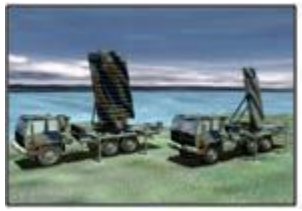
Applied NanoStructured Solutions LLC

ANS
APPLIED NANOSTRUCTURED SOLUTIONS LLC
The Power of Controlled Arrangement
A Lockheed Martin Company





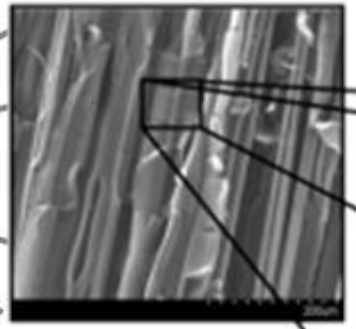
2011

Dr. Tushar Shah – Chief Technology Officer

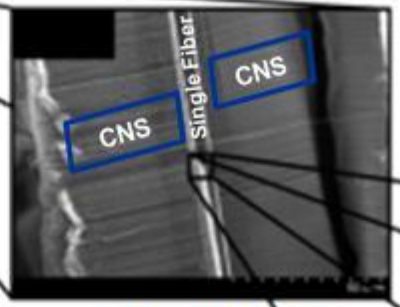
Carbon Nanostructure (CNS) Infusion

What's Different: CNS grown directly (infused) on surfaces

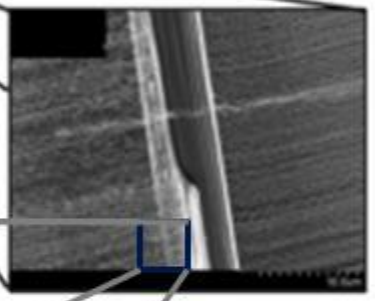
… a *continuous, in-line, production scalable process for glass, carbon ,ceramic , metals*

