Elect Nano™

Discrete Carbon Nanotubes vs. Carbon Fiber: Nano-Uniform Surface Resistance for Next Gen ESD-Safe Fixtures

Brandon Sweeney, Ph.D. CTO Elect Nano LLC.
Email: bsweeney@electnano.com

Presentation Outline

- Elect Nano Company Introduction
- Core Technology and Capabilities
- Discrete CNTs for Injection Molding
  - Dispersion of CNTs Thermoplastics
  - Use case for JEDEC trays
  - Electrical Property Testing
  - Laser Marking

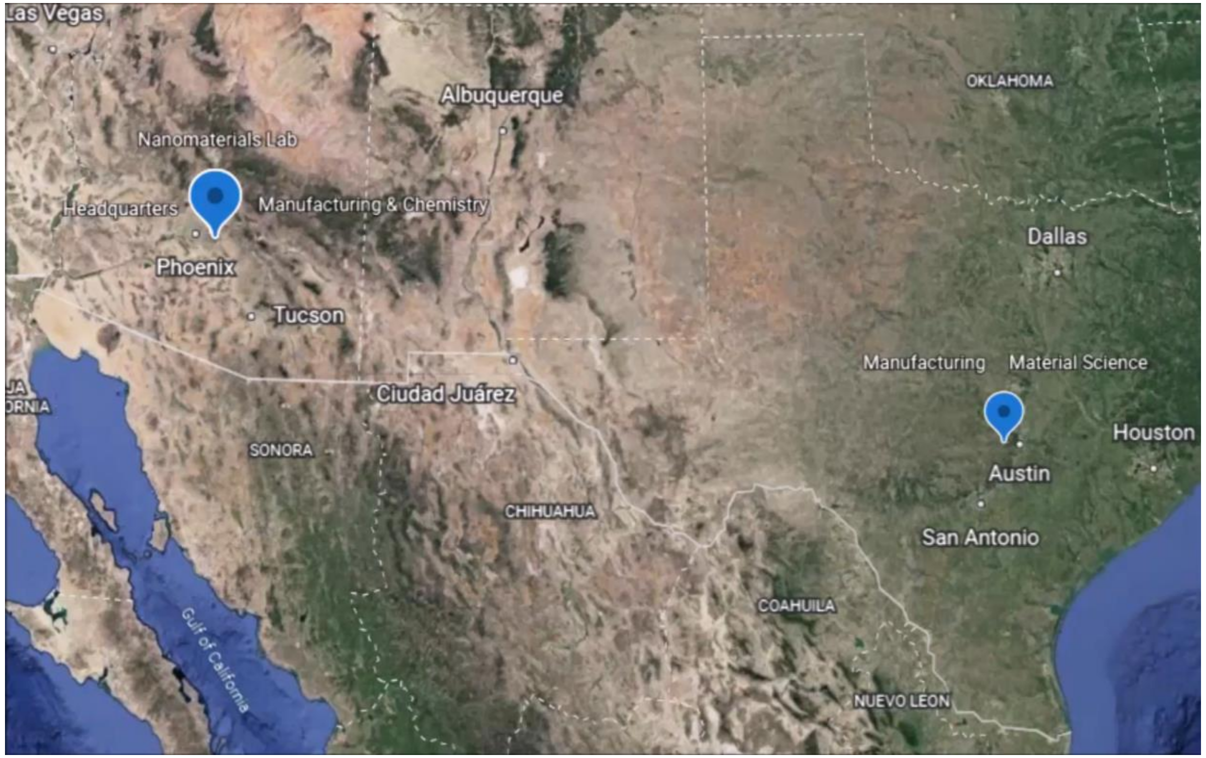
Company Vision

Create Exceptional Value Together

As We

Nano-Engineer Electronic Materials

Accomplishments & Readiness



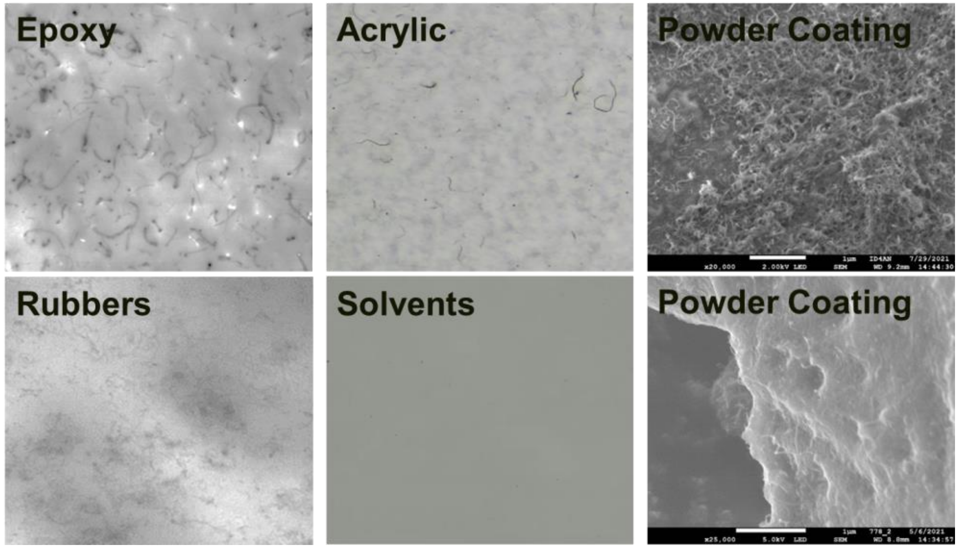
- Largest Functionalized CNT manufacturing facility in the world
- Captive manufacturing of masterbatches and final products
- Augmented with contract and toll manufacturing

120 Patents including dCNT ‘composition of matter’ patents

World’s ONLY discrete, functionalized, dispersed Carbon Nanotubes (dCNTs)

World’s first to:

- Ink jet CNTs (Polyjet systems)
- Add electrical conductivity into AM Resins
- Powder Coated CNTs
- Improve binding with CNTs
- Increase Impact with CNTs
- Much more…..

