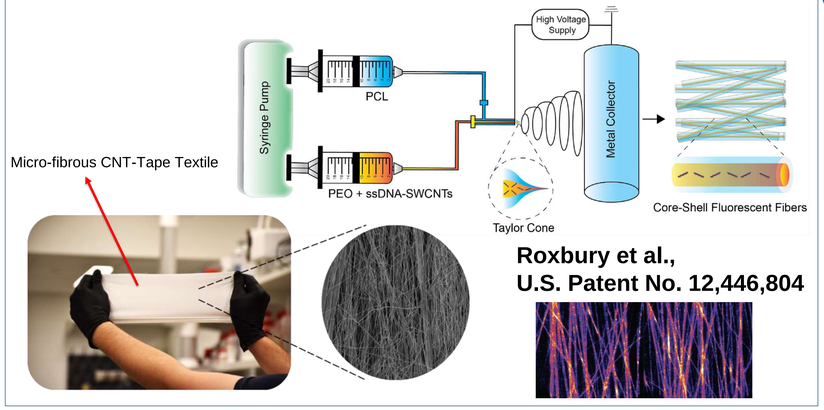






CNT-Tape

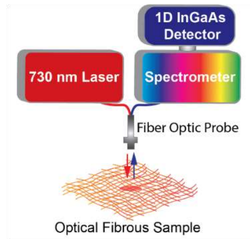
Core-Shell Electrospinning Process for Nano-sensor Encapsulation

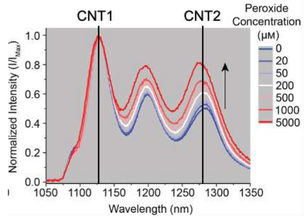


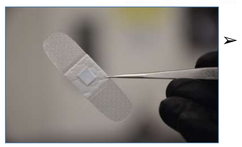
Roxbury et al.,
U.S. Patent No. 12,446,804

Application – H_2O_2Detecting Smart Bandage

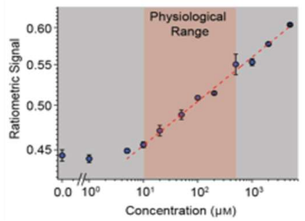
- Low levels of peroxide are essential for intracellular signaling in wound healing (~10 uM).
- High levels of peroxide are expressed for defense against bacteria (>100 uM).
- Frequent peroxide monitoring enables preventing infection and organ loss

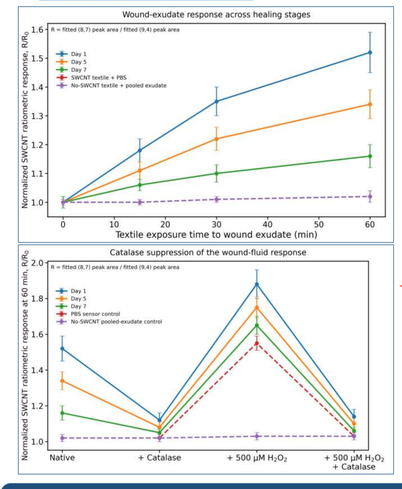


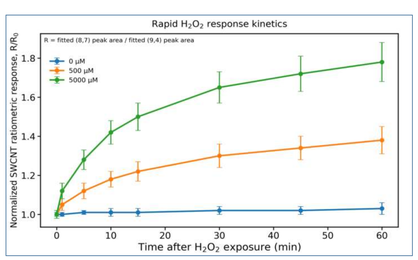




➢ CNT-Tape enables real-time, in situ detection of hydrogen peroxide in wearable application

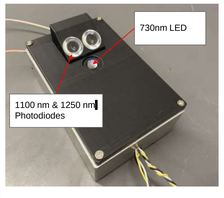


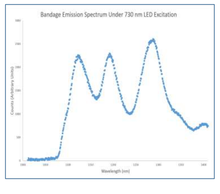




A combat medic treats a penetrating extremity wound at Role 1. Evacuation is delayed 18+ hours. CNT-Tape integrated into the standard wound dressing enables H_2O_2 monitoring every 2–4 hours via the handheld portable reader — no dressing removal, no re-contamination, no lab infrastructure required. A rising oxidative stress signal alerts the medic to deteriorating wound status before clinical signs appear, enabling earlier triage priority and more informed use of scarce evacuation resources.