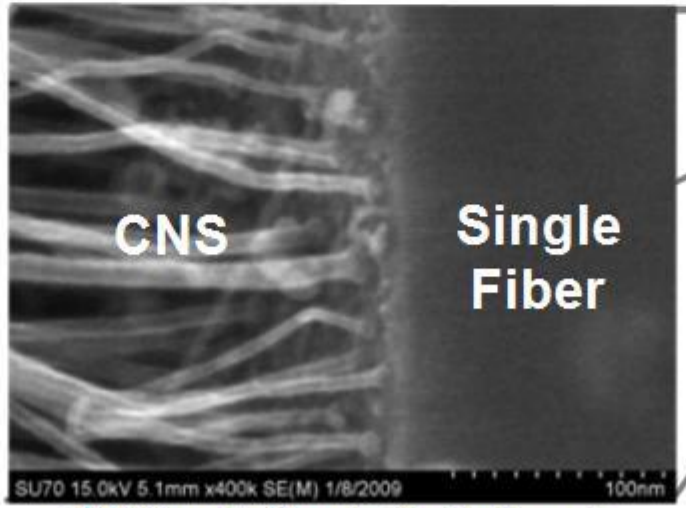


Bundles of Fibers and CNS



Individual Fiber with CNS Infused



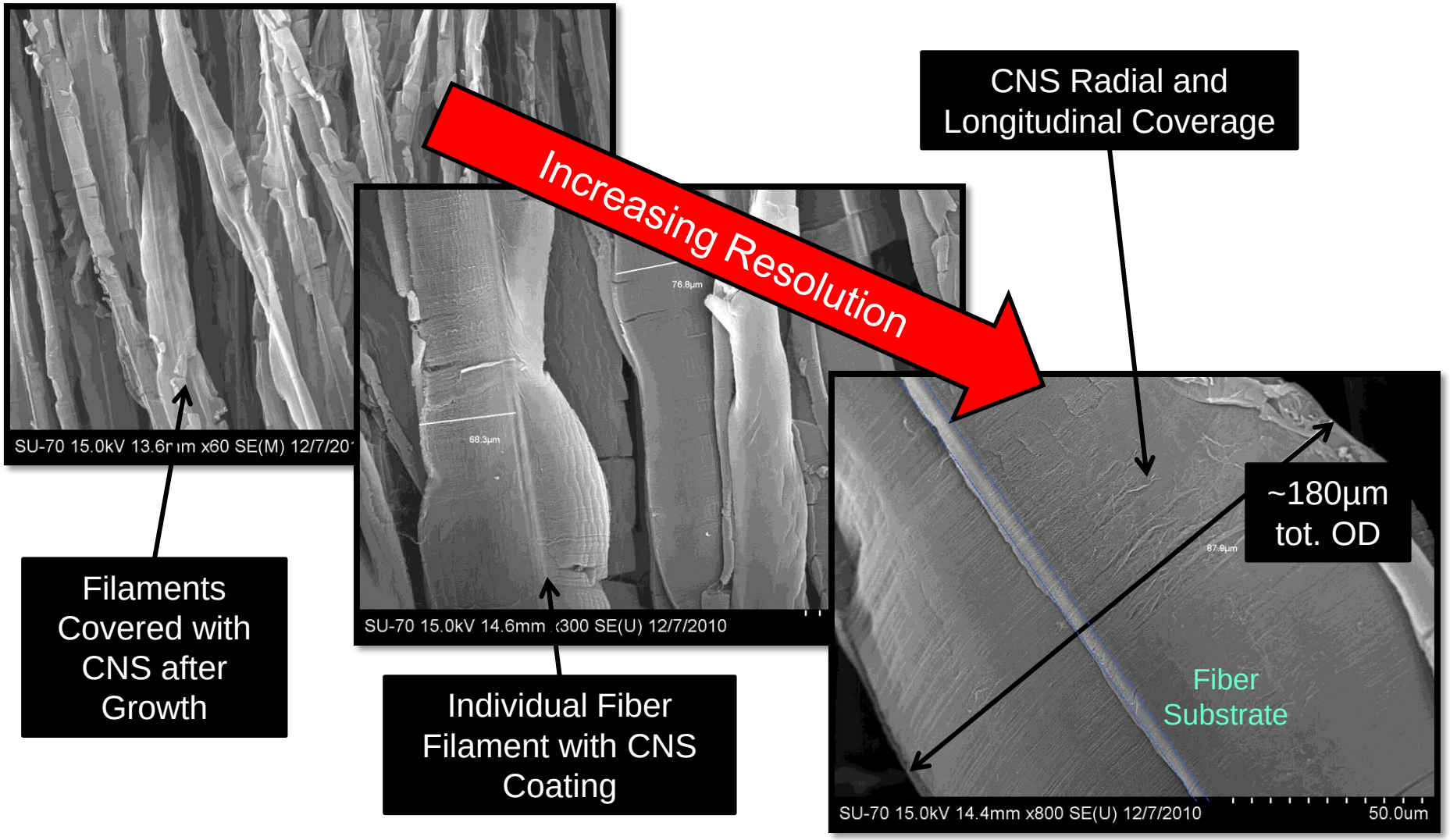


CNS Growth Directly On Surface of Substrate

2

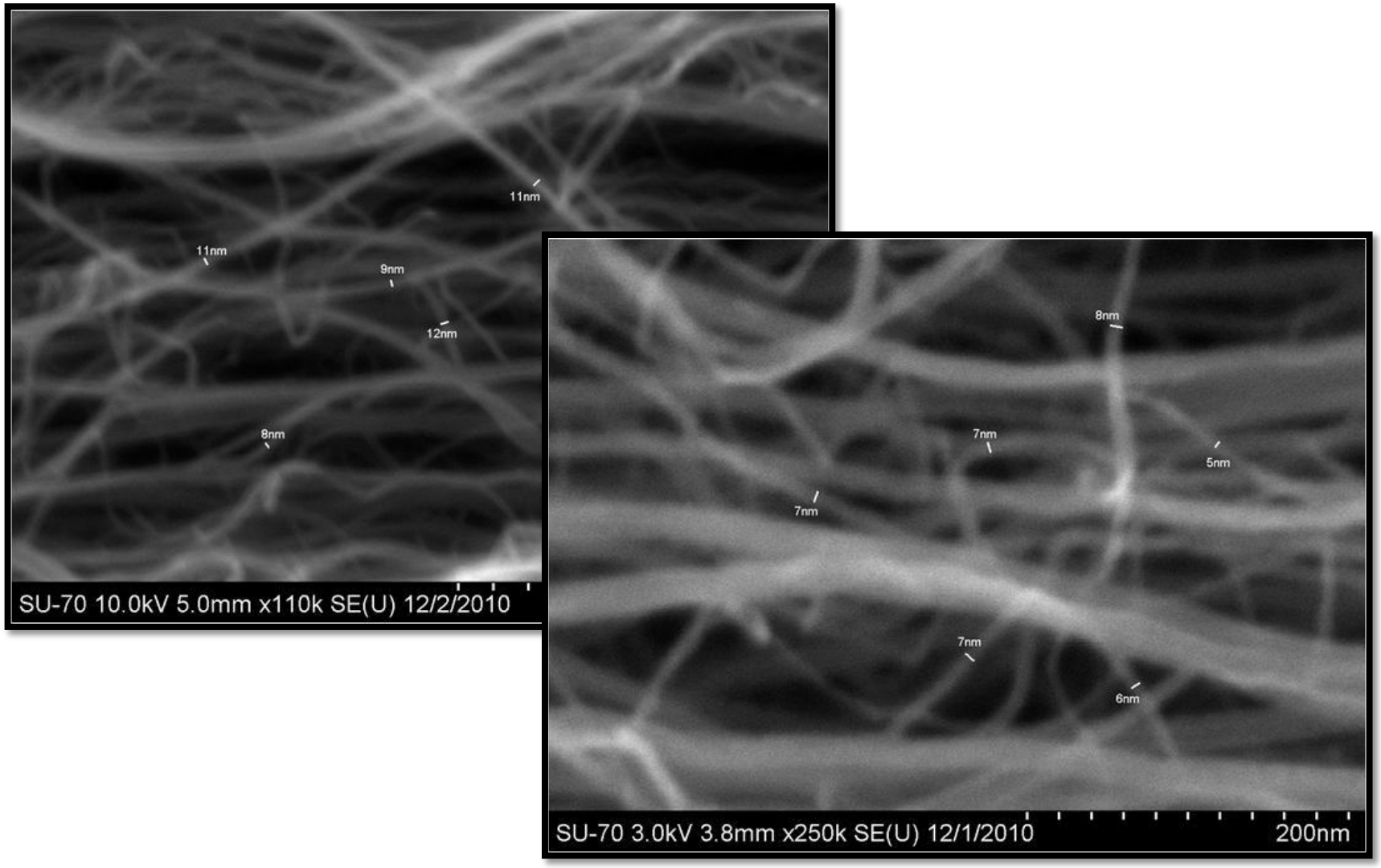
CNS General Appearance

SEM Images – CNS Infused on Fiber Substrate



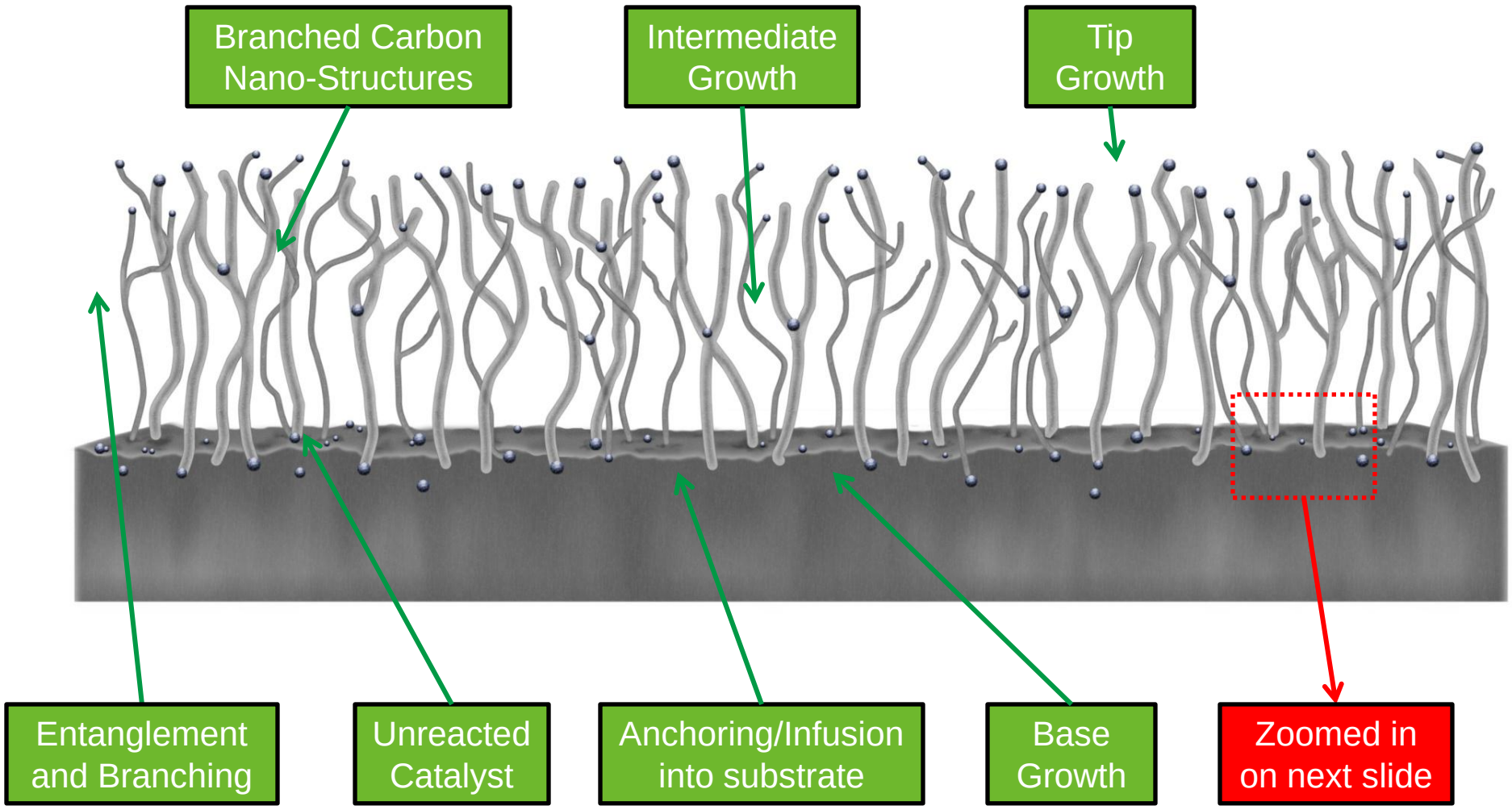
CNS Sizing Characterization

SEM Images – Diameter Measurements



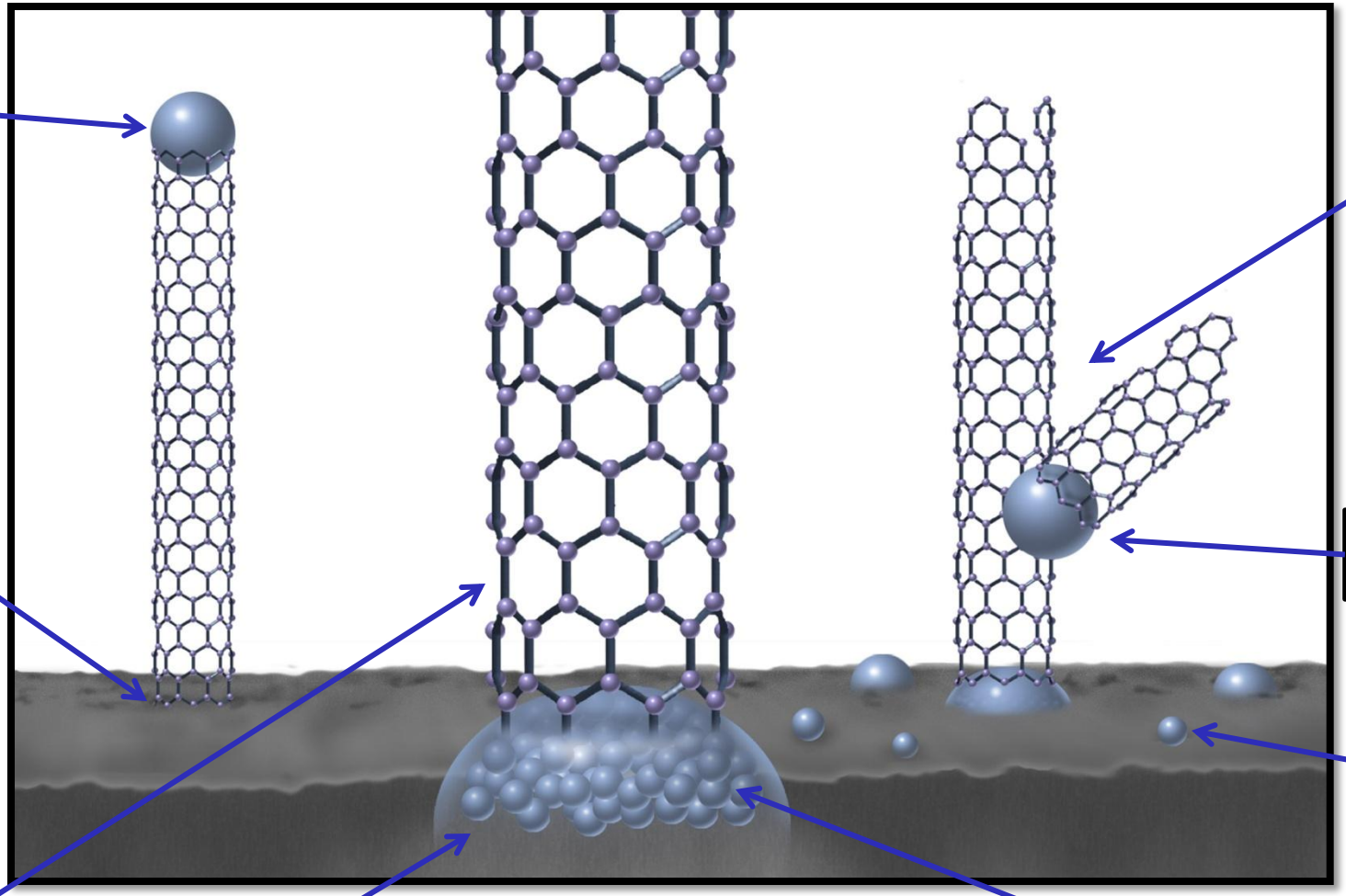
CNS Definition

Overall Structure Model



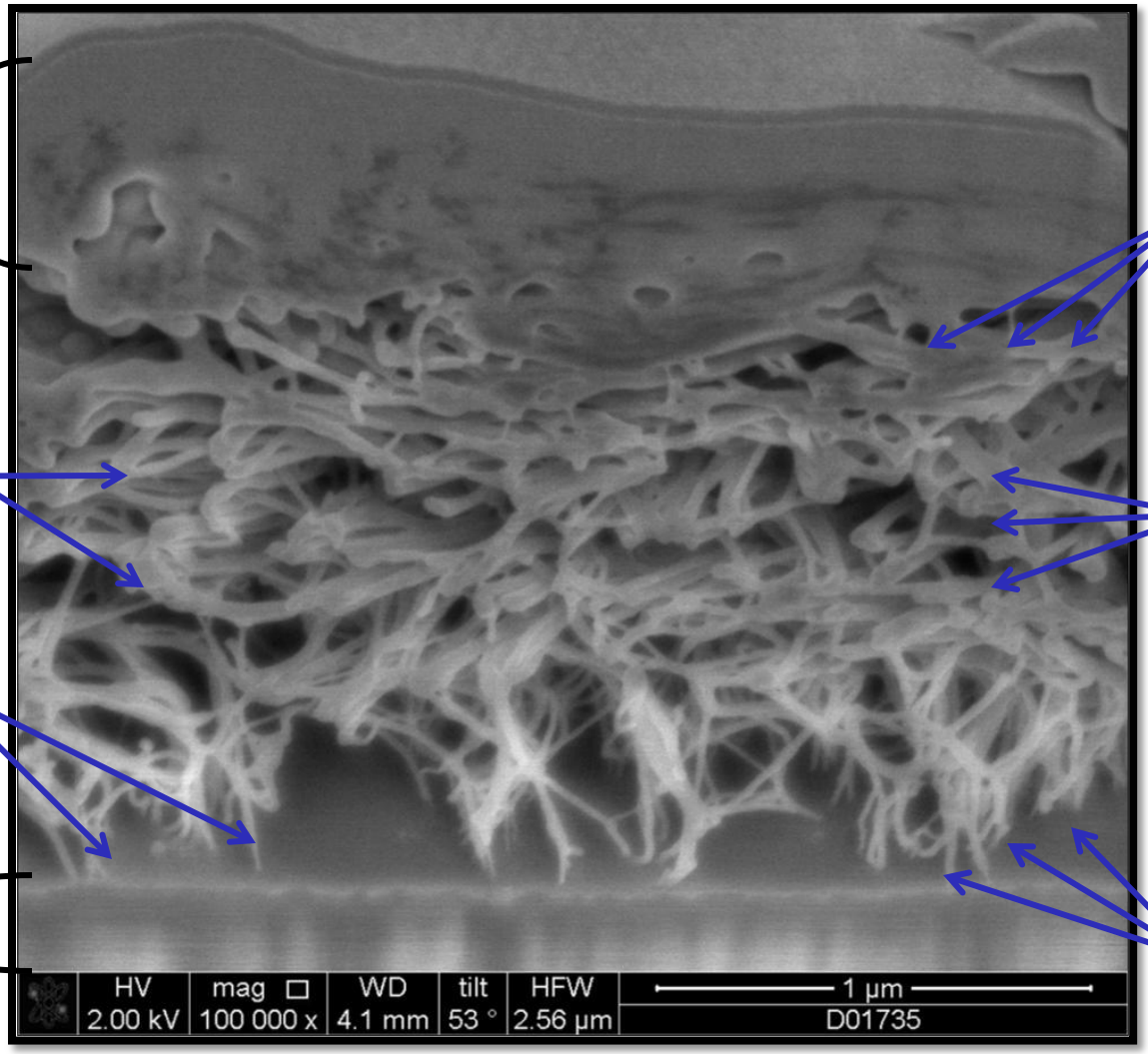
CNS Definition

Structure Model – High Resolution



CNS Structural Overview

High Resolution Cross-Section SEM Images



Capping Layer (necessary for analysis

Entanglement and Branching