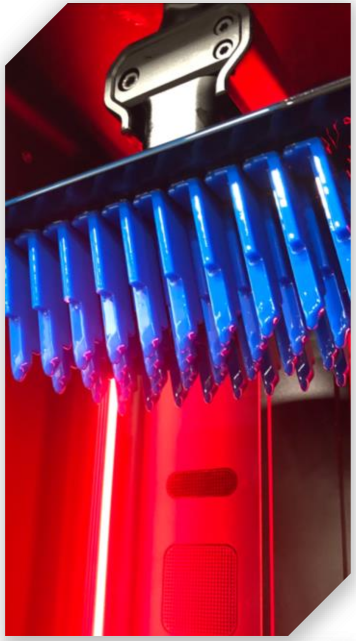


Protected & Proven

PROTECTED

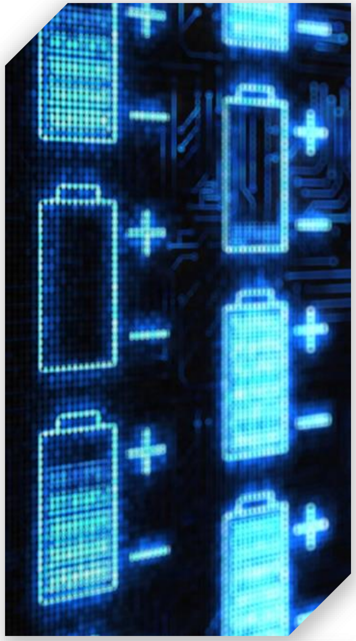
- 120+ Patents
- Composition of Matter Patents
- Secure Knowledge Library
- Proprietary Functionalization and Dispersion Technology

PROVEN



mechnano

Additive Manufacturing

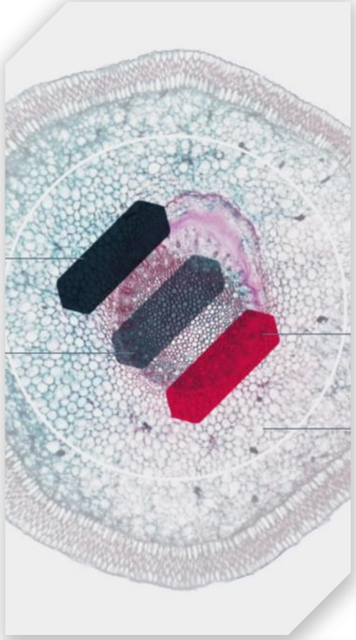


BLACK DIAMOND STRUCTURES

Energy Storage

MRD

Engineered Rubber



biopact

Medical Treatment

Executive Team

CEO

Steve Lowder

CLO/CFO

Scott Gillette

J.D, C.P.A., LL.M.

Director Business Development

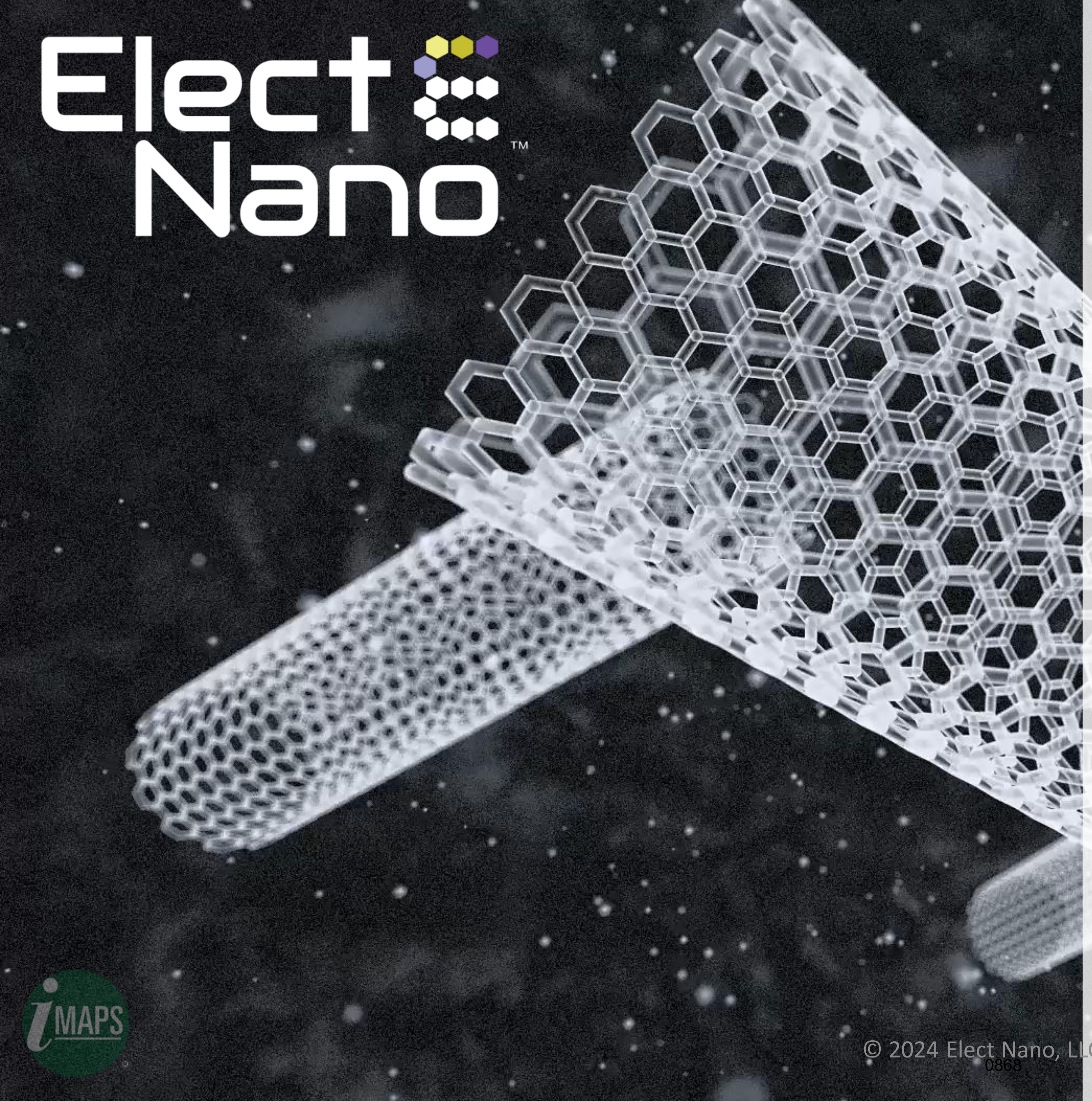
David Torp

PE

CTO

Brandon Sweeney

Ph.D.



