Enabling High Performance Sensors and Transistors with **Aligned Nanotube Technology (ANT)**

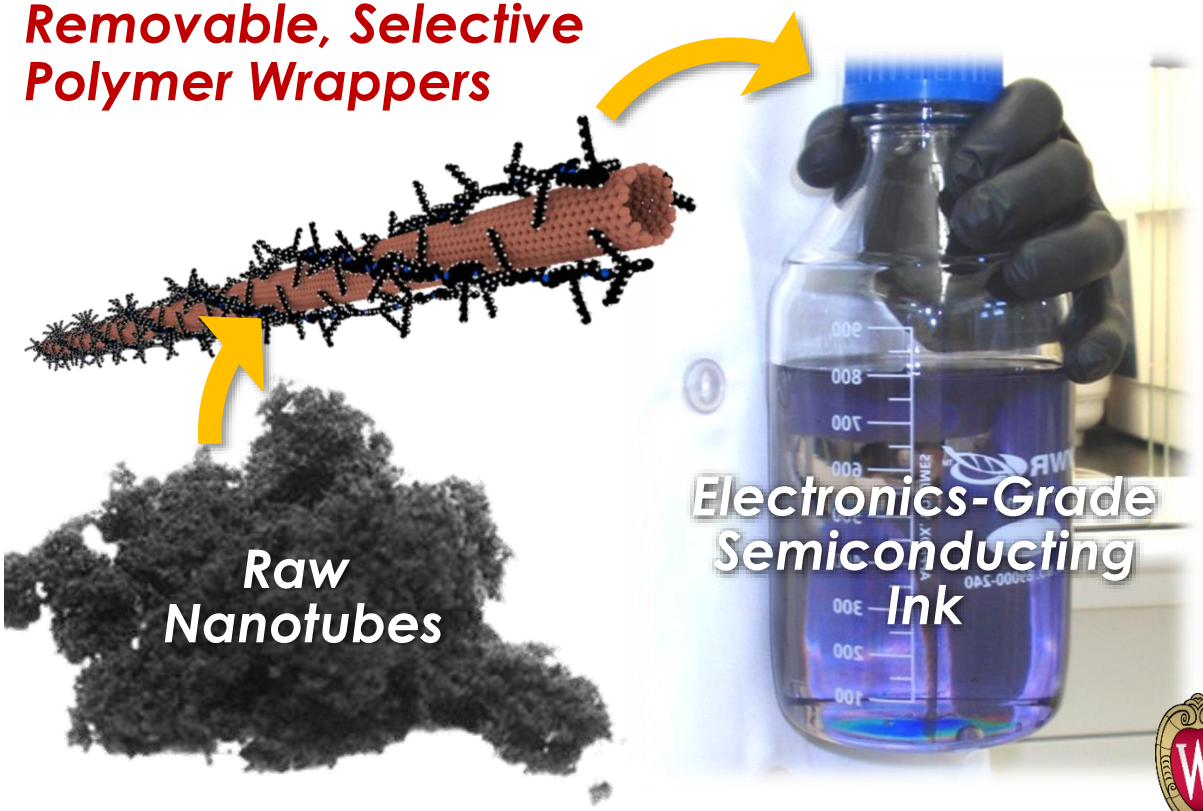
Prof. Michael S. Arnold
michael.arnold@wisc.edu
University of Wisconsin-Madison

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Innovation Description

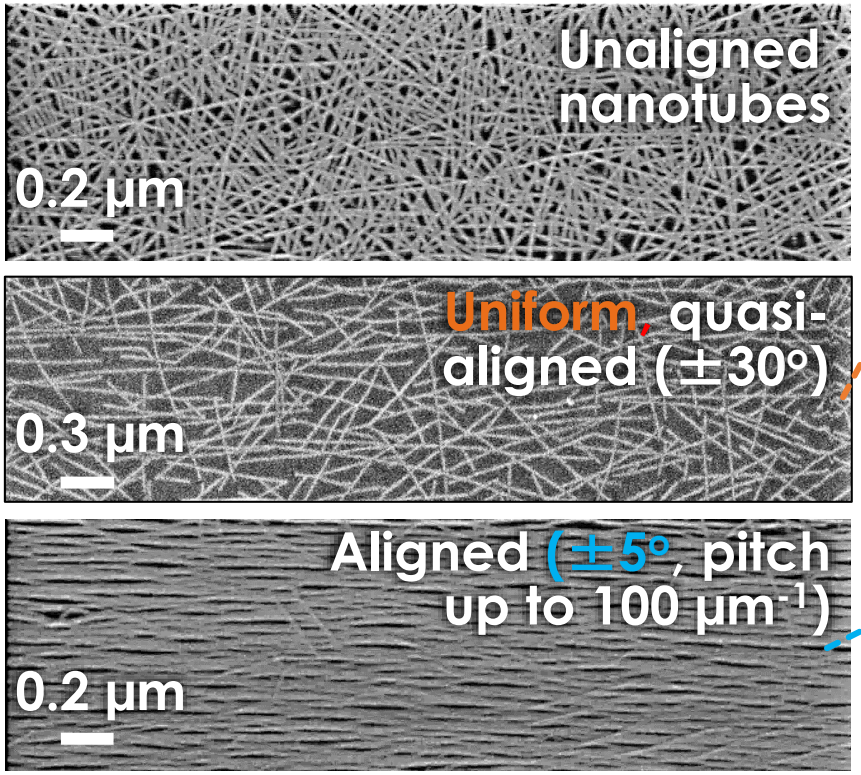
- Industry has dreamed of exploiting the enormous promise of semiconducting carbon nanotubes for faster, more efficient electronic devices for 20 years, but the promise has not been fulfilled due to problems purifying and aligning nanotubes.
- We have discovered multiple simple methods for aligning purified semiconducting nanotubes over large areas (ANT processes).
- The alignment works via scalable, demonstrated fluid-based methods.
- CNTs **enable** **ultrasensitive** electronic **biosensors for point-of-care detection and faster, more energy-efficient logic** and radio frequency (**RF)** electronics (compared to Si or GaAs).