Anchoring/Infusion into substrate

Fiber Substrate

Growth Mechanism

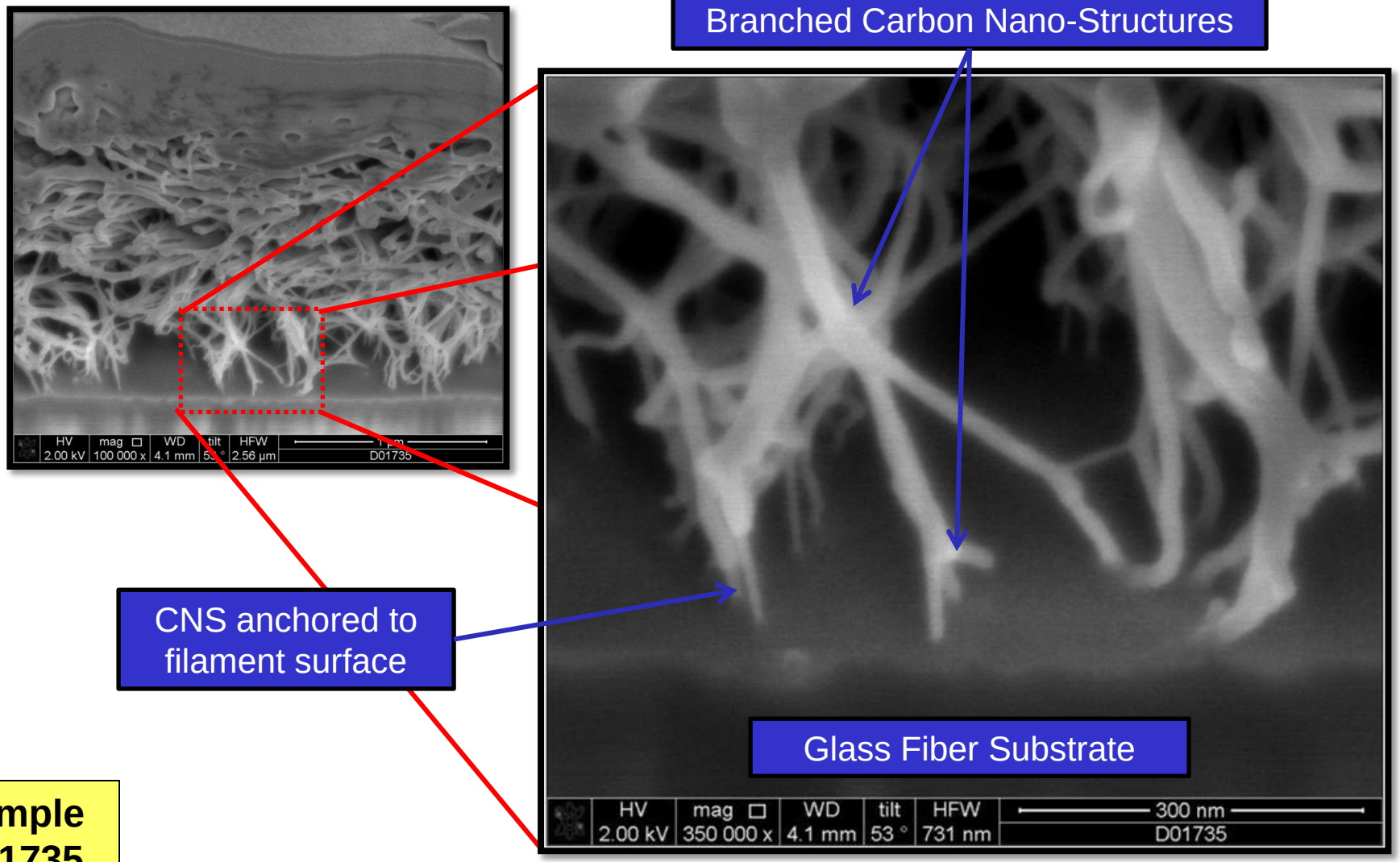
Catalyst Presence Here → Tip Growth

Catalyst Presence Here → Intermediate Growth

Catalyst Presence Here → Base Growth

CNS Branching and Anchorage

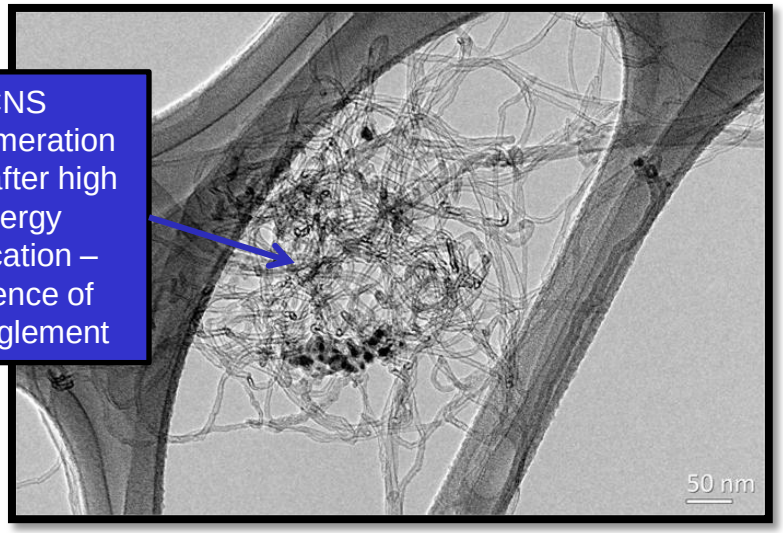
High Resolution Cross-Section SEM Images



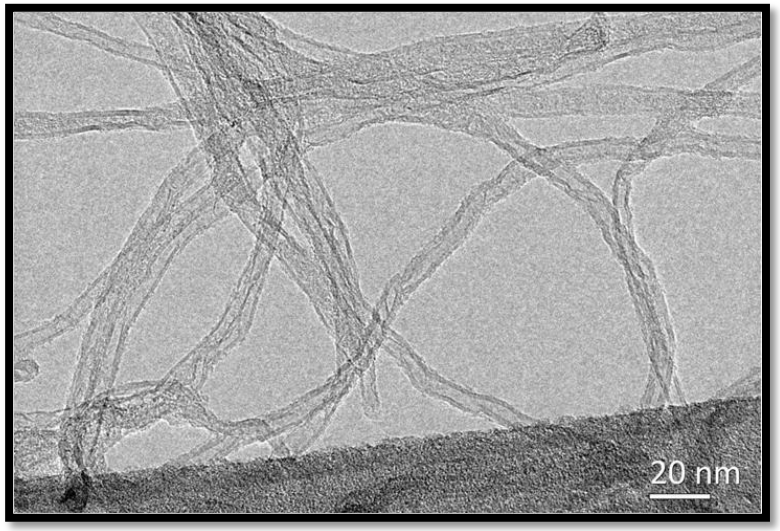
Sample D01735

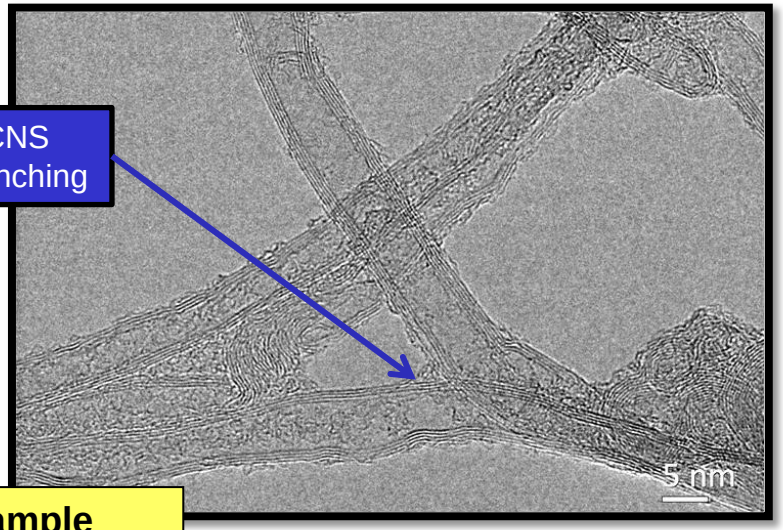
CNS Branching and Entanglement

High Resolution TEM Images

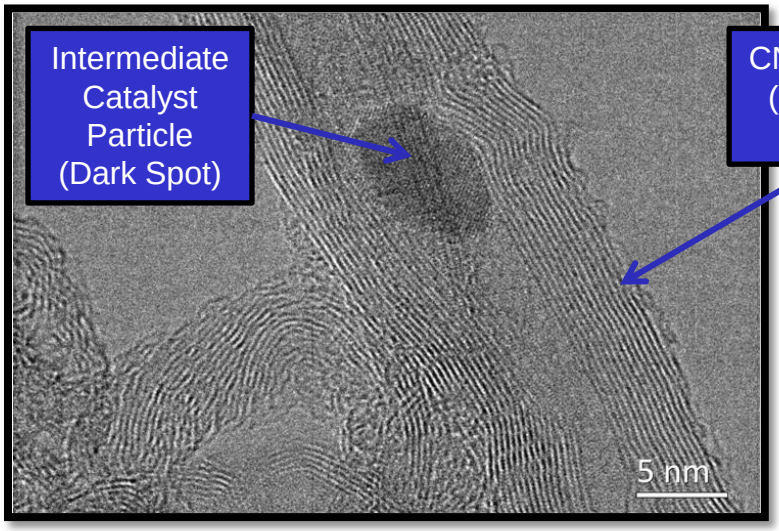


CNS Agglomeration even after high energy sonication – evidence of entanglement





CNS Branching



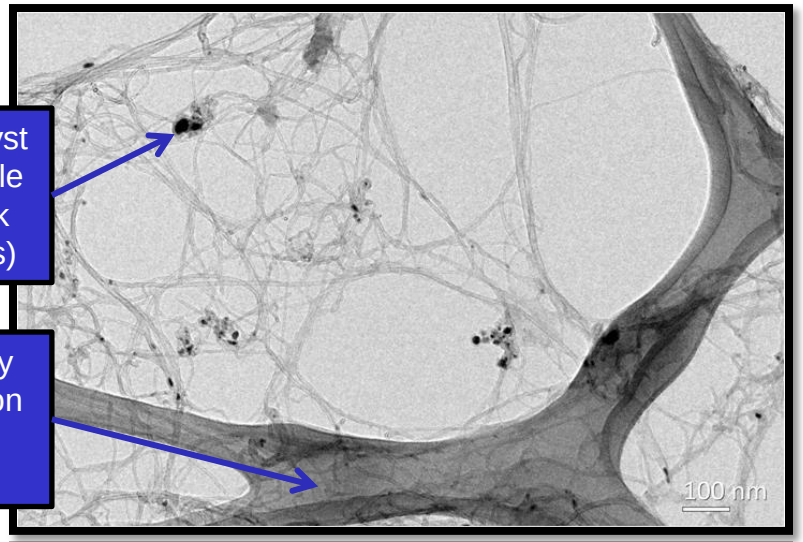
Intermediate Catalyst Particle (Dark Spot)