"Next Revolution in Material Science" – Discovered in 1991

- Diameter is 10,000× smaller compared to a human hair
- Compared to steel
  - 100× higher tensile strength (no fatigue failures)
  - 100× higher thermal conductivity
  - 6× lighter
  - 5× higher modulus
- Compared to copper
  - 5× electrical conductivity
  - 15× thermal conductivity
  - 1,000× current capacity

3 Fundamental Challenges

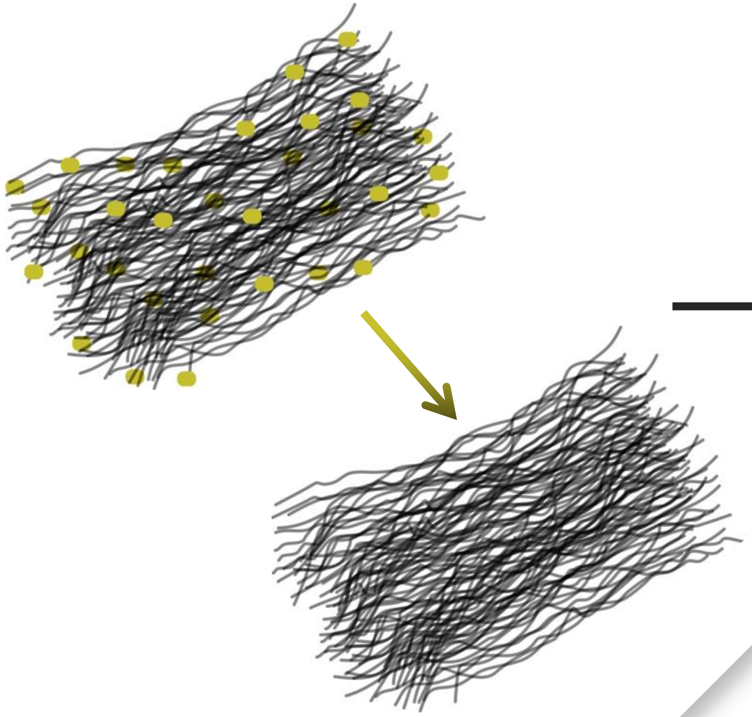
CNTs clump together during manufacturing into bundles that are extremely difficult to untangle.

CNTs are exceptionally challenging to disperse uniformly.

CNTs are hard to keep apart.

