Robust FARADAYIC® CNT Based Coating for Scattered Light Suppression

Dan Wang, Tim D. Hall, R. Radhakrishnan, M. Inman, E. Jennings Taylor, B.T. Skinn, and S.T. Snyder

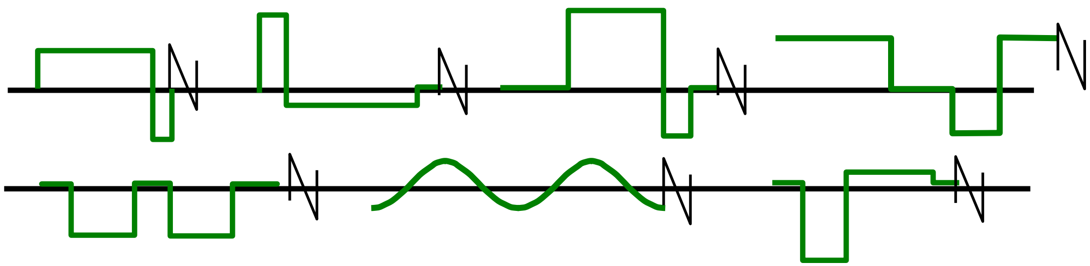
18th Annual Mirror Technology SBIR/STTR Workshop

Raytheon Space and Airborne Systems Event Center

El Segundo, CA

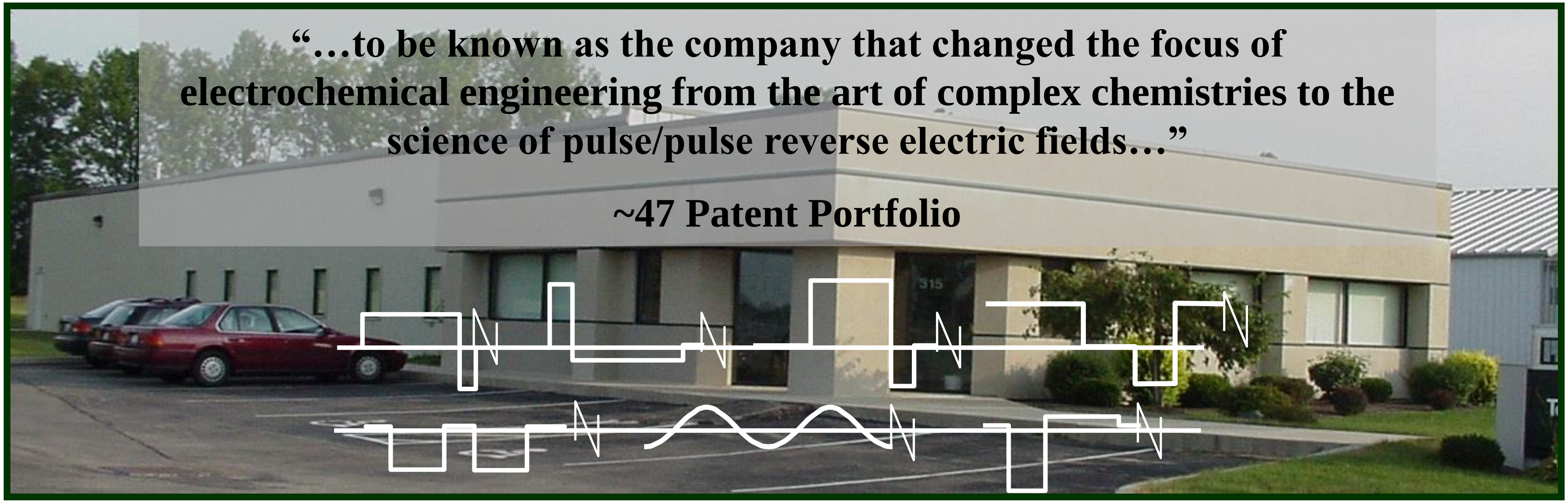
11/06/2018

Introduction to Faraday Technology, Inc.



FARADAY
TECHNOLOGY, INC.

Company Overview: FARADAY TECHNOLOGY, INC.

