The Brazil-U.S. Competition for Innovation and Technological Development
Strain Gauges of Carbon Nanotube Yarns: Towards Developing A New Sensing Technology (2019)

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Tips & Strategies for Developing a 100K Innovation Fund Grant Proposal

100,000 STRONG IN THE AMERICAS

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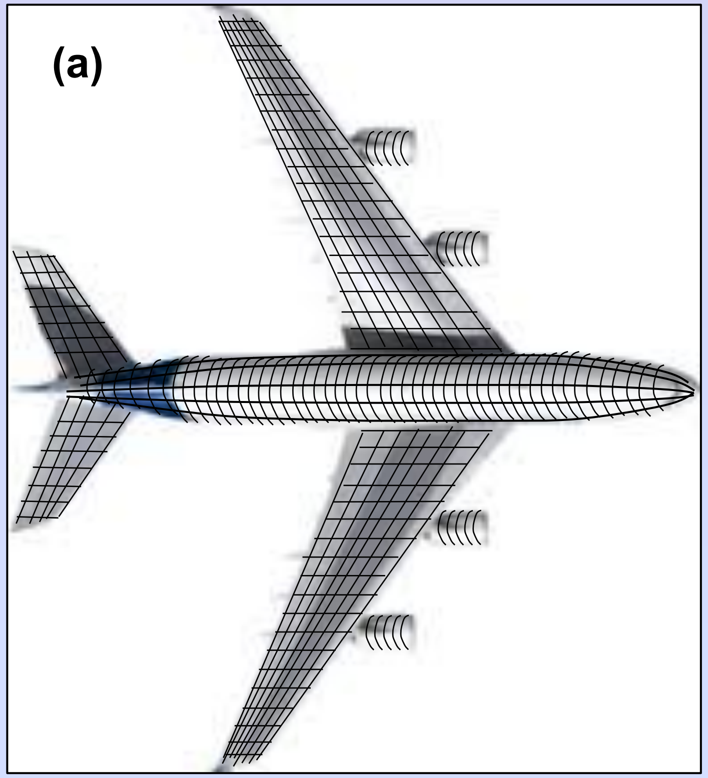
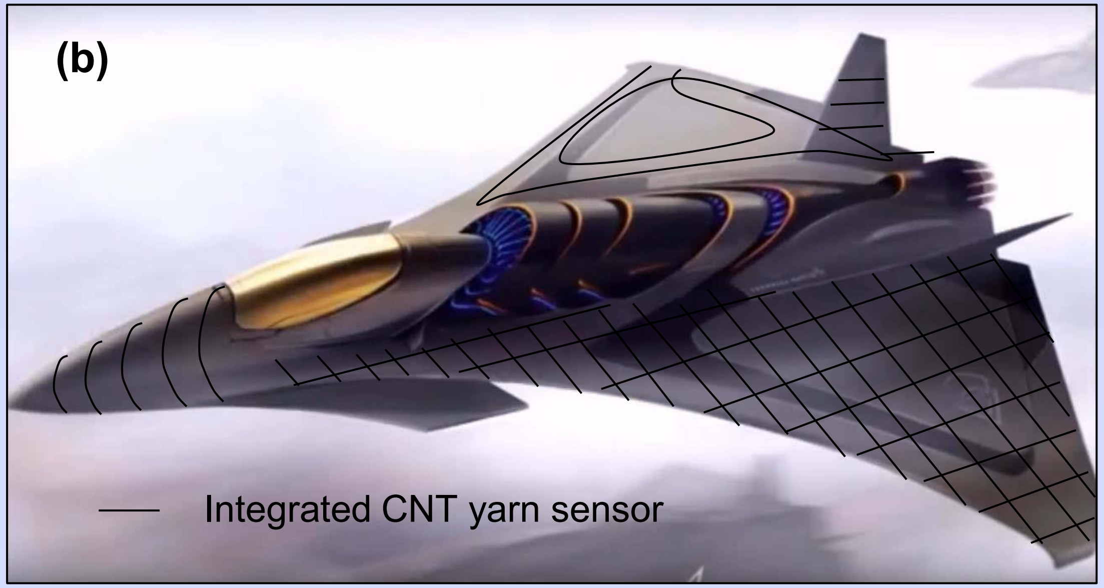
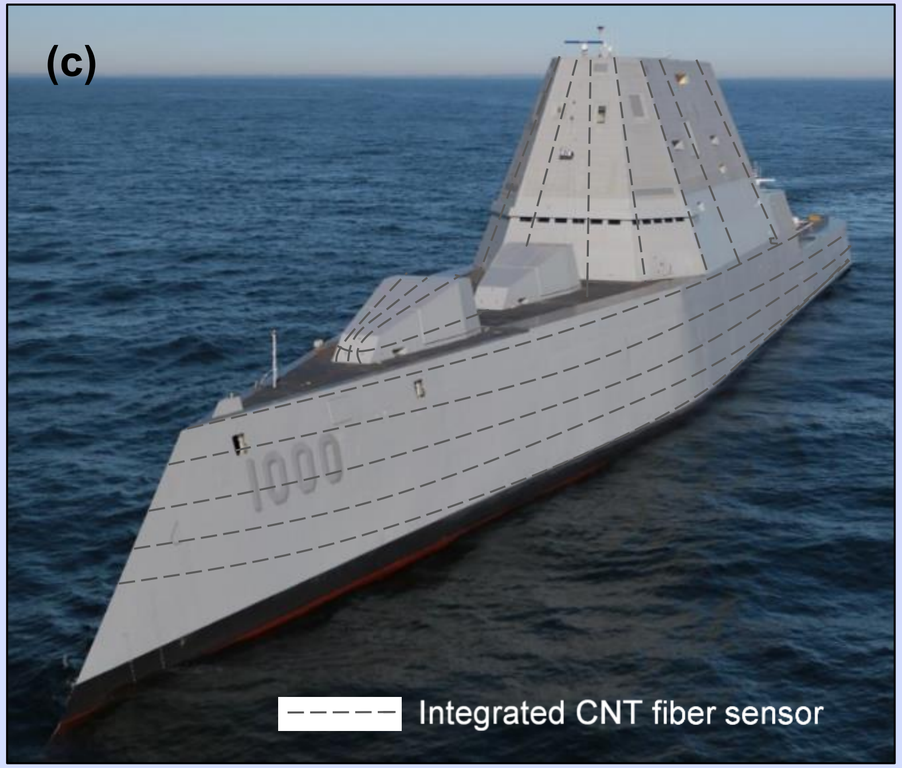
November 17th, 2021