3 Key Steps

1

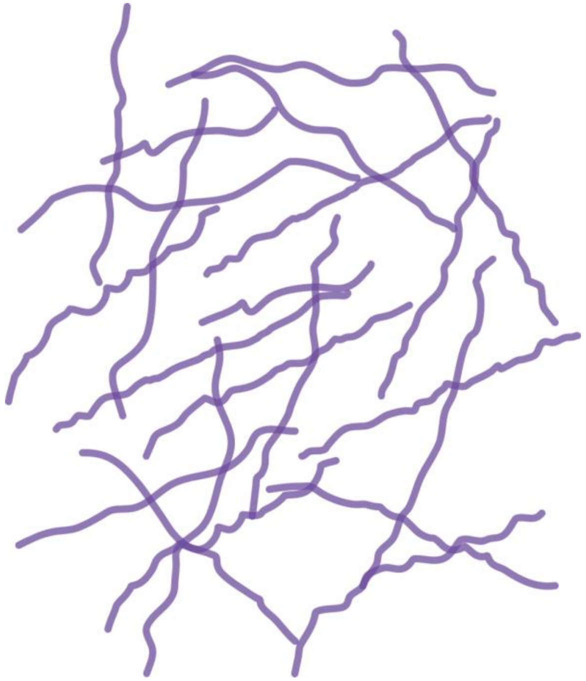


CLEAN

2

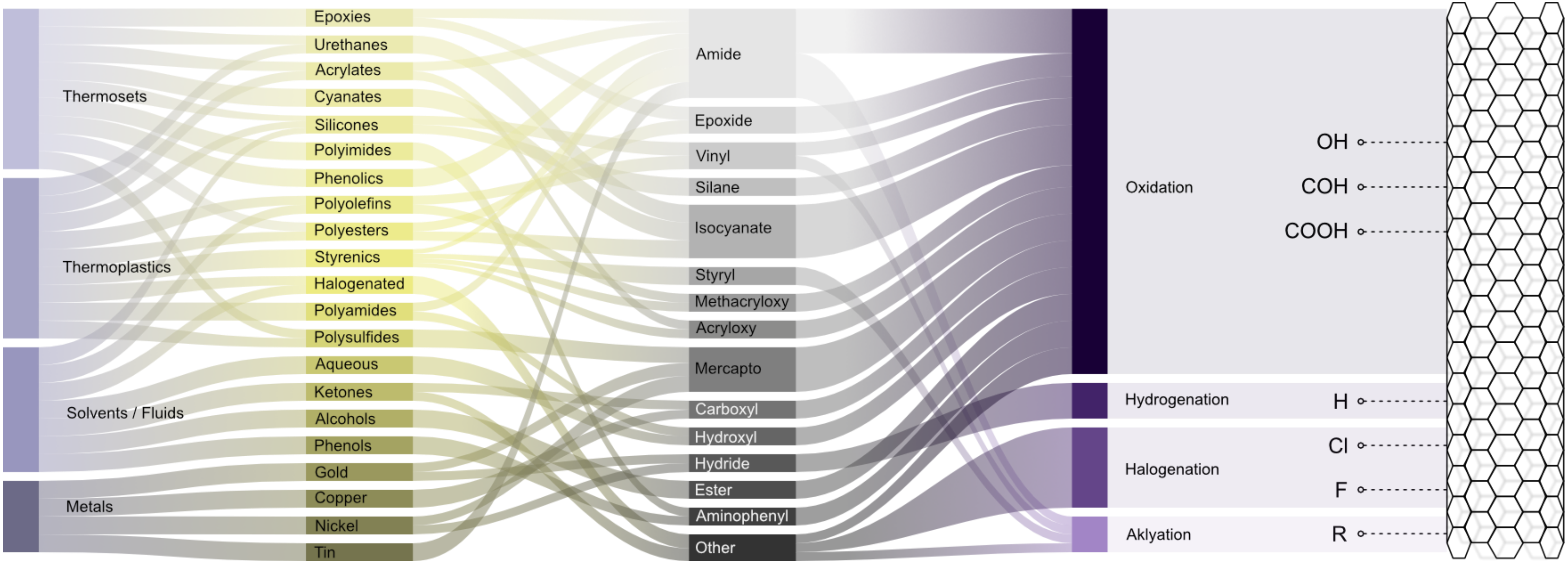
DEBUNDLE

3

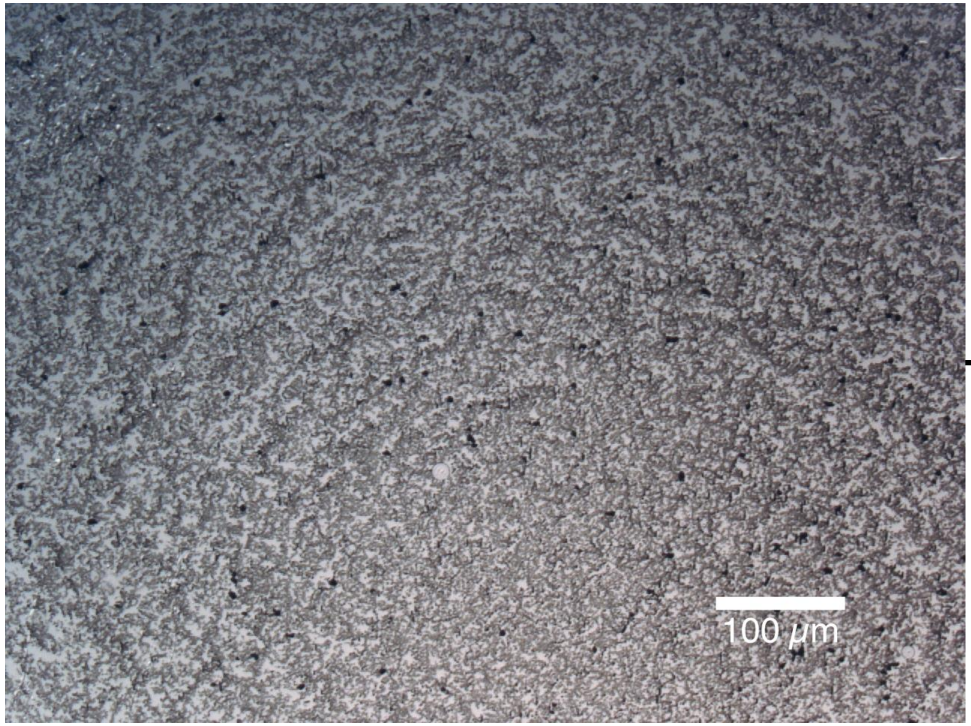


FUNCTIONALIZE

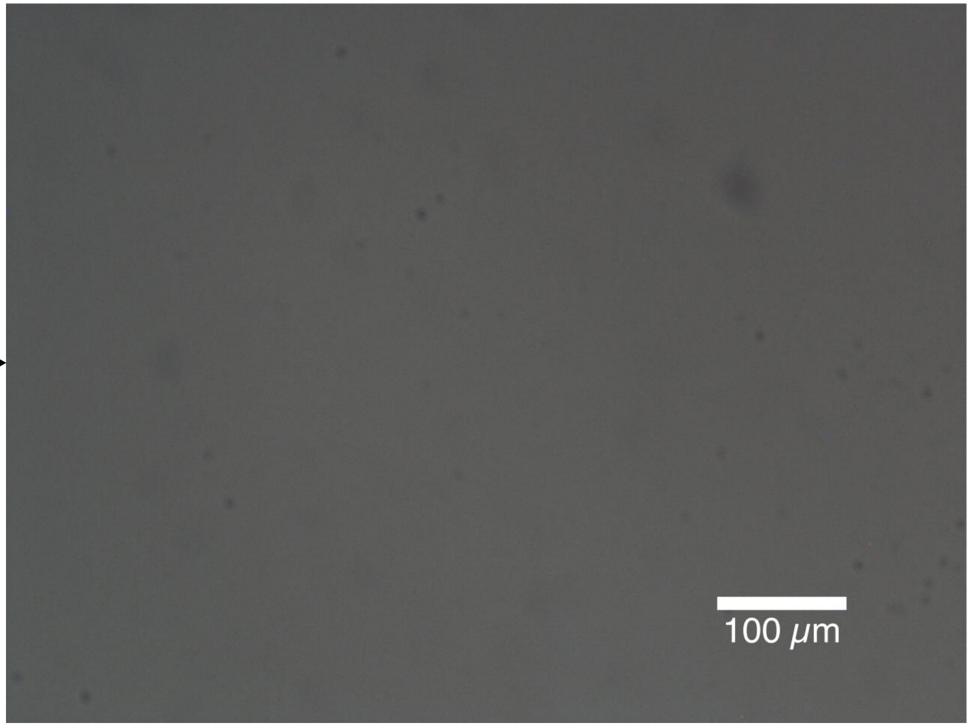