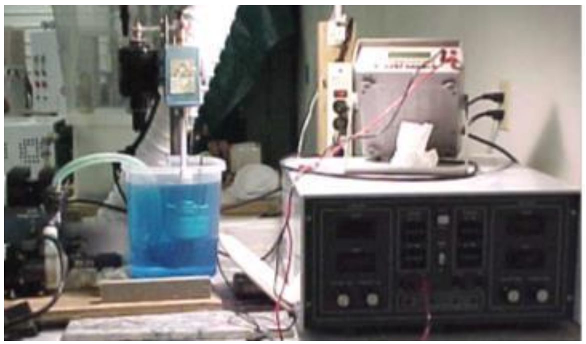


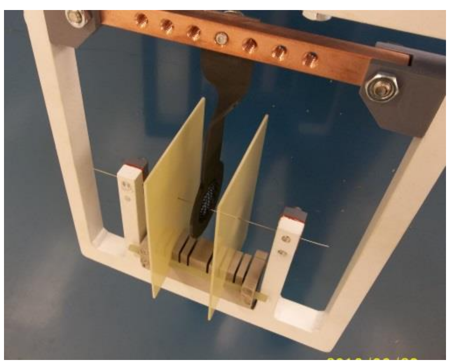
- Electrochemical engineering processes and technologies – founded 1991
  - ~32 Issued Patents and ~15 Pending Patents in this area
  - www.FaradayTechnology.com
- Subsidiary of Physical Sciences, Inc. (Boston, MA) – acquired 2008
  - www.psicorp.com

DEM/VAL: α- to β-Scale

Technology development begins conceptually and is demonstrated at the bench-scale and developed through α/β-scale validation. IP development with technology.

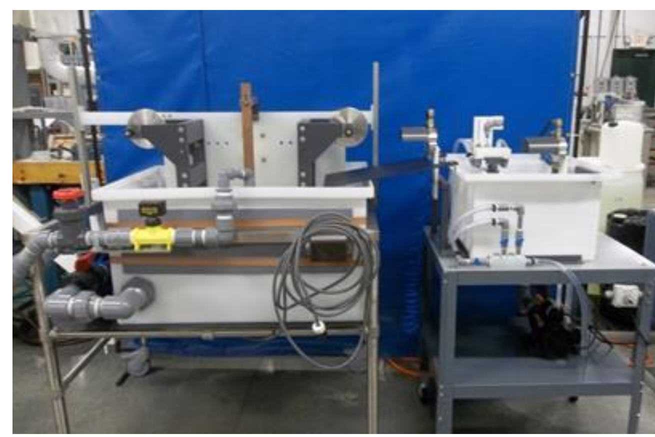
Bench-Top Feasibility





Pilot-Scale Validation

Production-Scale Validation



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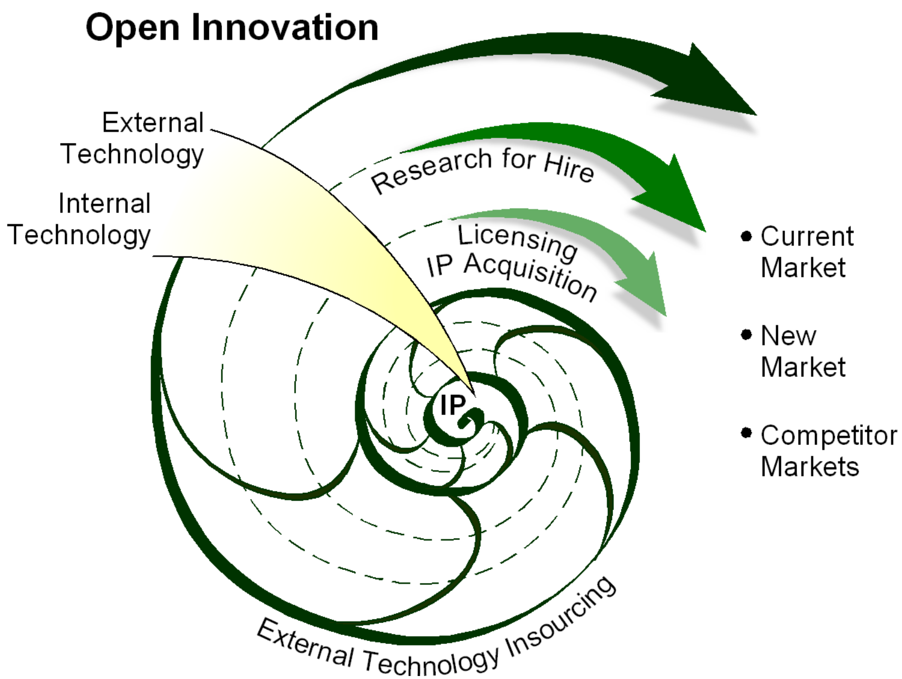
Business Model: Collaborative Open Innovation



- Establish IP (47 patents issued/know-how)
- Leverage Federal SBIR opportunities as non-equity technology funding
  - Retain IP rights
- Collaborate with university, government and commercial partners
- Develop electrochemical engineering solutions based on PC/PRC processes
- Transition technology & competitive advantage to large companies via
  - α-Scale to β-Scale Demonstration/Validation
  - Field-of-use licenses
  - Patent acquisition (8)
- Transition technology to government facilities via
  - α-Scale to β-Scale Demonstration/Validation

Development of robust process is critical!