Vision of Integrated Structural Health Monitoring System (SHM) Using Carbon Nanotube Yarns







(a, b) Schematics of SHM concept consisting of integrated and distributed sensor network of CNT yarns that monitors primary and secondary structures (aircraft image in (b) from Wordless Tech website). (c) Schematic of SHM concept in aerospace structures (image of Zumwalt from website).

<u>Self-Sensing Concept Features</u>

- Distributed Sensing
- Integrated Sensing
- Microstructure Integrity
- Minimal Additional Weight
- Real-Time Data Collection

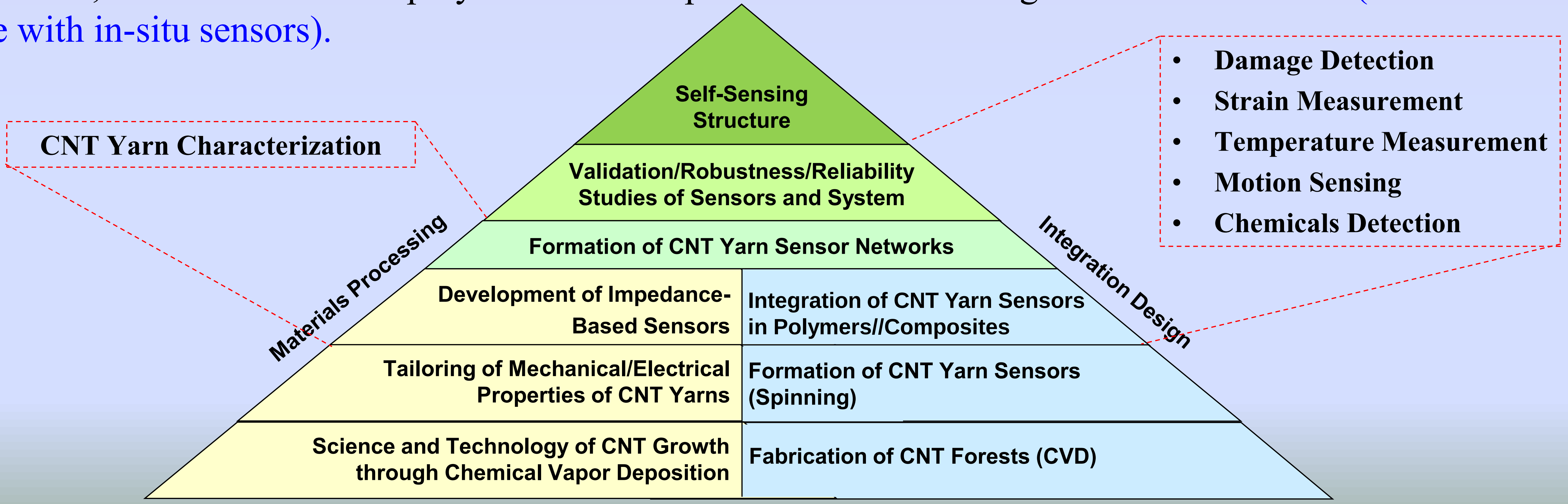
Sensing using Carbon Nanotube Yarns

Hypothesis

Carbon nanotube yarns (fibers) can be used as piezoimpedance/thermoresistive/chemoresistive-based sensors and integrated in polymeric and composite materials.

Vision

Develop distributed and integrated monitoring techniques to detect initiating damage, measure strain and temperature, detect chemicals in polymers and composites without altering their microstructure (not done before with in-situ sensors).



Schematic of research plan on sensing using carbon nanotube yarns.