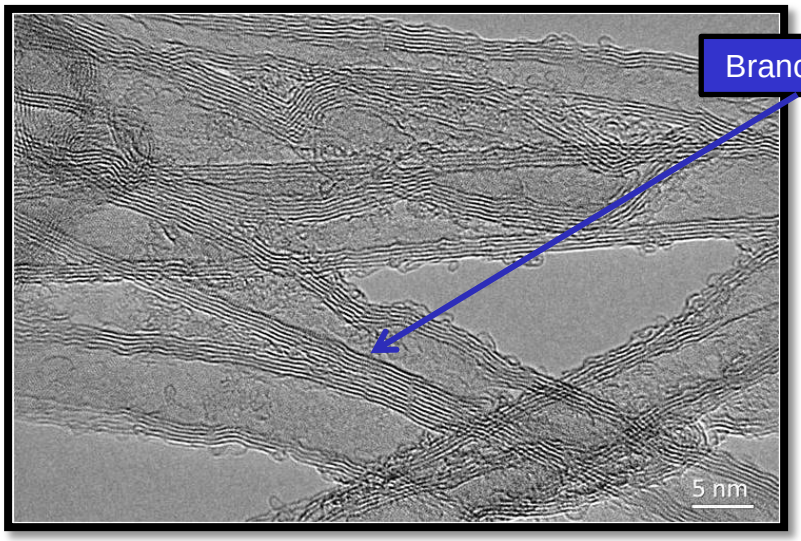
CNS Walls (parallel lines)

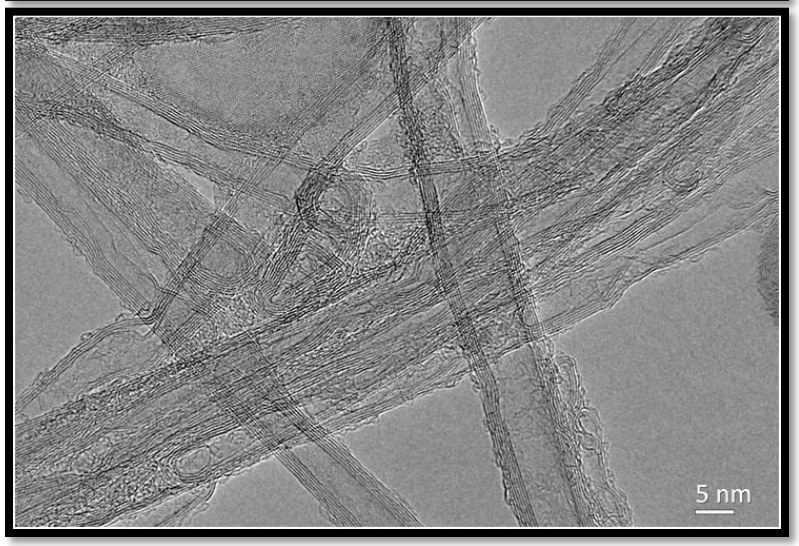
Sample 163+6B+CNS

CNS Branching and Entanglement

High Resolution TEM Images







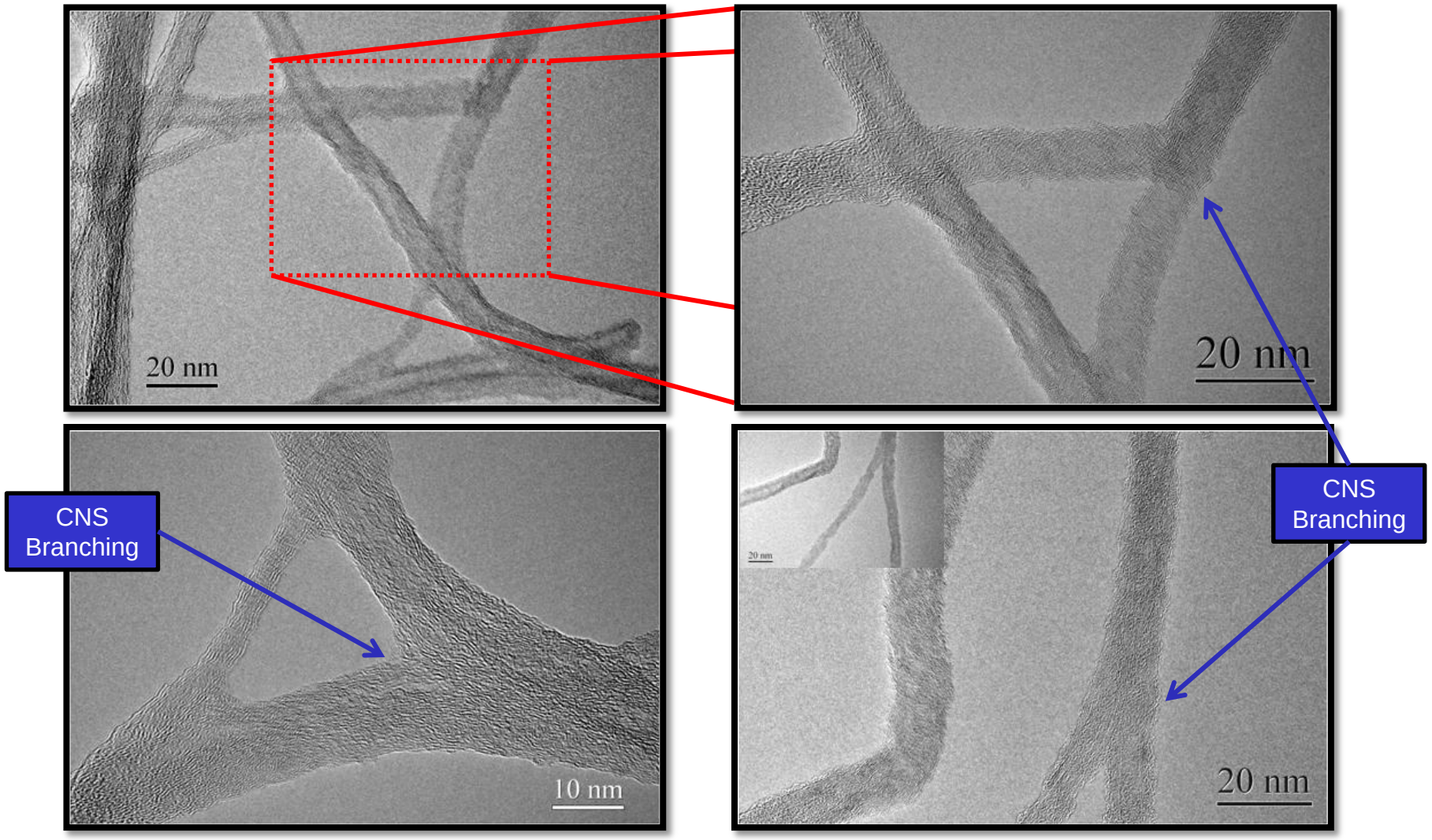
- CNS remained highly entangled after aggressive grid preparation (high energy sonication)

TEM images confirm entanglement of CNS

Sample B02382

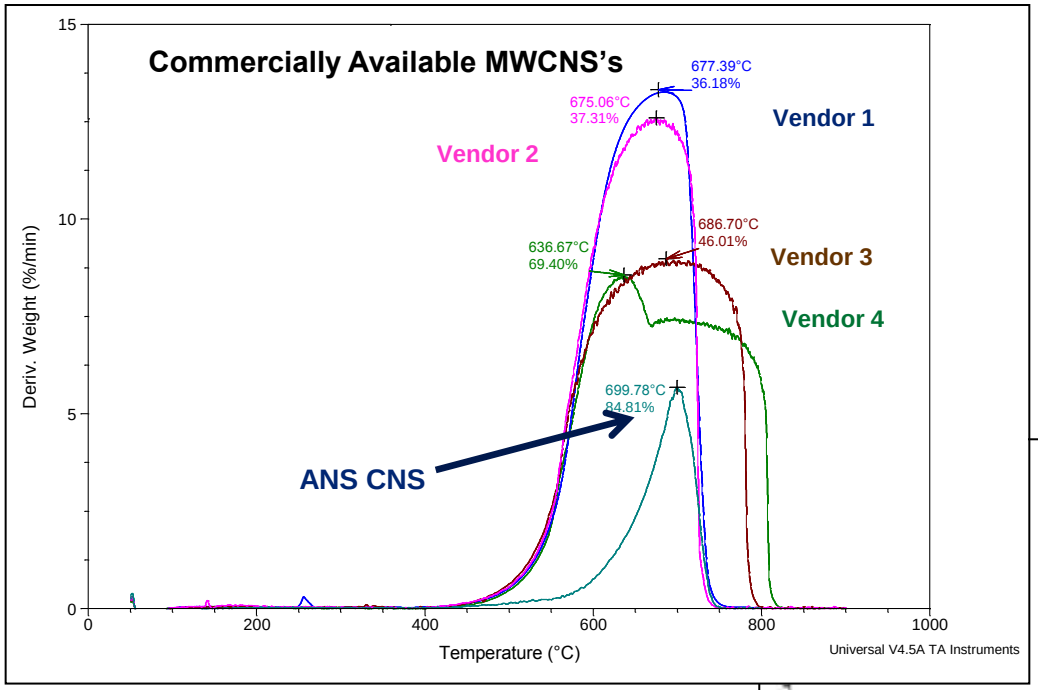
CNS Branching and Entanglement

High Resolution TEM Images

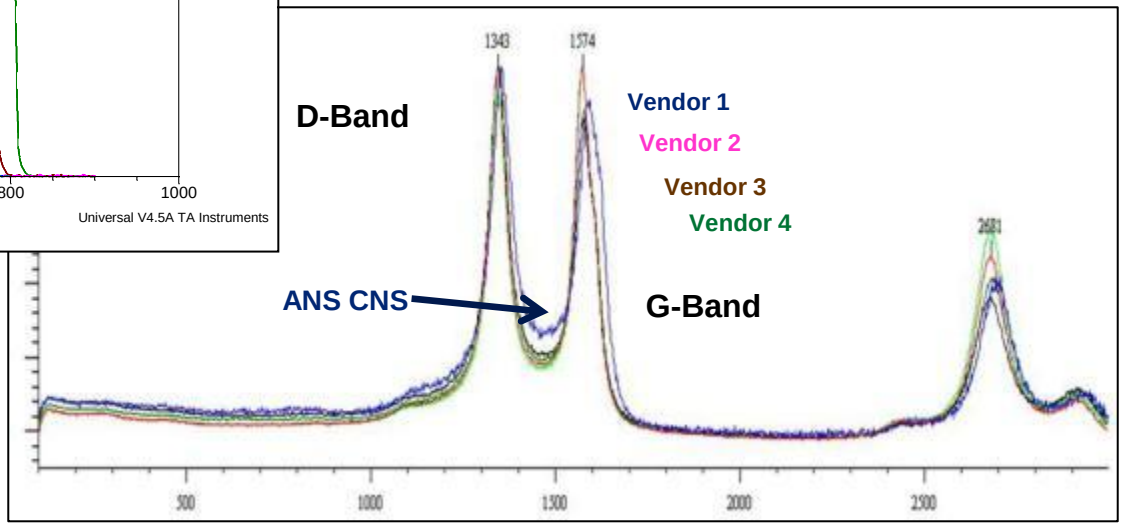


Thermogravimetric & Raman Analysis Of Infused CNSs

Thermogravimetric (TGA) Analysis



Raman Spectrums



CNS Infused On Fiber Equal In Quality To Commercially Available CNS

Carbon Enhanced Reinforcements (CER)