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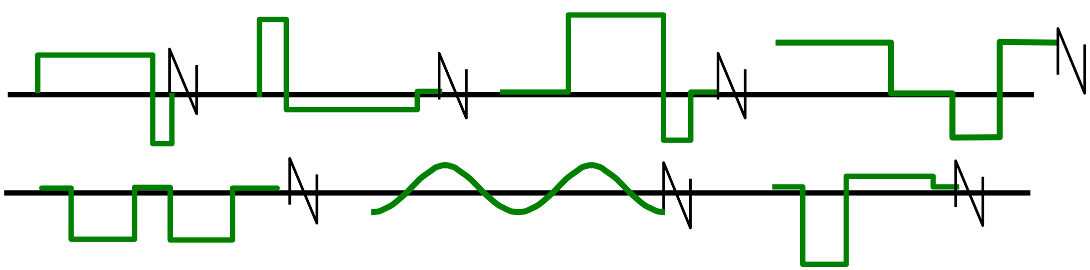
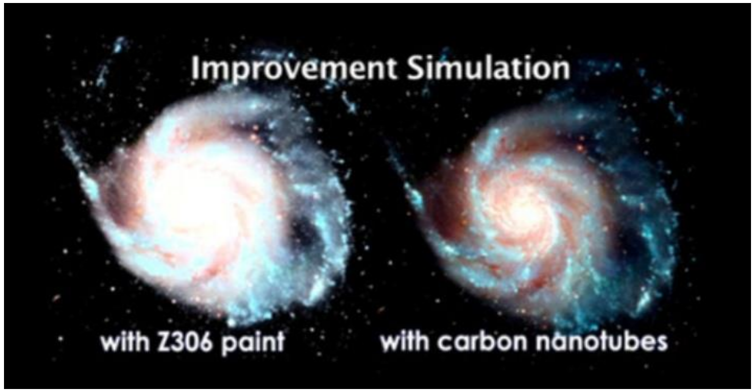
Program Description



Background

- Future NASA missions require low reflective surfaces to minimize scattered light for optical systems, such as beam-splitter, lasercom, and gravitational-wave application.
- The low reflective surfaces need to withstand space environments with marginal impact on their adhesion and optical performance in the broad spectral range (visible-near infrared).
- Low reflective surfaces have been obtained on black surfaces through anodization, painting, or electrodeposition of Martin black, carbon black, black chrome, etc.
- The CNT based materials absorb 99.5 of the light, dramatically reducing light contamination (NASA Goddard Space Flight Center).

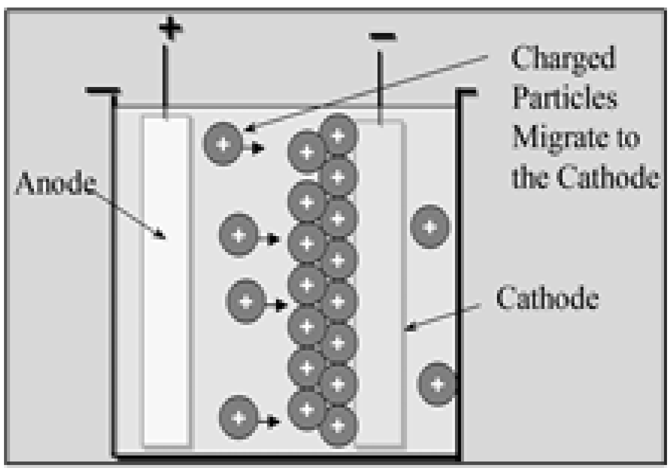


Objective of Program

- The objective of the Phase I program is to develop a scalable process for fabrication of low reflective CNT based black coating that is able to withstand and increase lifetime in challenging application environments.

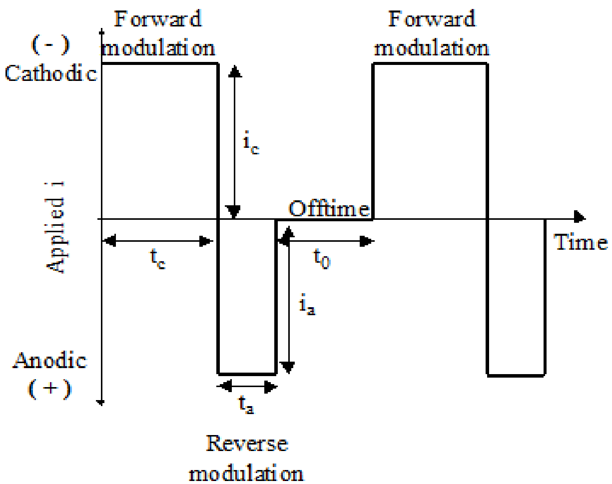
Technical Approach

Utilize combined conventional electrophoretic deposition (EPD) and pulsed electric fields to induce migration of charged particles (nanotubes) onto targeted substrates.