DCNTs Modification



Matching DCNTs Surface Thermodynamics

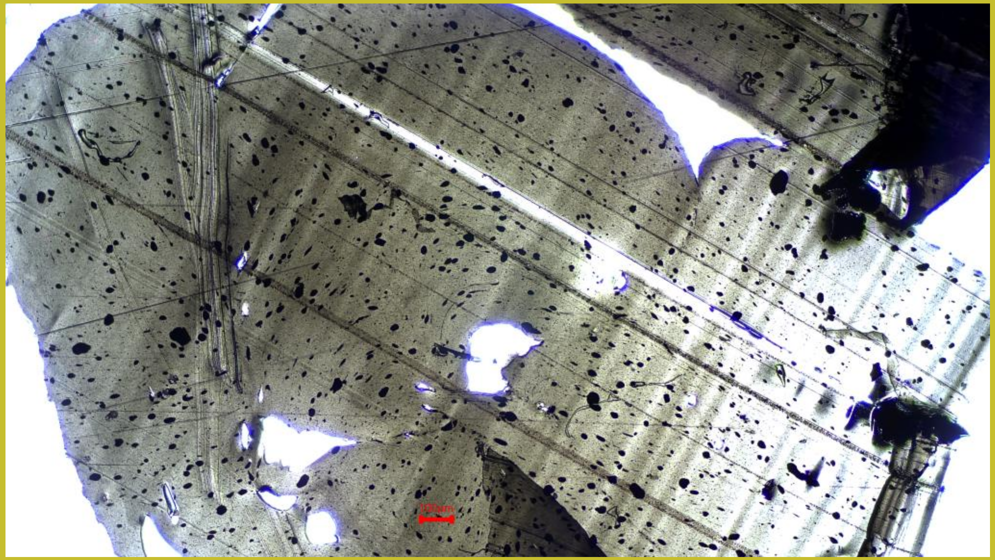
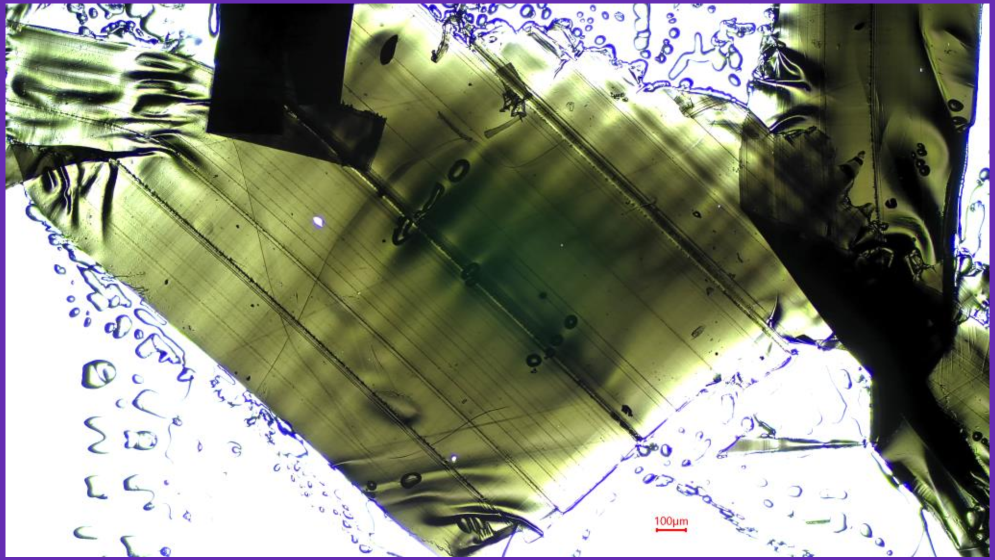
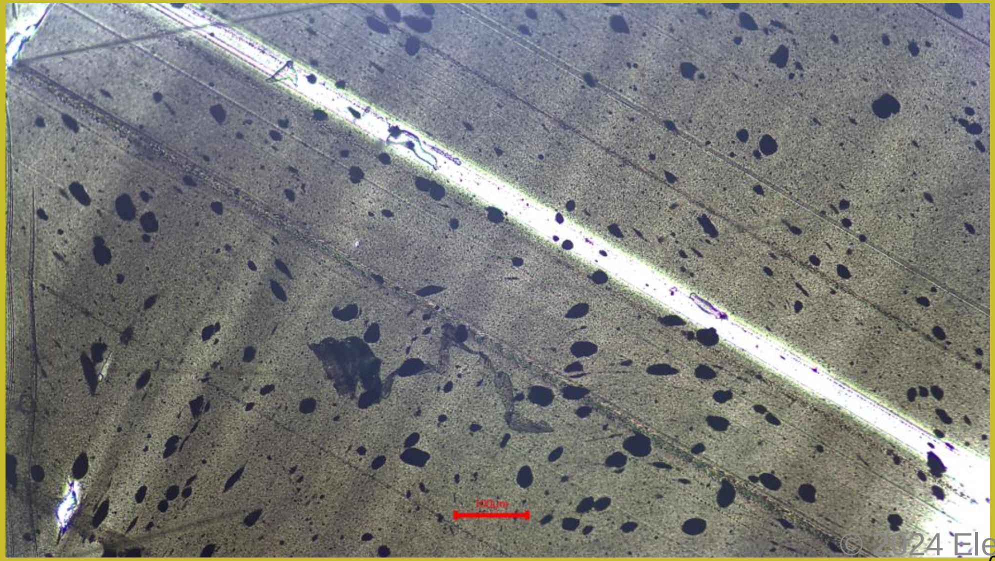
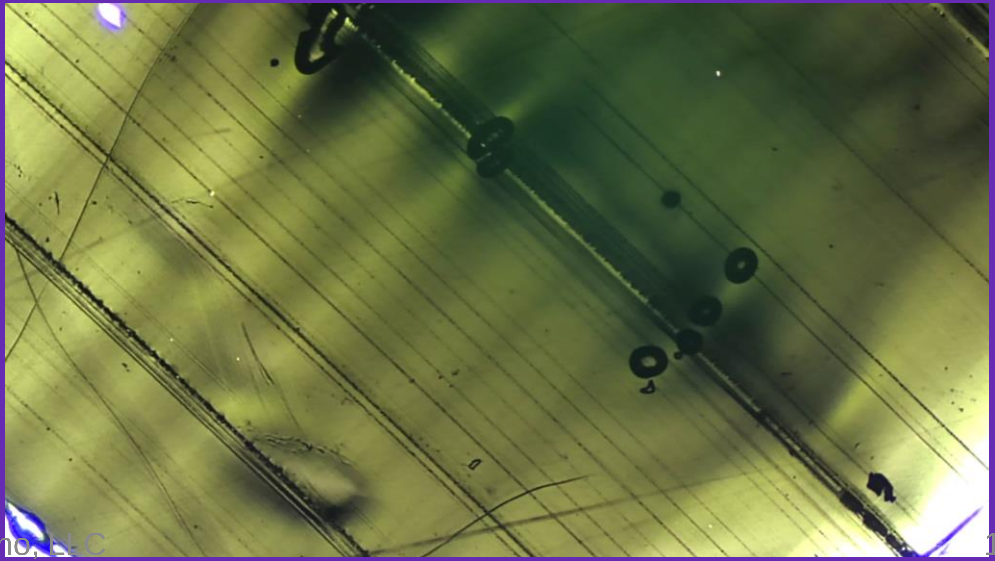