Product Forms with Multifunctional Properties

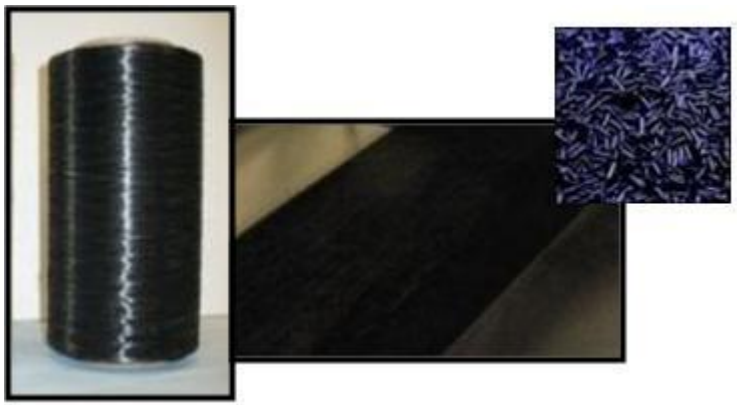
Product Forms

CER Fiber Tow Prepregs

CER Post Coated Tow For Fabrics

CER Fabric Prepregs

CER Thermoplastic Pellets



"Tunable" Properties

Physical

- **Density, thickness**

Mechanical

- **Toughness, isotropy**

Thermal

- **Control heat stability and conductivity**

Electrical

- **Shielding, storing, directing, absorbing**

Durability

- **Corrosion, wear, fatigue resistance**

Product Forms provided per Stewardship and Customer Requirements

CNS Material Forms

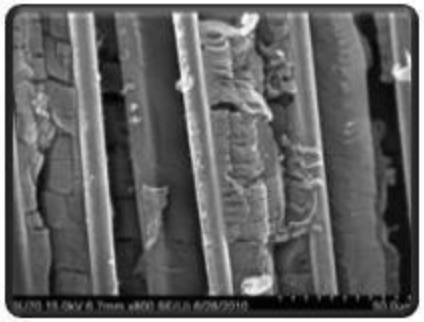
CNS infusion demonstrated on multiple material forms for broad range of composite manufacturing processes and product applications: bodies of rotation, multi-material flat panels, complex geometries

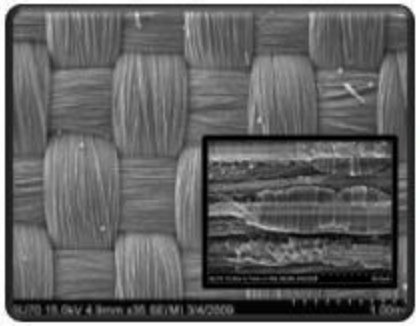
- Fabrics
  - Prepreg
  - Wet layup
  - VARTM
  - Resin film infusion
- Tow/roving
  - Wet filament winding
  - Towpreg
  - Unidirectional tapes
- Chopped
  - Sheet, bulk and injection molding compounds

Demonstrating Standard Material Forms and Manufacturing Processes for Rapid Technology Transition

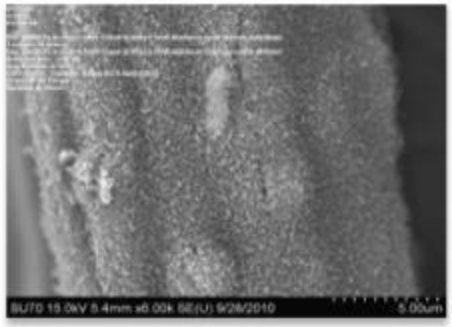
Substrate Materials and Architectures

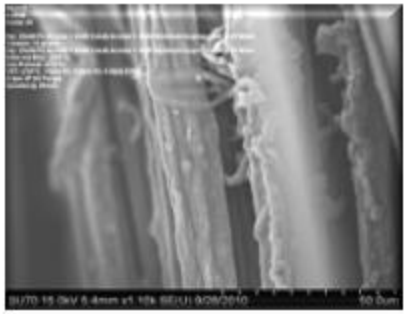
Glass Fiber & Fabric



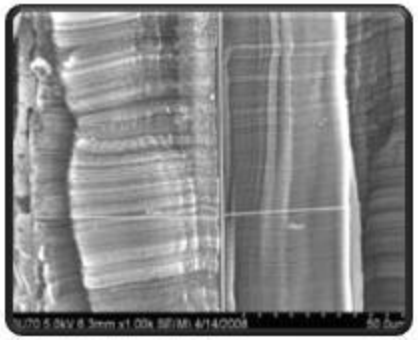


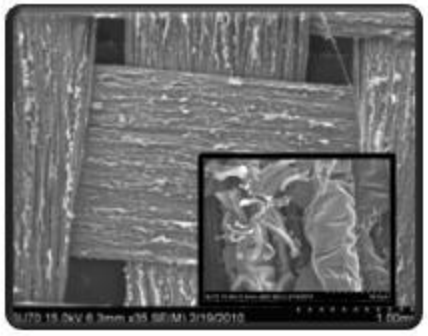
Kevlar Fiber



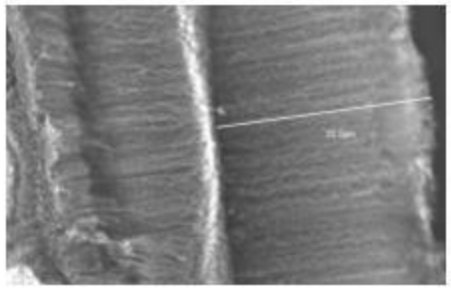


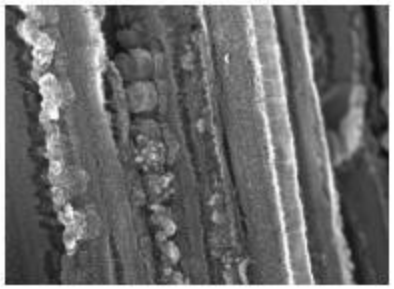
Carbon Fiber & Fabric



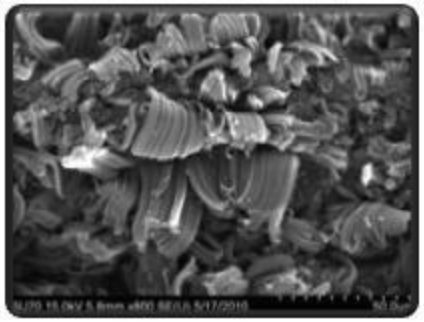


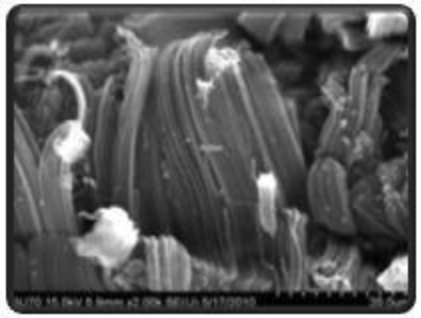
Ceramic Fiber





Metal Foil Substrates

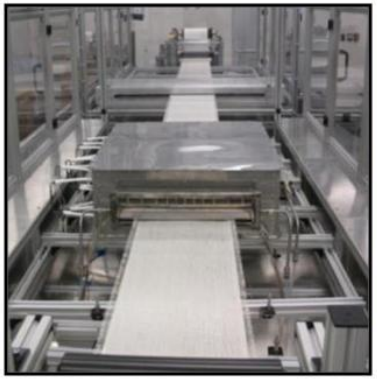




- **Our research can help to tailor various growth parameters to maximize specifications for a specific end use.**
  - **Growth Parameters Include: CNS Loading, CNS Length, CNS Size, # of CNS Walls**

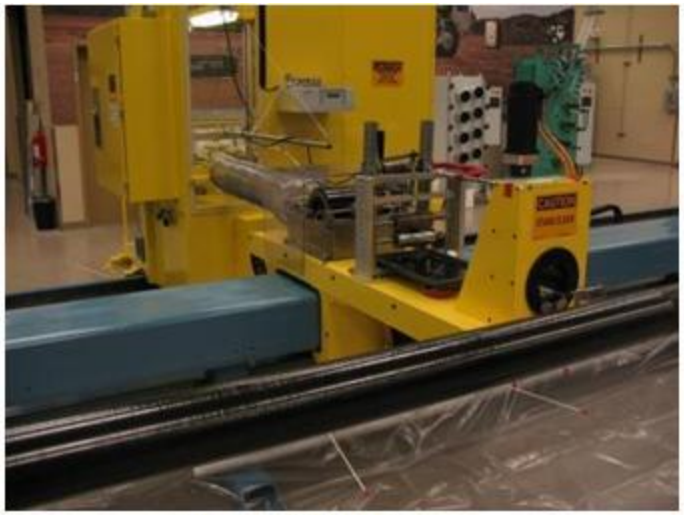
Process Can Be Tailored To A Variety of Substrates End Uses

ANS – Pilot Scale Manufacturing



Tows, 16” 40” moving to 60” Fabric Lines

ANS – Product Development Center

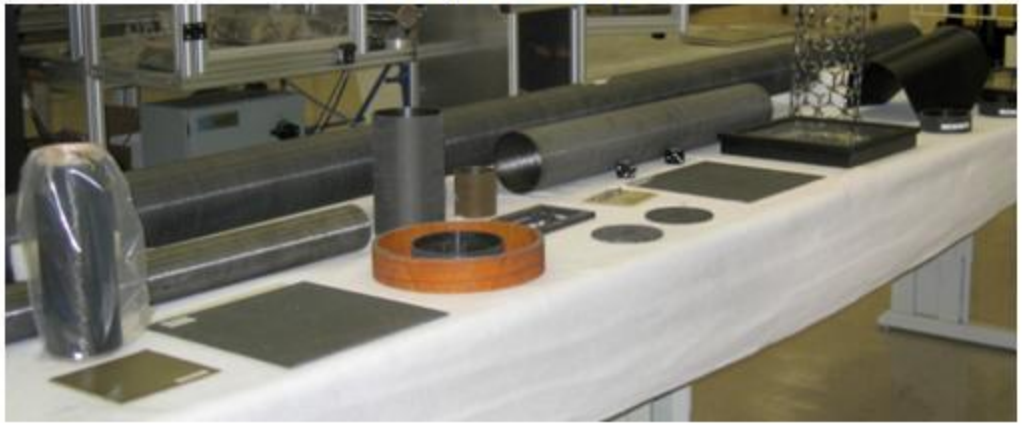


Filament Winder

Sample Products

Ovens

Autoclave
March 2011



Product Development Center for Prototype and Low Rate Manufacturing of Components

ANS Product Stewardship

- ANS / Government Progress to date:
  - Air Monitoring
  - NIOSH Method 7400
    - All tests to date have not yielded any respireable durable fiber
- Next NIOSH Audit Activity begins 2/22/11
- A 3-part Pre-Manufacturing Notification (PMN) has been submitted to the EPA for review and approval
  - 3 products designated by CNS length:
    - Short: .01-15µ
    - Medium: 15-50µ
    - Long 50-100µ