Conventional EPD process

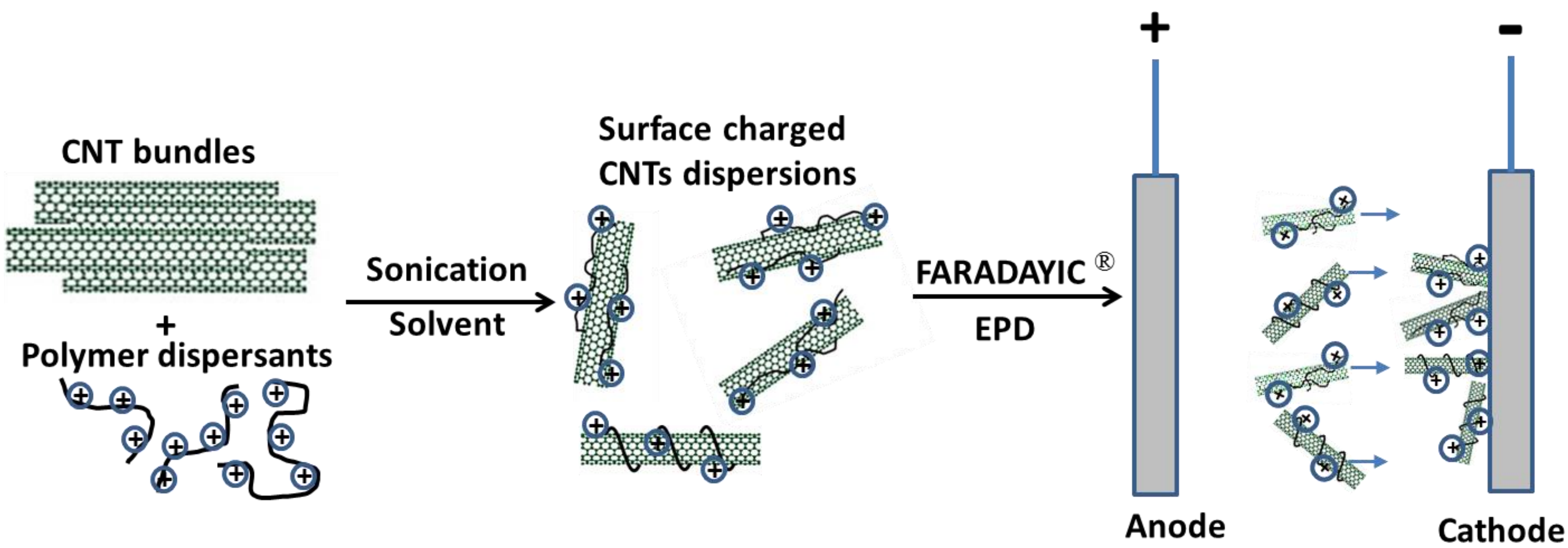
+



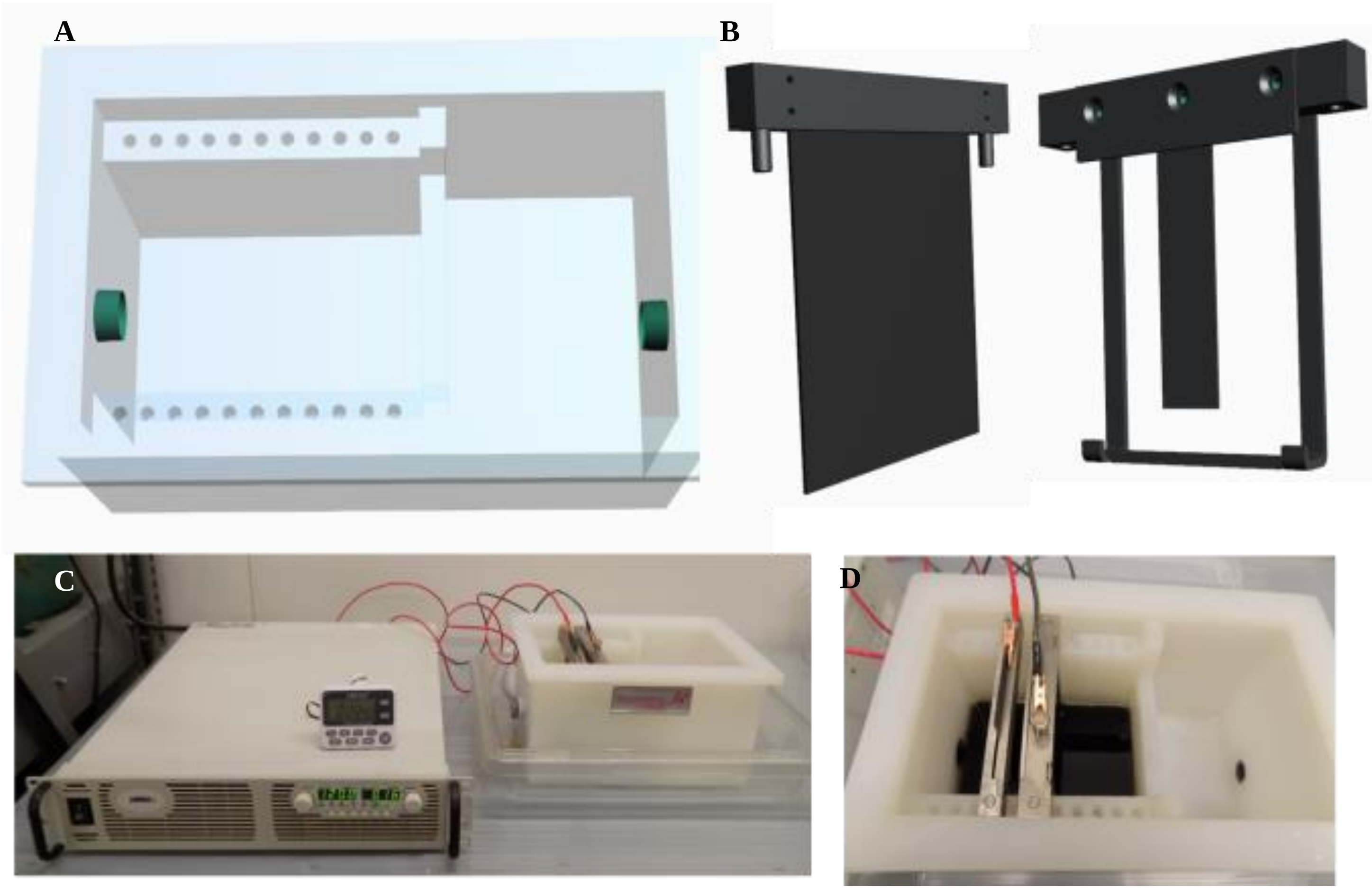
FARADAYIC® process

Technical Approach

- Carbon nanotubes will be surface charged and dispersed with the aid of dispersants or functional groups.
- Surface charged CNTs will be deposited on desired substrates through FARADAYIC® EPD process.



EPD cell Setup



The EPD cell setup for CNT coating: 3D representation of (A) EPD cell; (B) Counter and working electrodes; (C) The