UNSTABLE DISPERSION

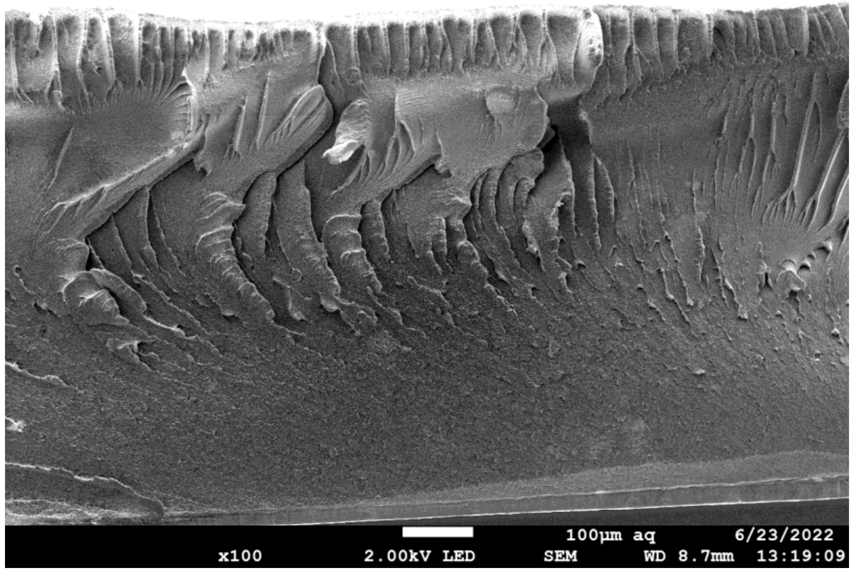


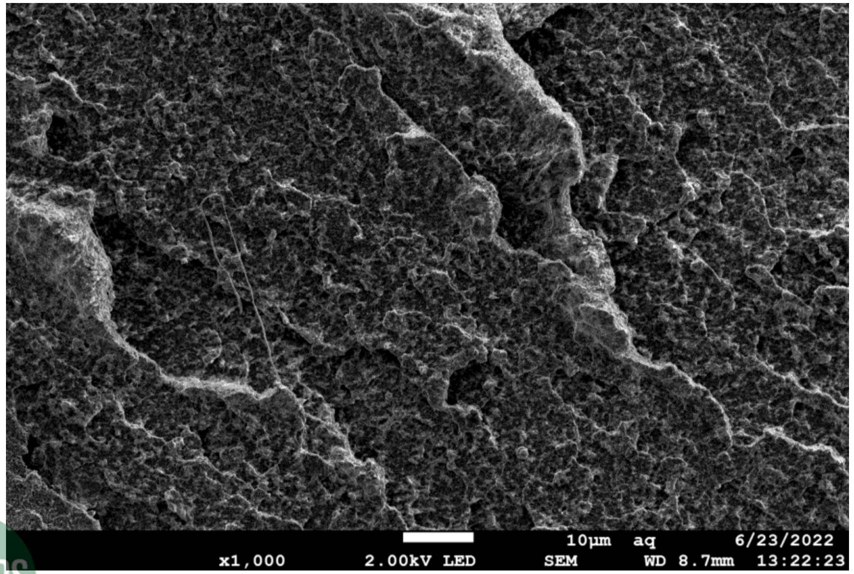
STABLE DISPERSION

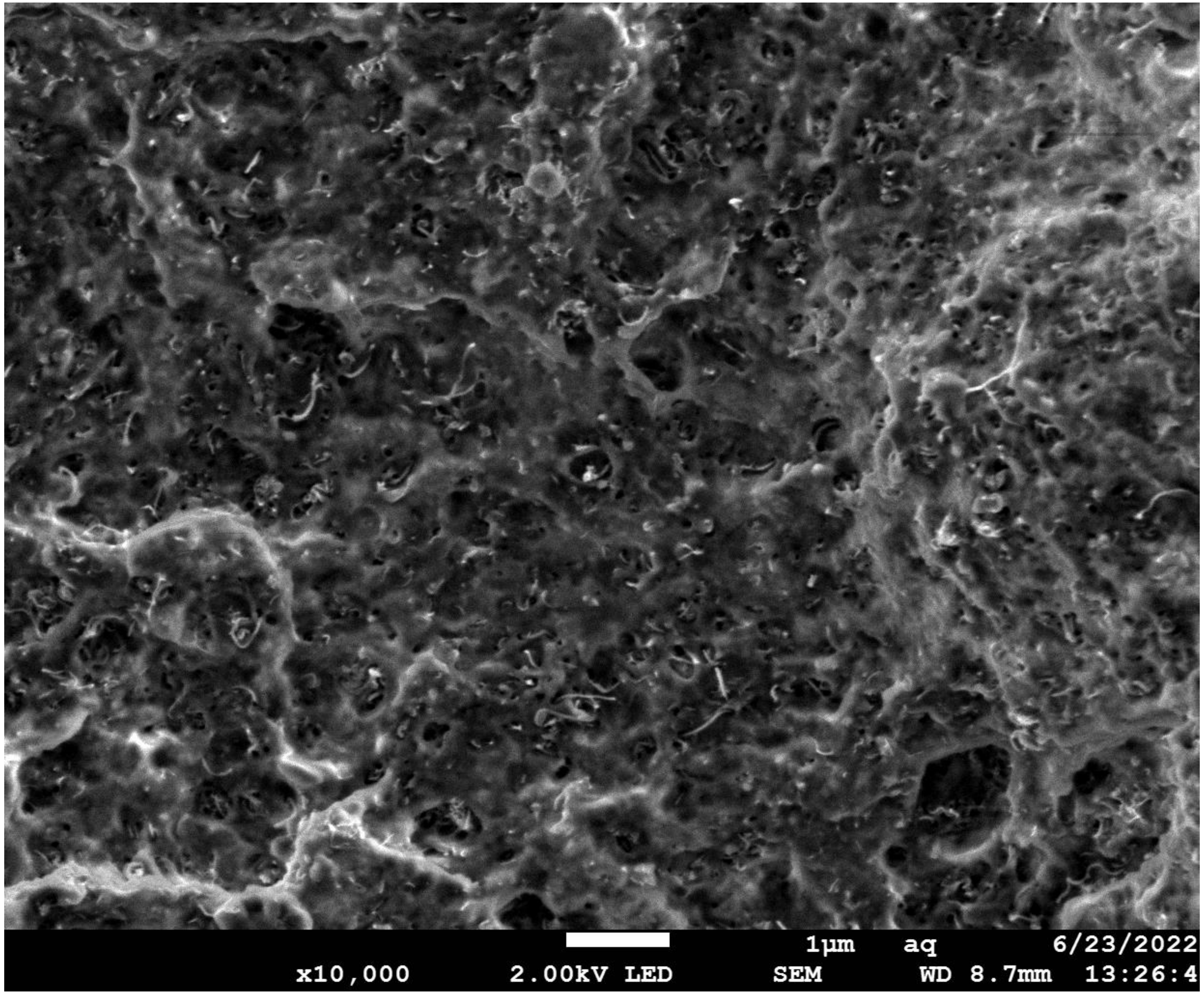
CNT Dispersion | Elect Nano vs. Others

	Commercial CNT MB in PETG	Elect Nano dCNT in mPPO
Mag = 4X		
Mag = 10X		

Discrete CNTs | SEM of Carbon Nanotubes in PC







Nano-Engineering Solution

Electrical

- ESD
- EMI
- Conductive
- Insulating

Mechanical

- Strength
- Impact
- Toughness
- Modulus

Thermal

- Conductivity
- CTE
- Stability

Chemical

- Corrosion
- Resistance
- Reactivity

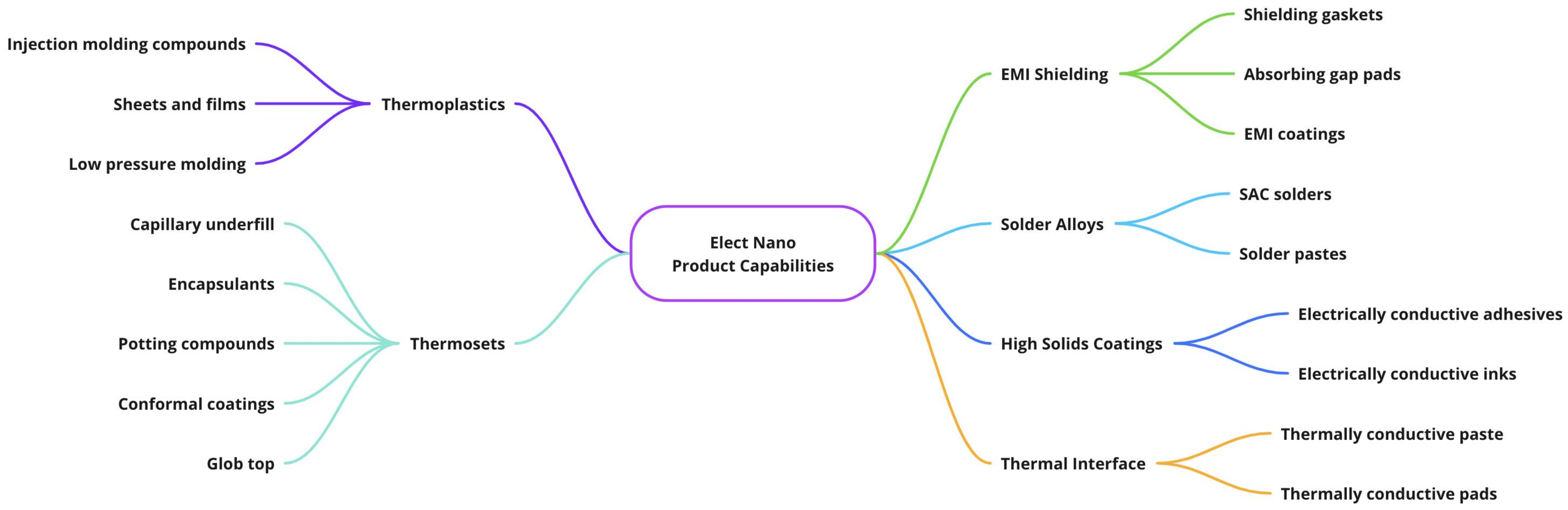
Magnetic

- Diamagnetic
- Paramagnetic
- Ferromagnetic

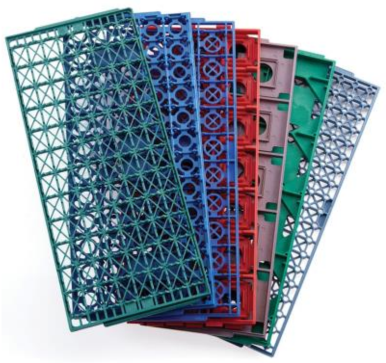
Optical

- Absorbance
- Transmittance
- UV Protection
- Anti-reflective

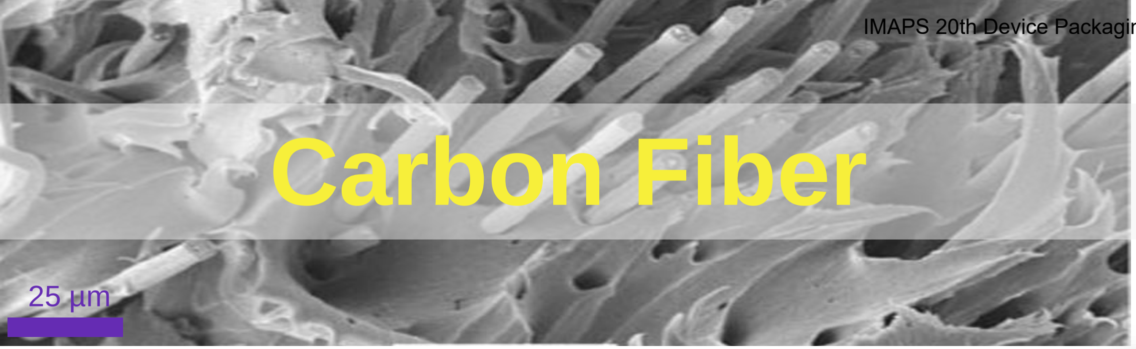