Electronics-Grade Semiconducting Nanotube Ink



WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

ANT Films



- Ideal for thin film transistors for biosensors, OLED displays and flexible electronics
- Demonstrated on a 4x4 in^2 wafer

- Ideal for high-performance transistors for logic and RF
- Only small area demonstration

Value of the Innovation

Eight issued and two pending patents cover ANT process and resulting composition of matter claims on aligned nanotubes.

- All owned by Wisconsin Alumni Research Foundation (WARF) who has provided a small amount of funding to Arnold's lab.
- License of first generation ANT process for RF devices in place.
- External funding from the National Science Foundation (NSF) Scalable Nanomanufacturing and Integrated Systems Program for Arnold's and collaborators' University labs totaling $1.5M.

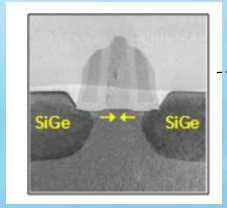
Market Size/Impact

- Current ANT capabilities point to targeting **biosensor devices with quasi-aligned films**.
- BCC Research reports that Biosensors will be a $31.8B marketplace (8.6% CAGR) by 2023
  - Nanosensors will make up $1B (12.7% CAGR) of that amount
  - Growth driven by need for more sensitive, fast, and accurate detection
- Diagnostic biosensors (e.g., cancer biomarkers) fabricated from lower performing (10*x* lower) and less-scalable CNT films have already been demonstrated with sensitivity that can be as good as ELISA.
- **ANT CNT films expected to offer better reproducibiltiy, higher sensitivity -- enabling fast, economical, point-of-care diagnostics.**

Market Size/Impact (ii)

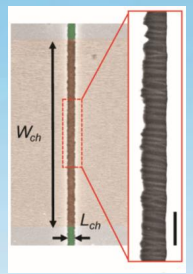
- Success in biosensors will position ANT process for opportunities across a **broad set of massive opportunities**: OLED displays, RF devices, and logic microprocessors.

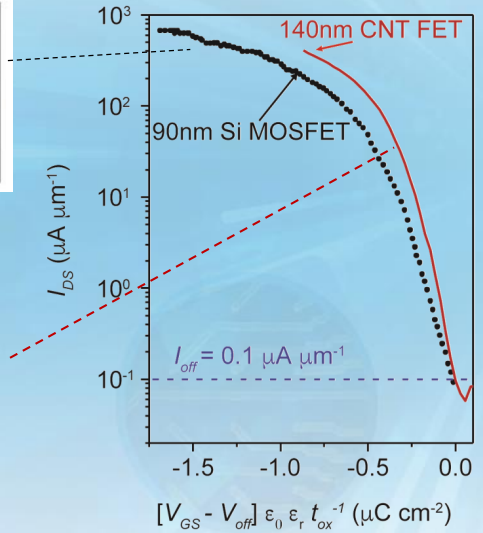
90 nm Si MOSFET



Ghani et al. *IEEE IEDM* 2003

140 nm CNT array FET





- **ANT CNTs demonstrated** 1.9x higher current density than Si, GaAs
- Can be improved further

Brady and Arnold et al. *Science Advances* 2016

What are You Looking For?

- **Industry partners** in the biosensor industry that can provide needed commercial and technical support:
  - Initial aim is to demonstrate competitive CNT biosensors in University lab, leveraging existing equipment, personnel and analytical resources.
  - Post-demonstration plan is to form Company to commercialize biosensor device with continued support from industry partner.
- In parallel, Company will seek equity financing and additional industry partners to exploit aligned CNTs to develop the next generation of devices for displays, RF devices, and integrated circuits that are smaller, faster, and require much less power.

Contact Information

Michael Arnold
University of Wisconsin-Madison
michael.arnold@wisc.edu
P: 608.262.3863
homepages.cae.wisc.edu/~arnold/

Greg Keenan
Wisconsin Alumni Research Foundation
gkeenan@warf.org
P: 608.960.9849
www.linkedin.com/in/gregorykeenan

Booth number 223 – University of Wisconsin-Madison (WARF)