EPD cell setup with DC power supply; (D) The EPD cell with CNT suspension.

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CNT dispersion for EPD Coating

- Plating bath development (CNT dispersion approach, dispersant, binders, solvent, etc.)

CNT bundles

Multi-walled carbon nanotube (Aldrich)

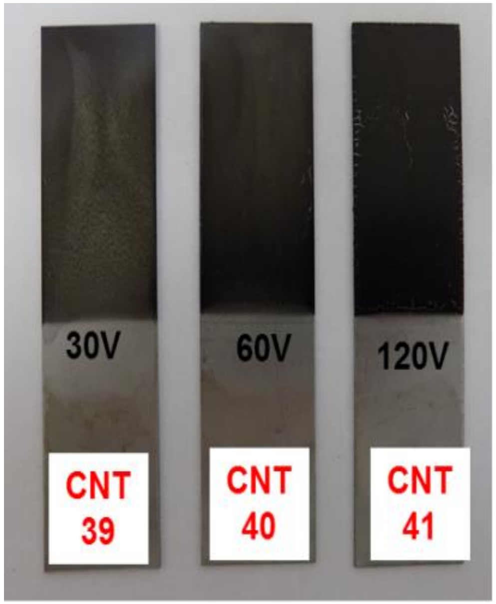
CNT dispersions

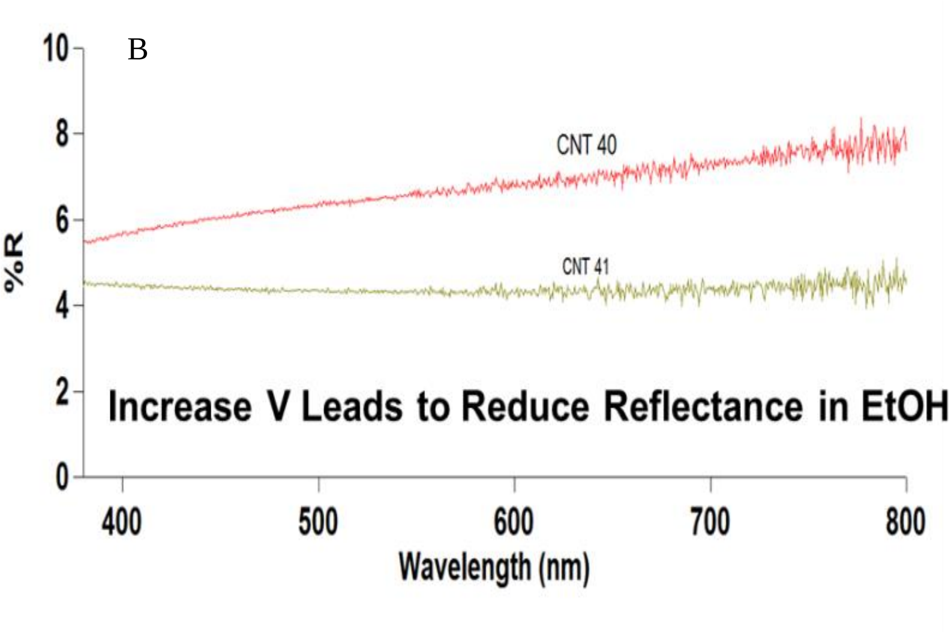
The experimental setup for preparing CNT dispersion with aid of sonication