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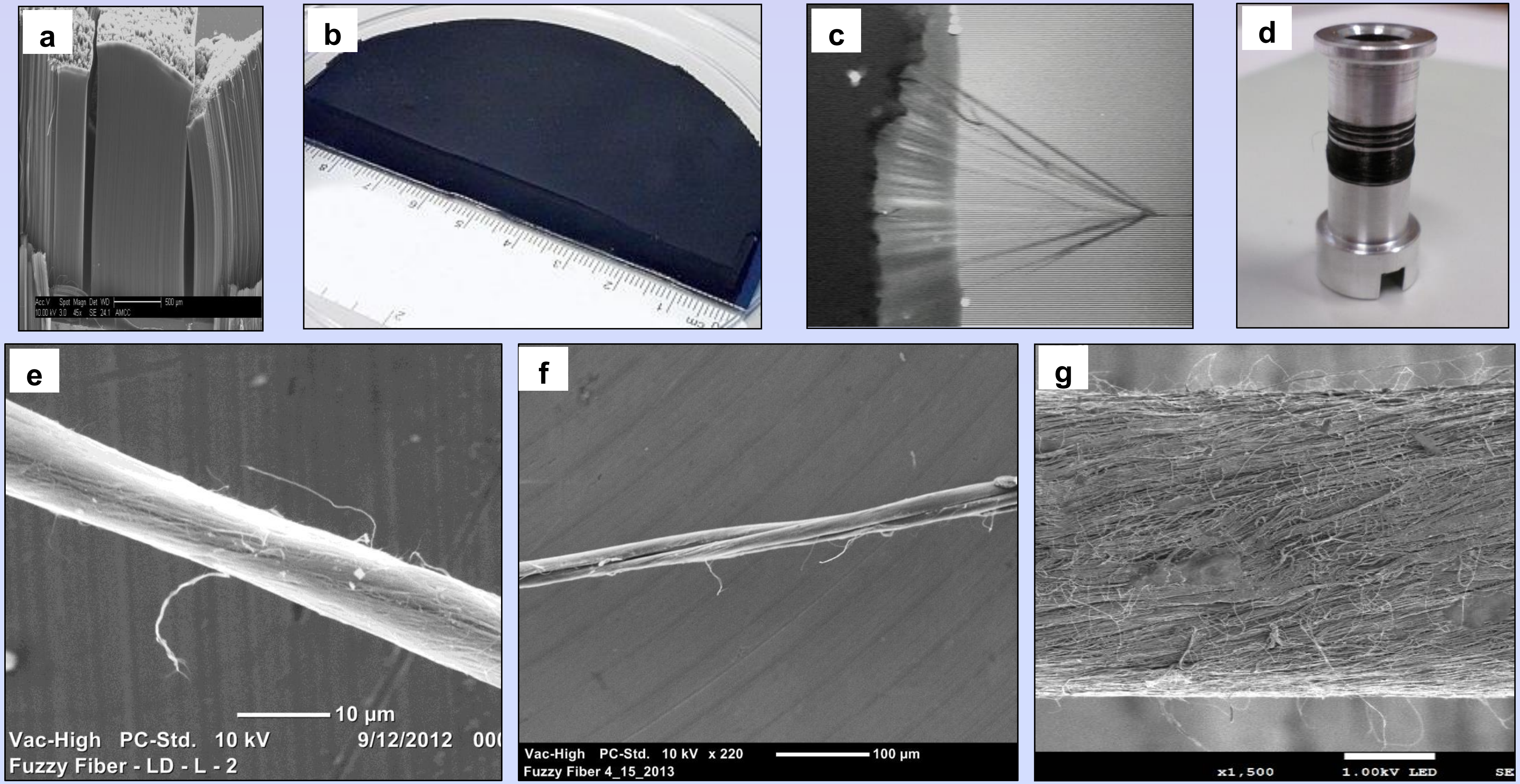
CNT Yarn Material