Product Capabilities



CNT Nanocomposite Injection Molding Compound



- Use case is for wafer media handling trays
  - JEDEC trays for wafer, die, and ICs
  - Wafer Cassettes
  - Waffle Packs
  - Matrix Tray
- Used in high volume for IC manufacturing
- High mix for new chip product with unique dimensions
- Must be ESD safe
- **Current molding compounds have shortcomings addressable by Elect Nano discrete CNT technology**



Carbon Fiber VS. Discrete CNTs

Carbon Fiber		Discrete CNTs
High	Orientation	Low
High	Percolation	Ultra-Low
Poor	Matrix Bond	Excellent
Poor	Surface Finish	Excellent
Very High	Stiffness	Low (With Secondary Bulk Fillers)

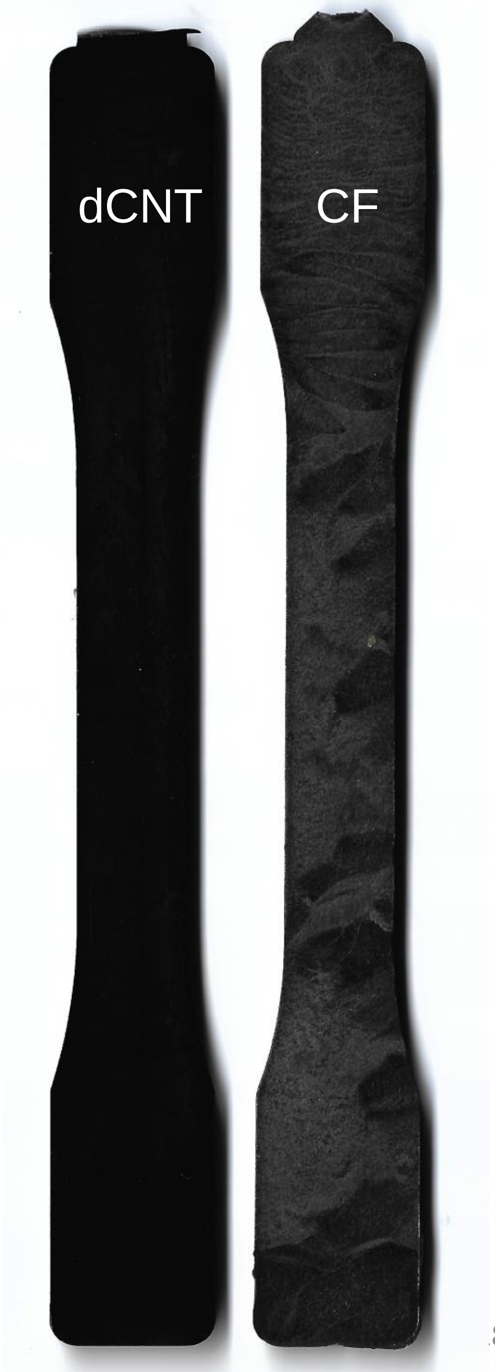
Carbon Fiber

- ✗ HIGHLY VARIABLE ELECTRICAL CONDUCTIVITY
- ✗ HIGHLY VARIABLE MECHANICAL PROPERTIES (STIFFNESS)
- ✗ >10WT% REQUIRED FOR ESD