Results

Increasing the applied DC voltage leads to reduce reflectance of CNT films

A



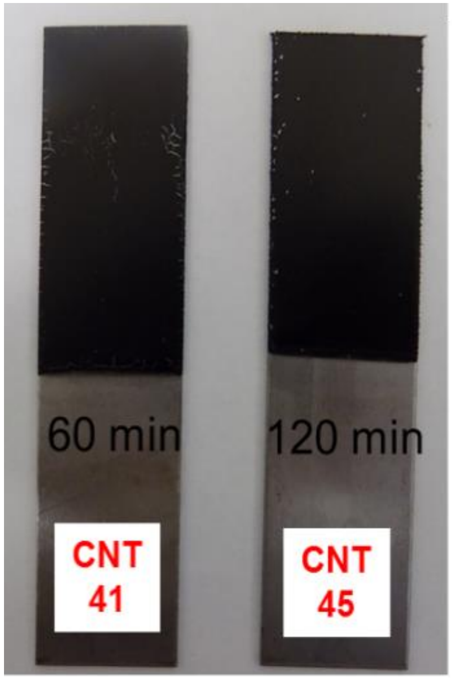


Photograph (A) and diffuse reflectance spectra (B) of Trial CNT39, 40,& 41

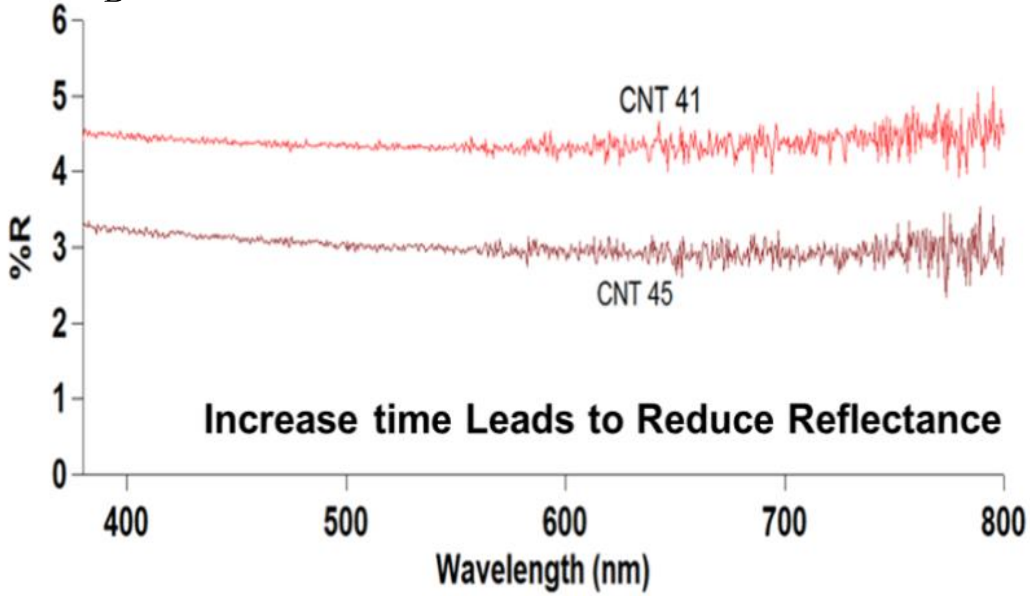
Results

Increasing deposition time leads to reduce reflectance

A



B



Photograph (A) and diffuse reflectance spectra (B) of Trial CNT41& 45

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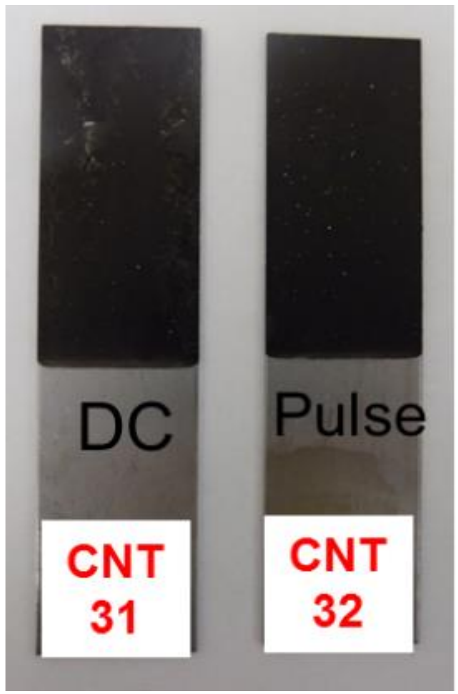
Results