Miniaturized Detector Current Efforts

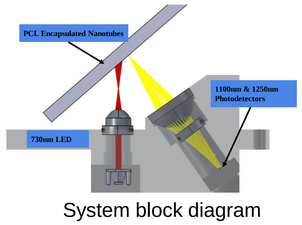




➢ Portable reader prototype: operational and available for bench-top and field-translational testing (current capability).

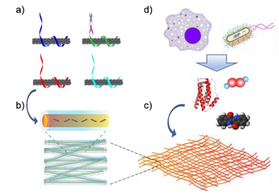
➢ A prototype device has been built to test the low-cost, portable detection method. CNT-Tape fluorescence output is detected with inexpensive LED excitation (730 nm) and small photodiodes (1100 nm & 1250 nm).

Handheld Detector

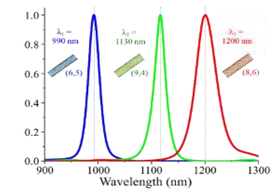


System block diagram

Future Directions

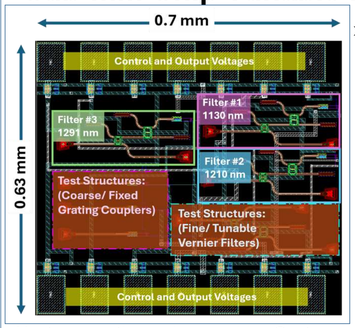


➢ Development of a CNT-Tape that can detect multiple or single biomarkers simultaneously via a single NIR output signal.



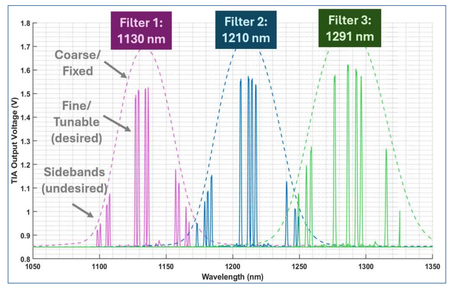
➢ Utilize the multiplexed nature of CNTs; each chirality tuned to detect a different biomarker, e.g. Procalcitonin and Lactate for Sepsis diagnosis.

Sub-mm Chip Tunable for CNT-Tape NIR-II Detection

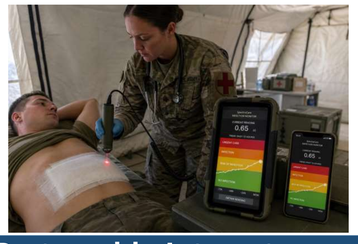


Next generation sub-mm chip: Custom 45 nm Silicon Photonic process (Global Foundries). Chip tape-out completed July 2026 – enabling full wearable form-factor integration.

➢ Custom design of optical components for NIR-II spectrum; all optical filters & analog sensors to be integrated into a single wearable spectroscopic system.



Field Applications



Translational Roadmap & Partnership Interests

Stage	Milestone	Status
TRL 3–4	In vitro validation; bandage integration; lab sensing	✓ Complete
TRL 4	Portable reader prototype demonstrated	✓ Complete (Testing Pending)
TRL 5	Sub-mm chip integration; wearable system	In Progress (2027)
TRL 6	Role 1–2 field demonstration with military medical partner	Seeking DoD Partner

Seeking DoD Collaboration & Transition Partners:

- CDMRP — Combat Casualty Care Research Program (CCCRP)
- MTEC — Medical Technology Enterprise Consortium
- SBIR / STTR Phase I–II
- Role 1–2 clinical testing and field demonstration partnerships
- DARPA — Defense Sciences Office (DSO) / Biological Technologies Office (BTO)

We are actively seeking military funding and medical partners to conduct operational testing in austere and field-forward environments.

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References

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