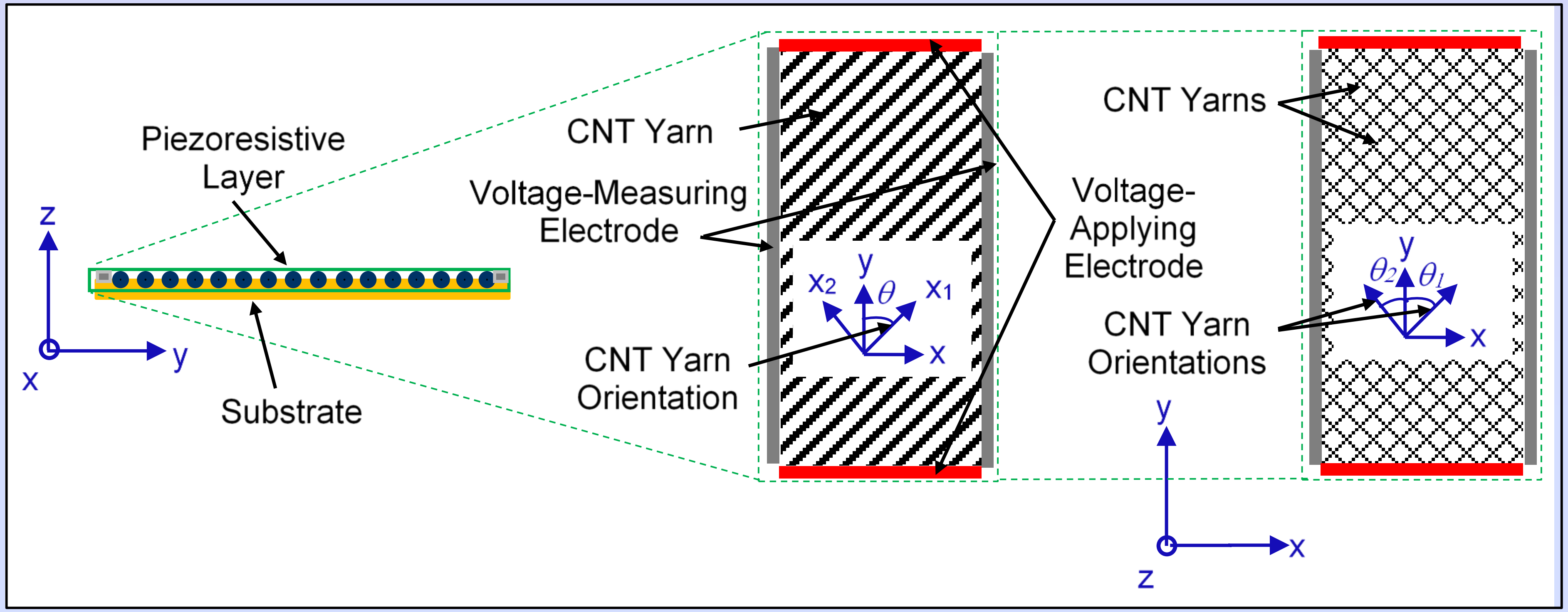


(a) Tall CNT forest. (b) CNT forest (array). (c) CNT thread being drawn. (d) CNT thread wound onto spool. (e) One-thread yarn (diameter of 8 µm, angle of 8.9°). (f) Three-thread yarn (diameter of 22 µm). (g) Close-up view of CNT yarn.

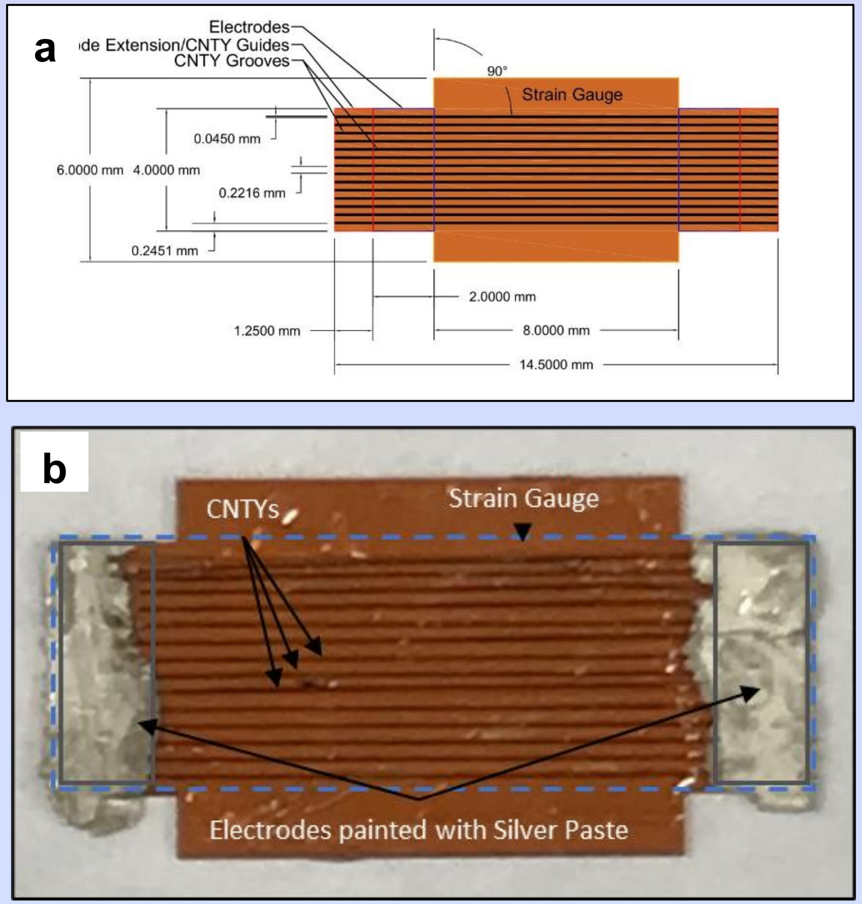
Abot, J. L. and Punnakattu Rajan, C. Carbon Nanotube Yarns, *Carbon Nanomaterials Sourcebook*, edited by Klaus Settler, Taylor & Francis, ISBN 978-14-822527-2-9 (2016).