FARADAYIC® EPD (CNT 32/46) improves deposit uniformity

A



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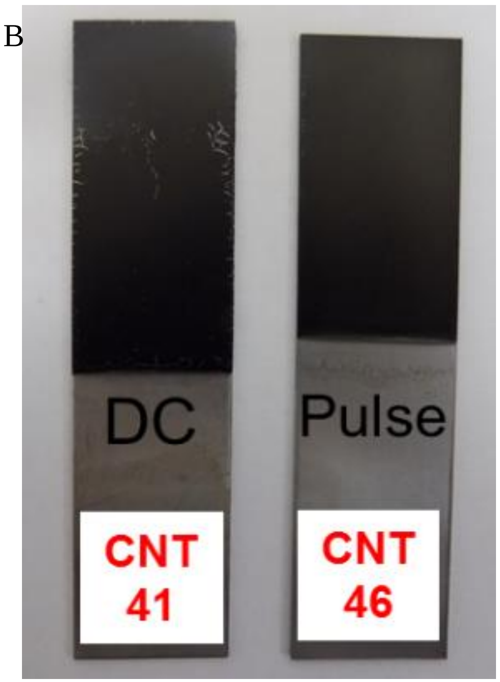

Photographs of CNT coatings formed in (A) DMF (B) EtOH

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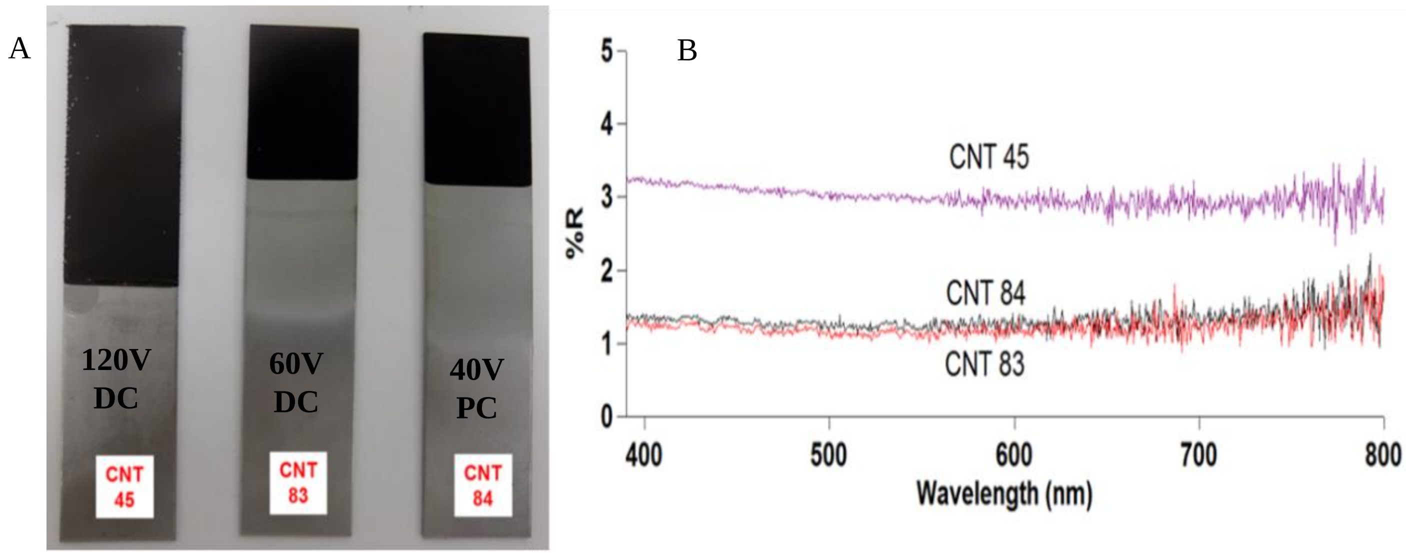
Discussion

- ~3% was the lowest observed diffuse reflection across visible wavebands that was found with CNT films consisting of polymer dispersants
- Polymer dispersants absorbed on the CNT surfaces and block the CNT absorbing the light
- Replacing the polymer dispersants with charged function groups on CNT sidewalls

Results

The removal of polymer dispersants from the process enables the diffuse reflection to be reduced to 1.1%.
Pulse EPD can achieve the same reflectance performance with much lower applied voltage (lower power).