SAFETY DATA SHEET
Infused CNS-G Post Coat

SECTION 1: PRODUCT AND COMPANY IDENTIFICATION

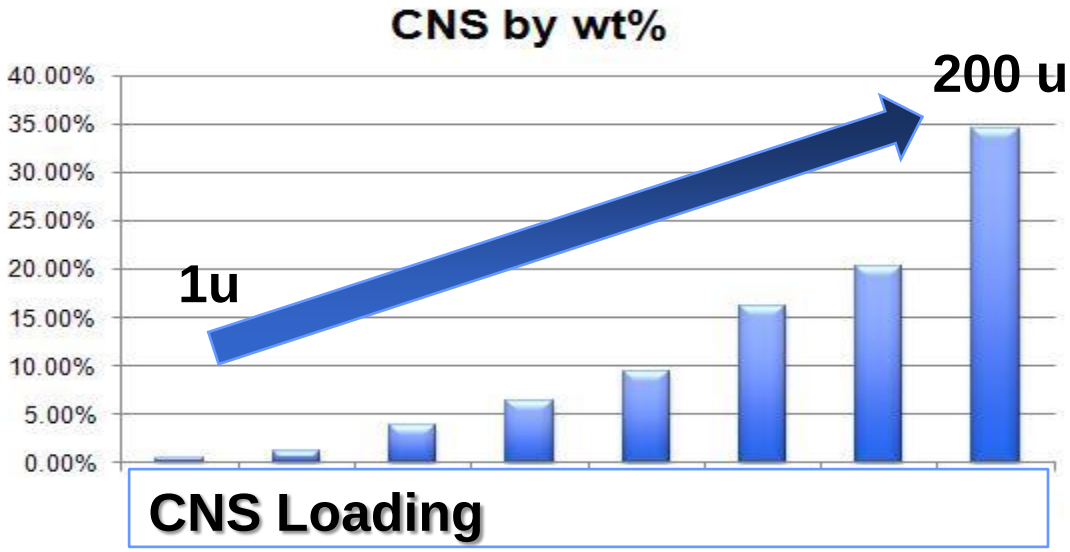
PRODUCT NAME: Infused CNS-G Post Coat
SYNONYMS: None
PRODUCT CODES: None

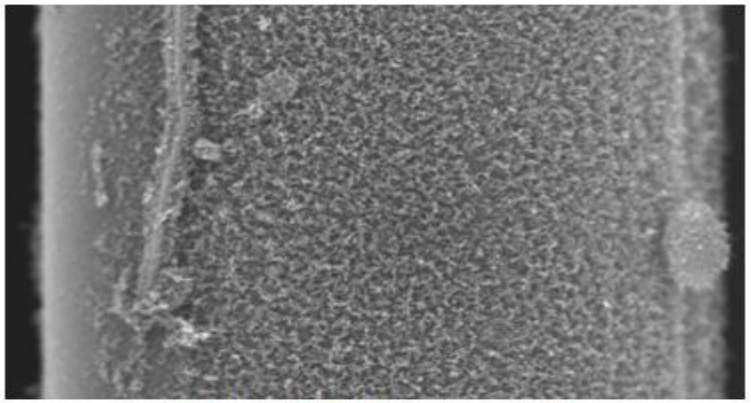
MANUFACTURER: Applied NanoStructured Solutions, LLC
ADDRESS: 2323 Eastern Ave,
Baltimore, MD 21220

Goal: No Respireable Durable Fiber

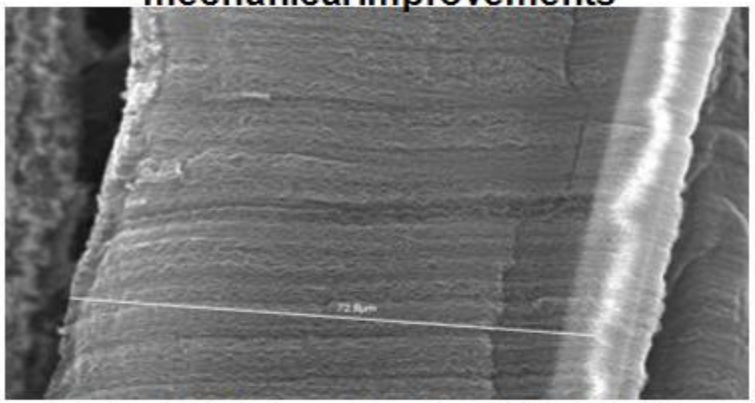
ANS Tunable Properties
Material Characteristics

CNS Infused To Glass Fiber Tow





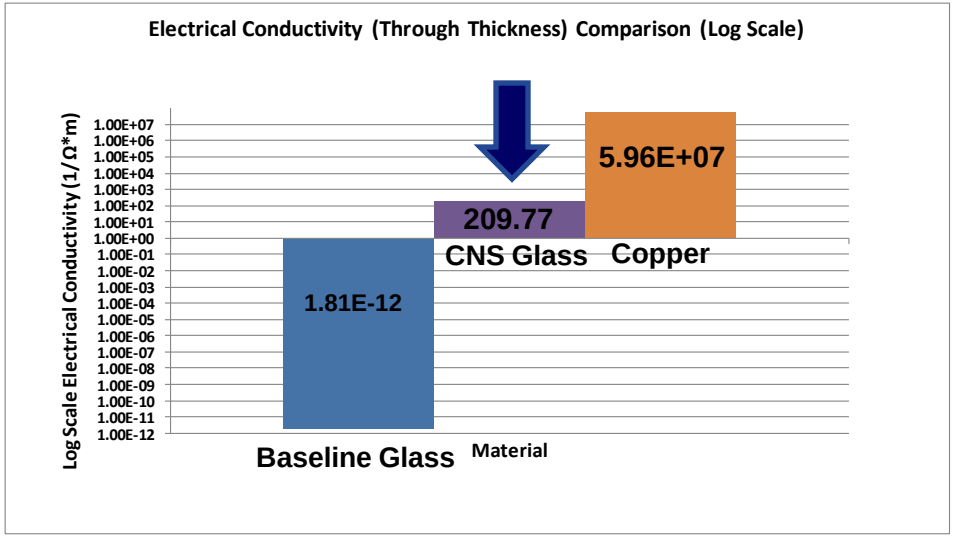
0.5% wt CNS Loading for mechanical improvements