Strain Sensing: Foil Strain Gauges Concept and Configurations

- Consider four-terminal or two-terminal foil strain gauge sensors comprised of CNT yarns.



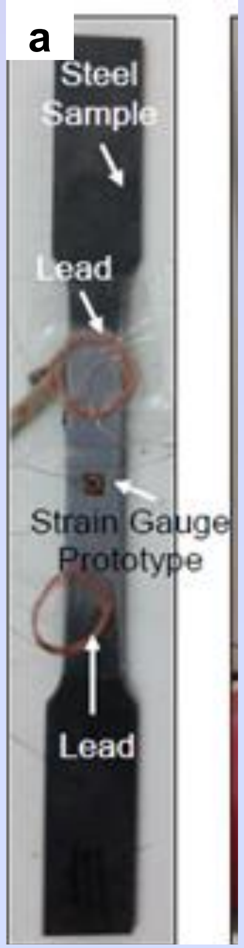
Cross-section schematic view of the four-terminal strain gauge sensor comprised of CNT yarns. Inset: top schematic views showing the arrangement of the CNT yarns and the electrodes including unidirectional and bidirectional configurations.

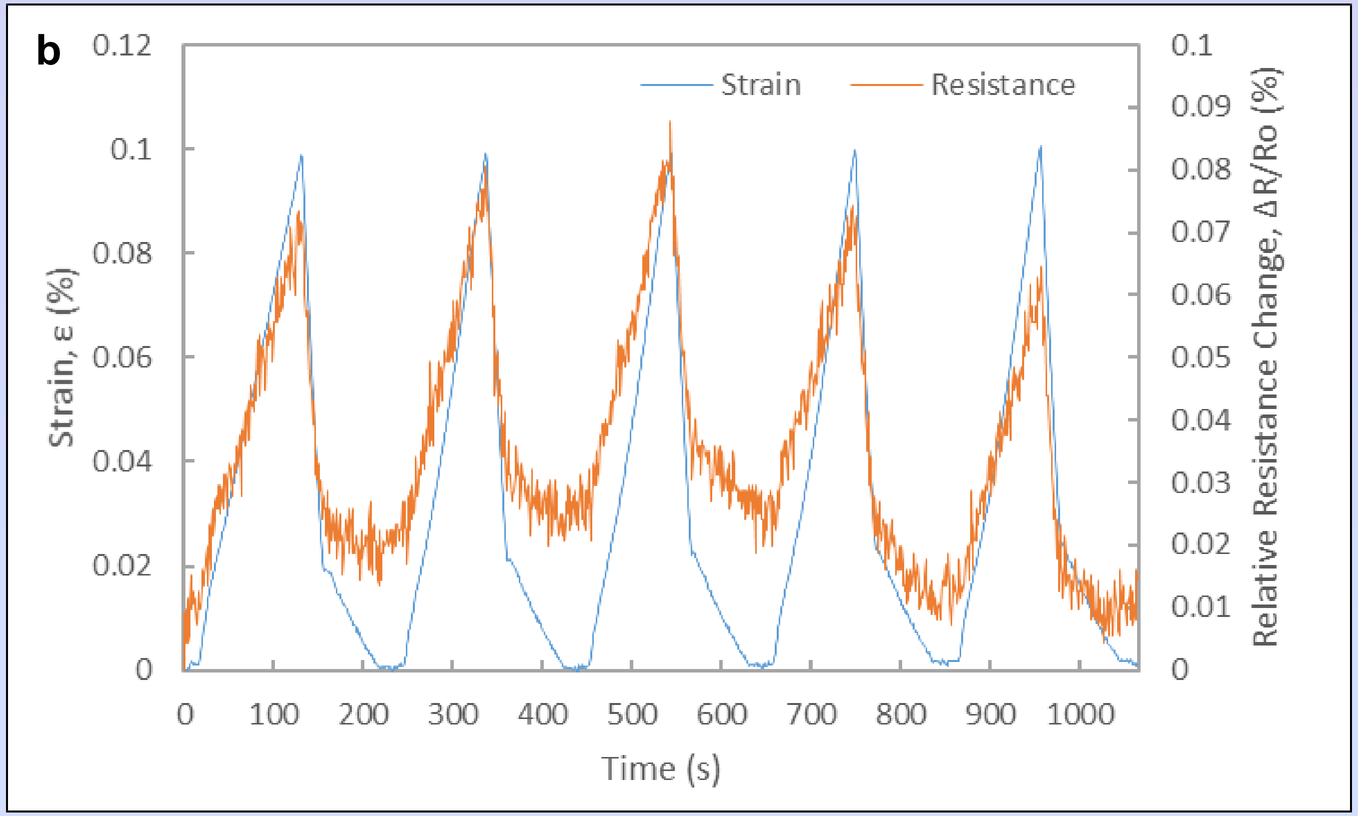


Foil strain gauge prototype with grooves and CNTYs oriented at 0°: (a) Schematic. (b) Optical image.

Abot, J. L., Kiyono, C. Y., Thomas, G. P. and Silva, E. C. N. Strain gauge sensors comprised of carbon nanotube yarn: Parametric numerical analysis of their piezoresistive response. *Smart Mater. Struct.* 24 (7): 075018 (2015).

Strain Sensing: Foil Strain Gauges Experimental Results





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Displacement Rate	Pause Duration	Gauge Factor
100 microns/min	0	0.458
100 microns/min	1 min	0.541
100 microns/min	5 min	0.157
200 microns/min	1 min	0.455
200 microns/min	5 min	0.475
1 mm/min	0	0.500
1 mm/min	1 min	0.406
1 mm/min	5 min	0.458

(a) Strain gauge consisting of CNT yarn in a metallic sample. (b) Strain and relative resistance change histories in five-cycle test with a 0.1%-maximum strain at a displacement rate of 1 mm/min. (c) Average gauge factor found for each displacement rate and pause length combination.

- Calibration results indicate foil strain gauges are responsive under cyclic loading.
- Observed drawbacks include relaxation and hysteresis.
- New configurations are being fabricated and studied.