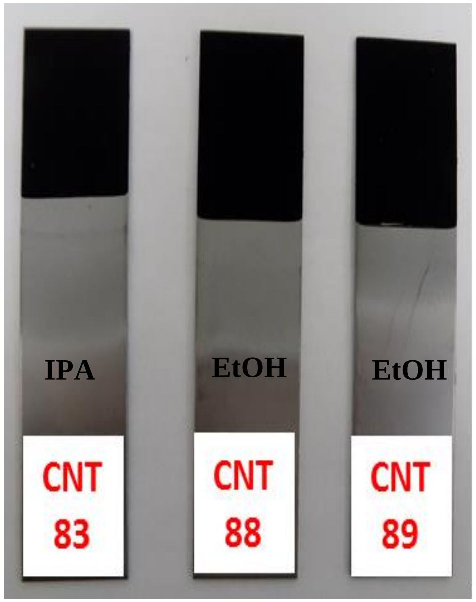


Photograph (A) and diffuse reflectance spectra (B) of Trial CNT45,83& 84

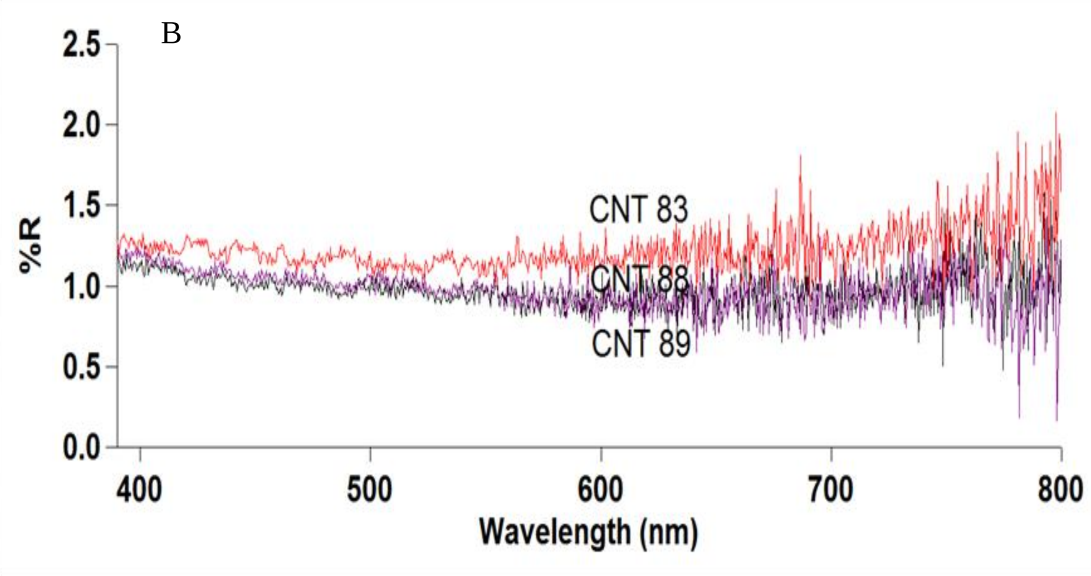
Results

The use of EtOH instead of IPA solvent further decreases diffuse reflection to 0.8% across visible wavebands.

A



B



Photograph (A) and diffuse reflectance spectra (B) of Trial CNT83,88& 89

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Summary

- **Designed and built electrophoretic deposition (EPD) cell with adjustable distance between cathode and anode for CNT coating**
- **Investigated the effects of solvents, binders, dispersants, functional groups on the dispersion of CNTs and reflectance of CNT coatings**
- **Obtained CNT black coatings on stainless steel substrates using EPD under both DC and PC**
- **Initiated pulse waveform EPD and found improved CNT coating uniformity**
- **Achieved diffuse reflectance of ~0.8% across the visible wavebands of the developed CNT coatings.**

Next Step

- **Optimize the PC waveform for lower reflective CNT coating formation (approaching ~0.1% target)**
- **Evaluate the effects of diameter and alignment of CNTs on the reflectance of CNT coatings**
- **Complete an economic evaluation of the EPD approach for anti-reflective CNT coatings**

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The financial support of NASA Contract No. 80NNSC18P2062 is acknowledged.

Special thanks to all our team members for their support

THANK YOU FOR YOUR ATTENTION!
QUESTIONS?

Contact Information:
Dan Wang, Tim Hall, M. Inman, or EJ Taylor

Ph: 937-836-7749
Email: danwang@faradaytechnology.com
timhall@faradaytechnology.com
mariainman@faradaytechnology.com
jenningstaylor@faradaytechnology.com