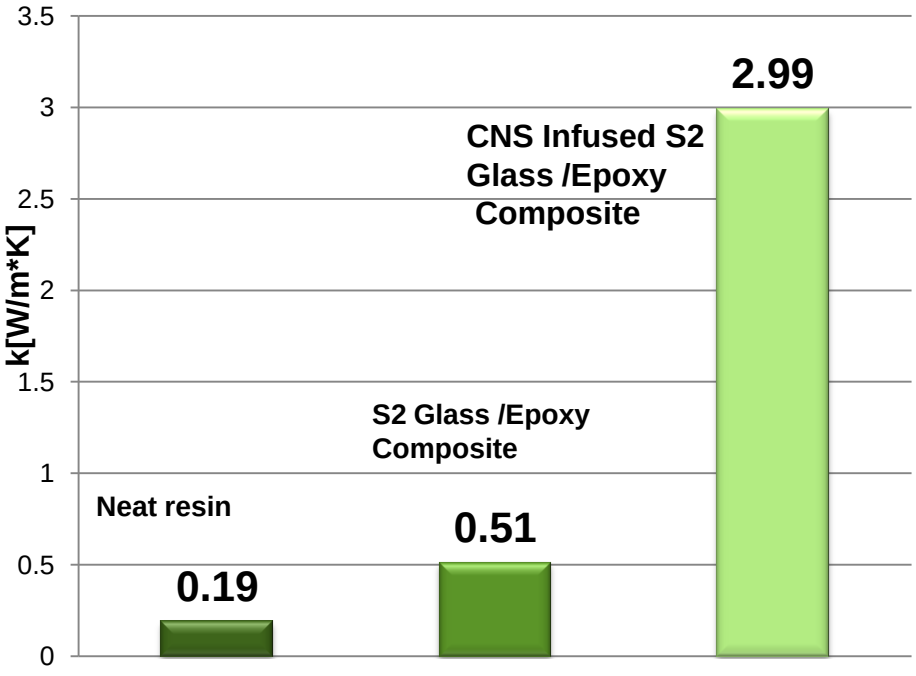
15% wt CNS Loading for EMI Shielding

Infused Low and High Density CNS

Electrical & Thermal Conductivity of Glass/Epoxy Composites

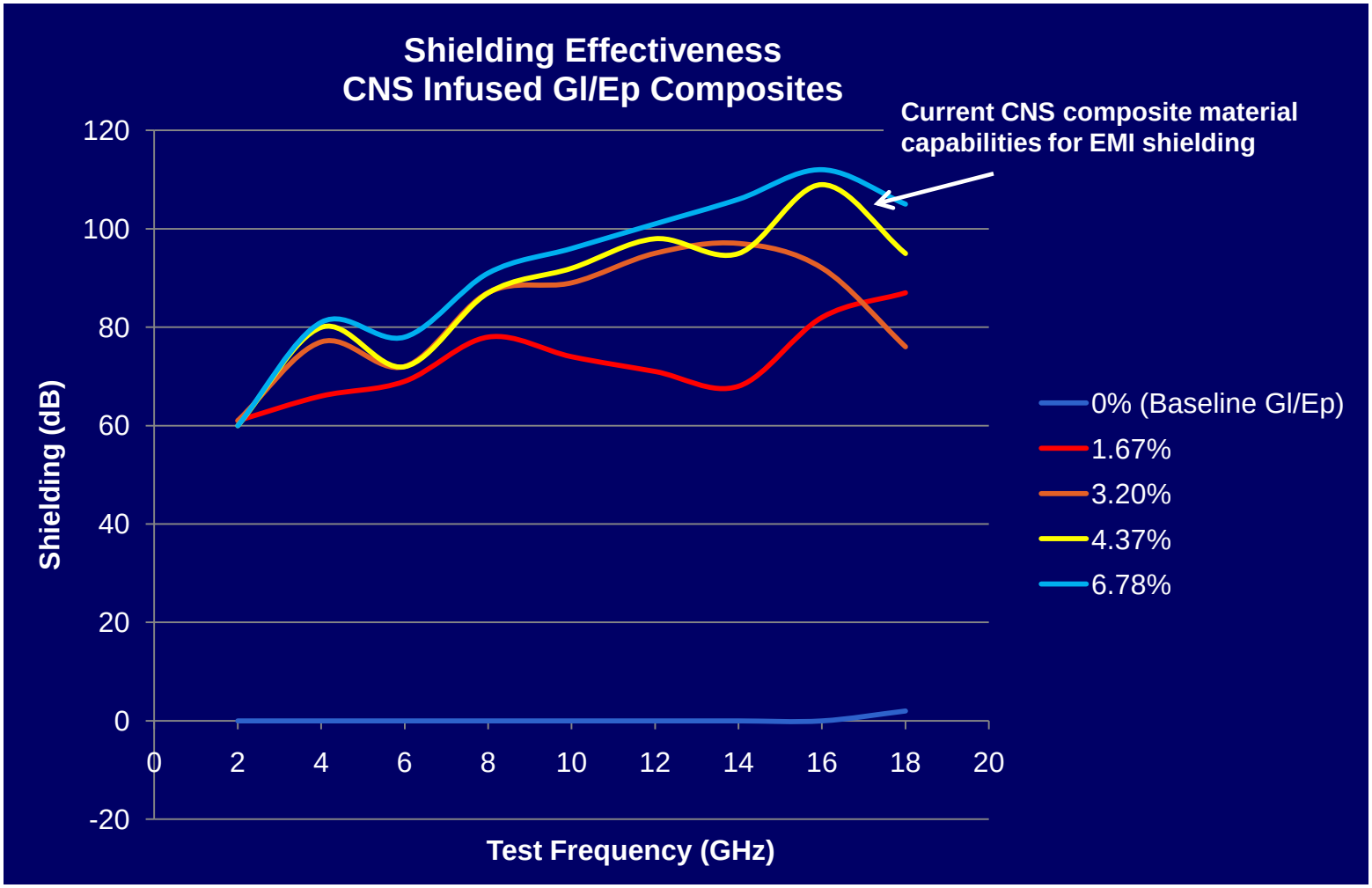


Conductive Composites



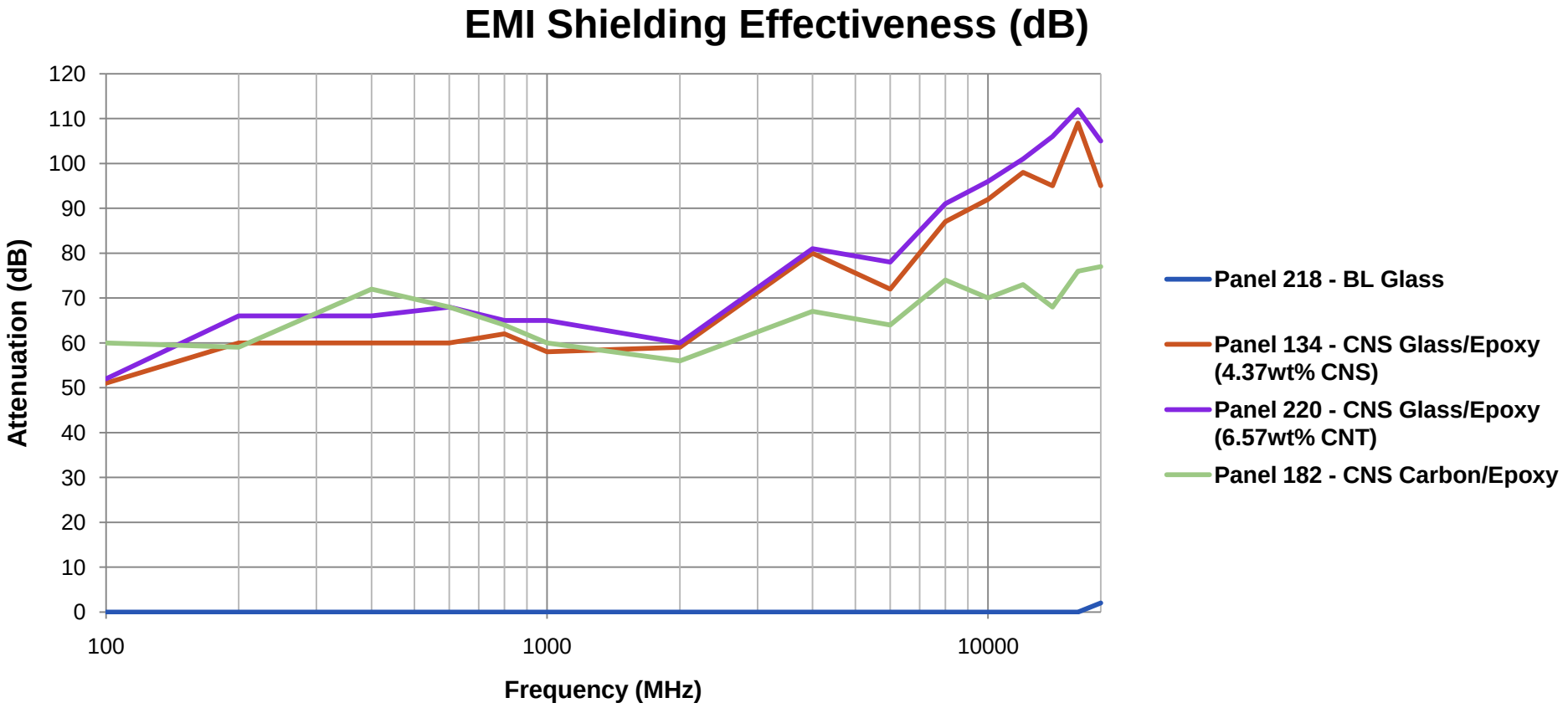
Improved Thermal Conductivity

EMI Shielding (2-18 GHz)



Increased Wt% CNS in Composite Improve EMI Shielding Characteristics

EMI Shielding (100Mhz – 1GHz)



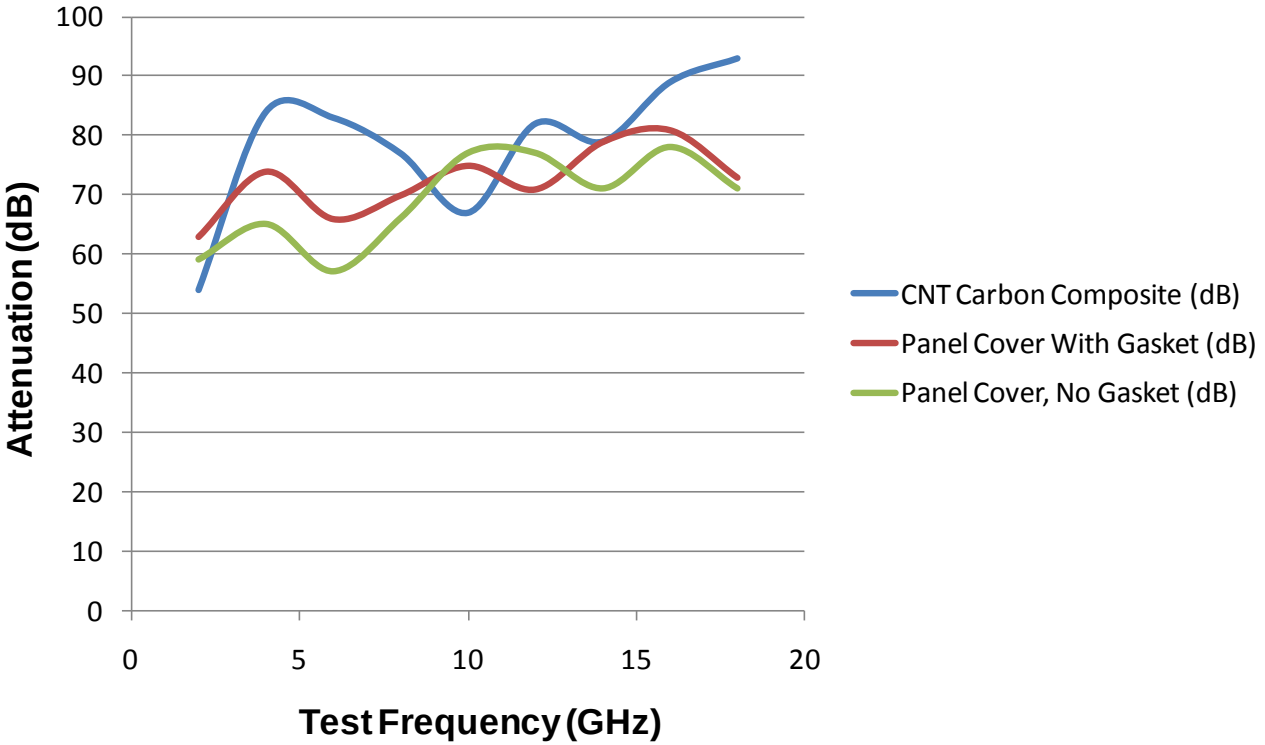
Increased Wt% CNS in Composite Improves EMI Shielding Characteristics

EMI Shielding

- **Demonstrate EMI shielding for composite construction**
  - **Evaluate effects of seams, gaps, gaskets**

- 26” x 26” Flat Panel
- 10” x 10” Window

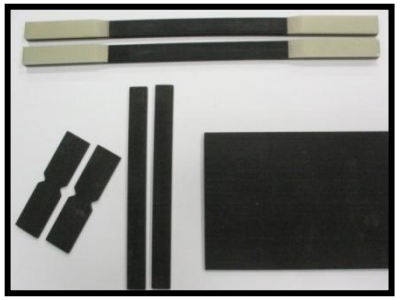
CNS Composite Cover Plate

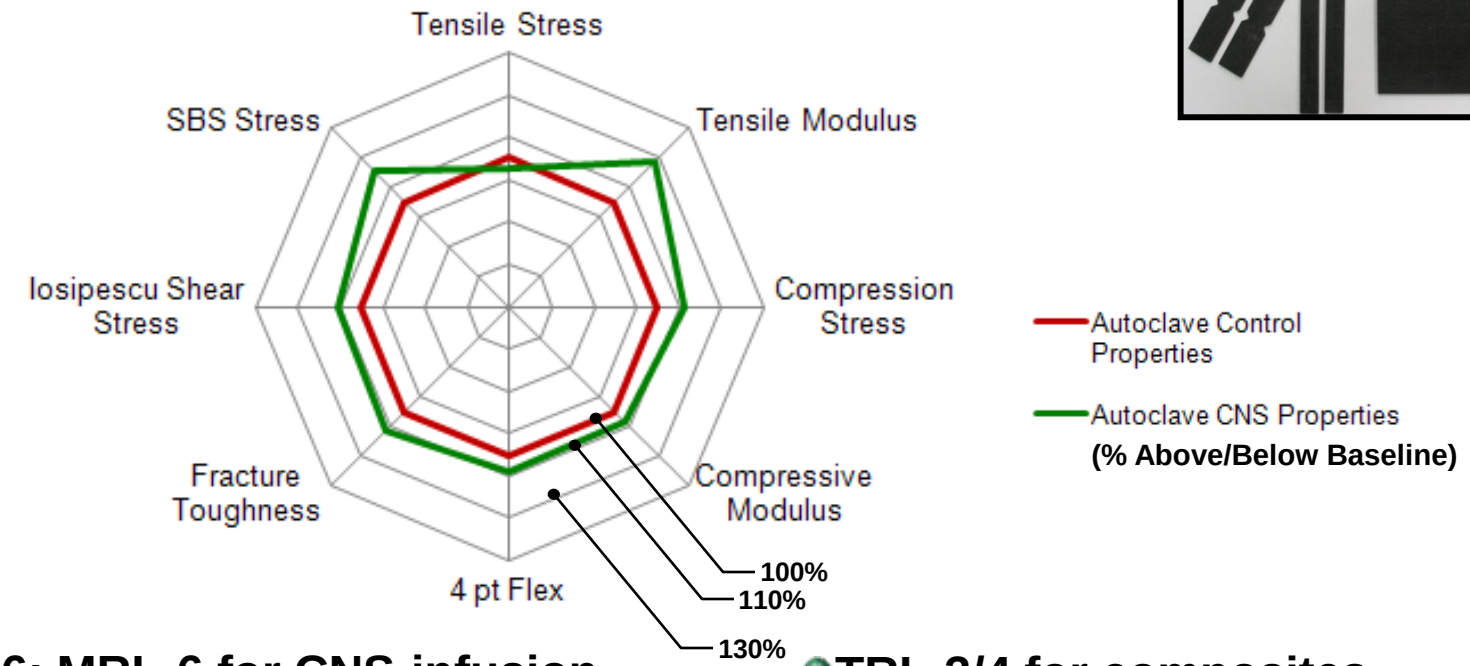


Bonding of CNS Composite Structures Not Critical

Multifunctional Properties
Mechanical Strength

- **Demonstrating mechanical performance through industry standard test methods**
  - **Optimizing CNS processes to realize mechanical improvements in all properties and all material forms**
  - **ANS Technical Data Sheets with design allowables will be published**