Rodríguez-Uicab, O., Woo, B., Nardo, L., Seabra, A. and Abot, J. L. Foil strain gauge sensors comprised of carbon nanotube yarns: Mechanical response. (to be submitted).

Pre-Proposal: My Experience

Professional Components

- Had ongoing innovative research and projects funded in the US.
- Conducted a Fulbright US Scholar Program in the country (Brazil) prior (2014-2015) with funding from both US and Brazil.
- Built collaborations with several academic institutions in the country (Brazil): USP São Paulo, ITA, USP São Carlos
- Built collaborations with laboratories in the country (Brazil): IPT São Paulo, IPT São José dos Campos.
- Advised many students from the country (Brazil) that studied at CUA through the BSMP (CsF).

Personal Components

- Learnt and spoke the language.
- Visited the country with colleagues recently.
- Had some cultural affinity growing up in a neighboring country and visited when younger.

Proposal: My Experience

- Proposed a multidisciplinary and complimentary team (CUA, USP São Paulo, SENAI).
- Assembled a team of US and Brazil students who would work in the project in both countries.
- Proposed a project on a topic that could lead to patents/commercialization in both countries.
- Prepared a technical narrative section that included:
  - Clear and achievable objectives.
  - Clearly delineated plan that would include good communications among all team members.
  - Proper project monitoring.
- Prepared a broader impacts section including the following components:
  - Educational.
  - Publishing.
  - Commercialization.

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Proposal Contents

Contact Information

- For questions or potential advice, please feel free to reach:

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