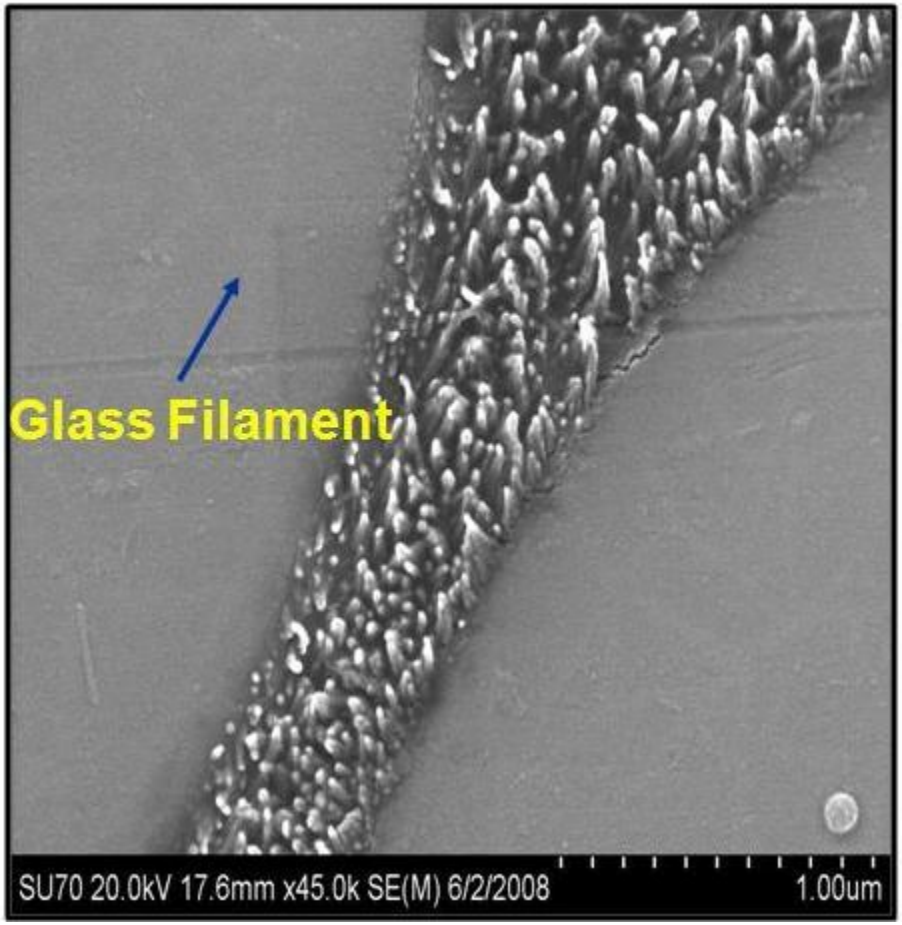


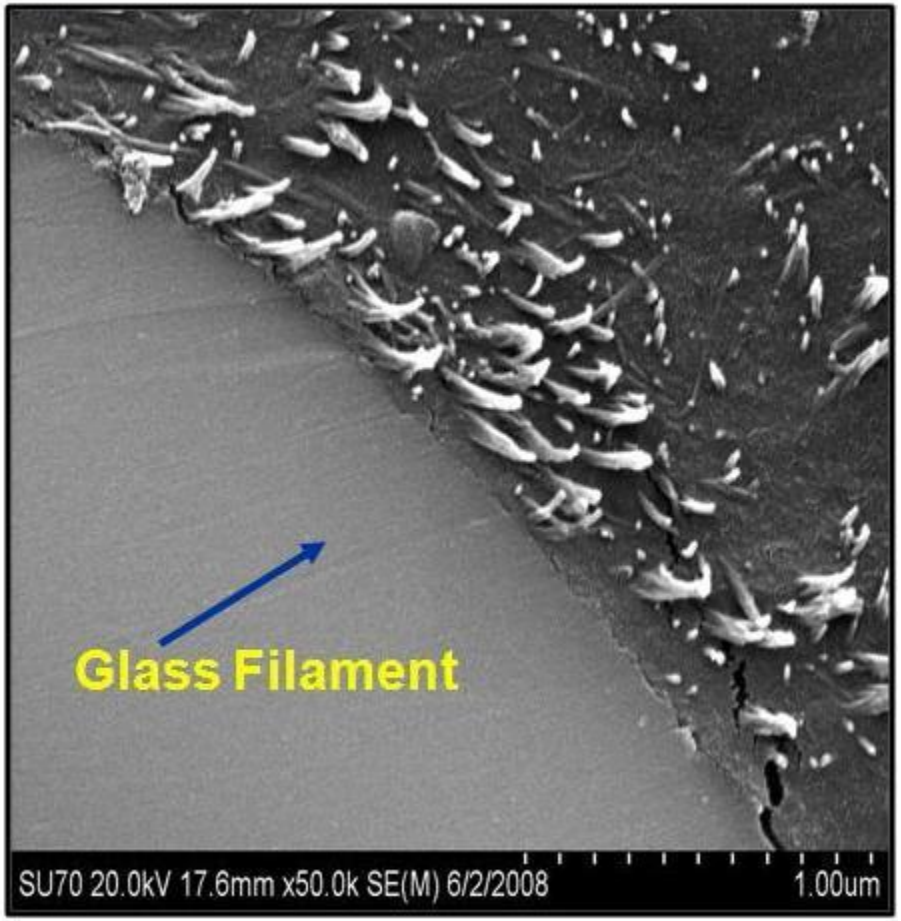
- **TRL-6; MRL-6 for CNS-infusion**
- **TRL-3/4 for composites**

Optimizing CNS Process Recipe and Composite Manufacturing Processes

Composite Processes Development

Cross Sections





CNS improve critical failure interfaces in composites

Lightning Strike Test

30kA

Panel RFI 73 – CNS Glass/Epoxy

4 Plies Fabric, Surface Resistivity: 12

TOP (Strike Surface)

BOTTOM

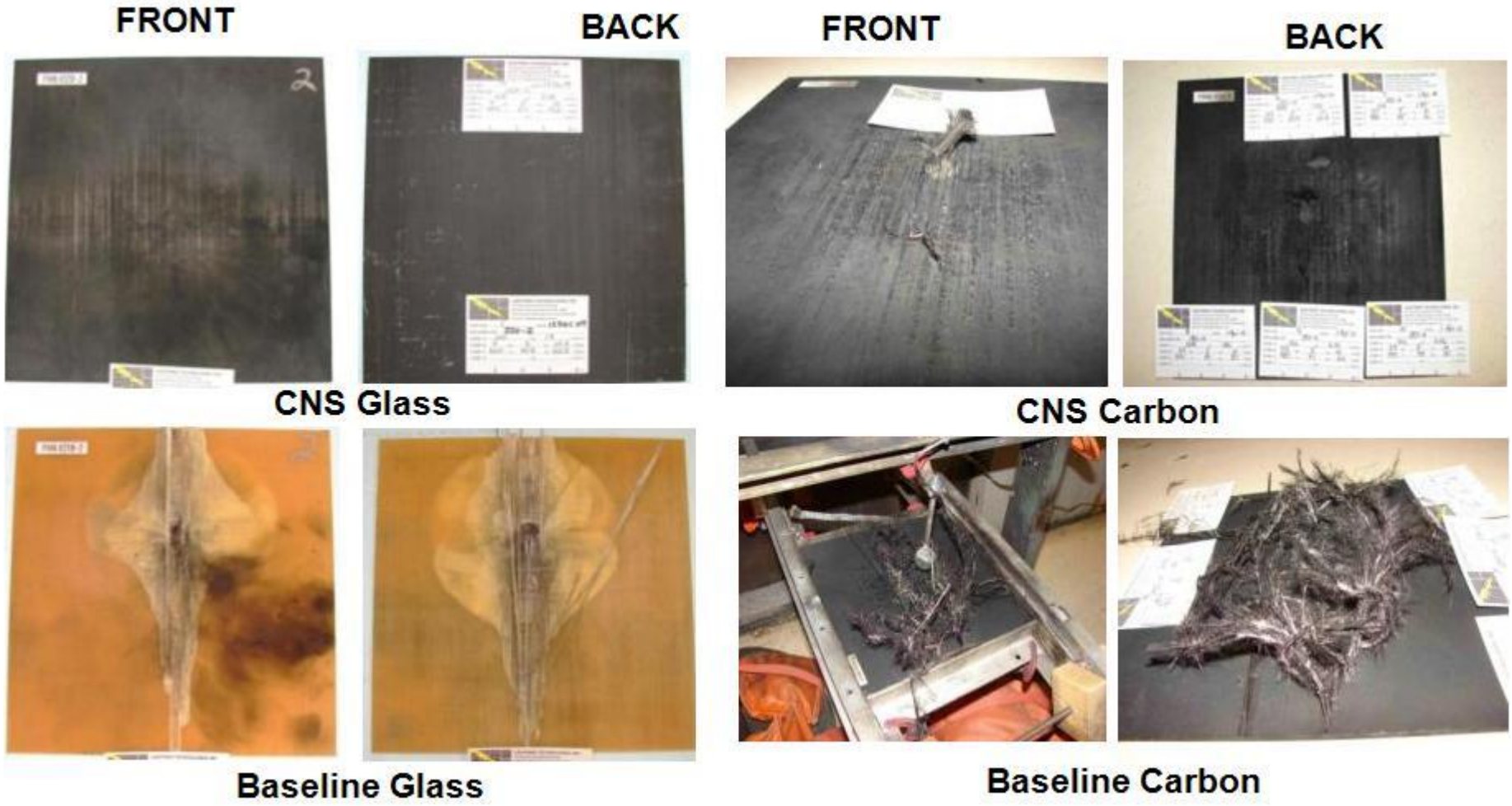
200kA

Panel RFI 472 – *1 Pliy Fabric*

CNS Carbon/Epoxy on 3 base plies

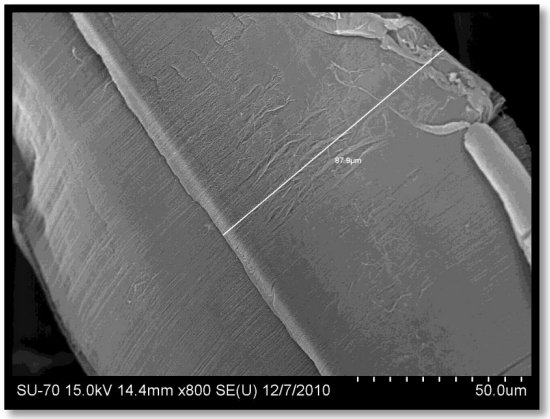
Lightning Test – High Current Test

Baseline Glass/Epoxy Panel Vs. CNS Glass/Epoxy Panel



BL Glass/Epoxy is Punctured and Delaminates,
CNS Panel Strike Surface has surface abrasion

Future Needs



- Very Complex CNS produced at high speeds on various sustrates
- Need for high speed real-time analytical tools
  - Surface analysis techniques
  - Determine variations in density
  - Type of nanostructures
  - Functionalization

Thank You

Questions ?