- ✗ SHEATHING AND SLOUGHING
- ✗ GENERATING FPM
- ✗ HIGHLY VARIABLE SURFACE FINISH
- ✗ NON-UNIFORM GRAY VALUES (VARIABLE GRAYS)
- ✗ UNREADABLE LASER MARKING
- ✓ HIGH STIFFNESS AT TYPICAL LOADING LEVELS

Discrete CNTs

- ✓ PRECISE, TUNABLE ELECTRICAL CONDUCTIVITY
- ✓ UNIFORM ISOTROPIC MECHANICAL PROPERTIES (STIFFNESS)
- ✓ <5WT% REQUIRED FOR ESD
- ✓ NO SHEATHING, NO SLOUGHING
- ✓ NO FPM
- ✓ UNIFORM SURFACE FINISH
- ✓ ULTRA-LOW GRAY VALUES (VERY BLACK)
- ✓ EXCELLENT LASER MARKING
- ~ LOW STIFFNESS AT TYPICAL LOADING LEVELS, CAN BE IMPROVED WITH SECONDARY FILLERS

Sample Preparation
Injection Molded Dogbones



Surface Resistance | Flow Alignment Effects

CARBON FIBER

Position	Resistance (Ohms)
Top	<1.00E+03
Middle	5.49E+09
Bottom	>1.00E+12
Log Trans. Mean	**1.76E+08**
Log Trans. Range	**>1.00E+09**

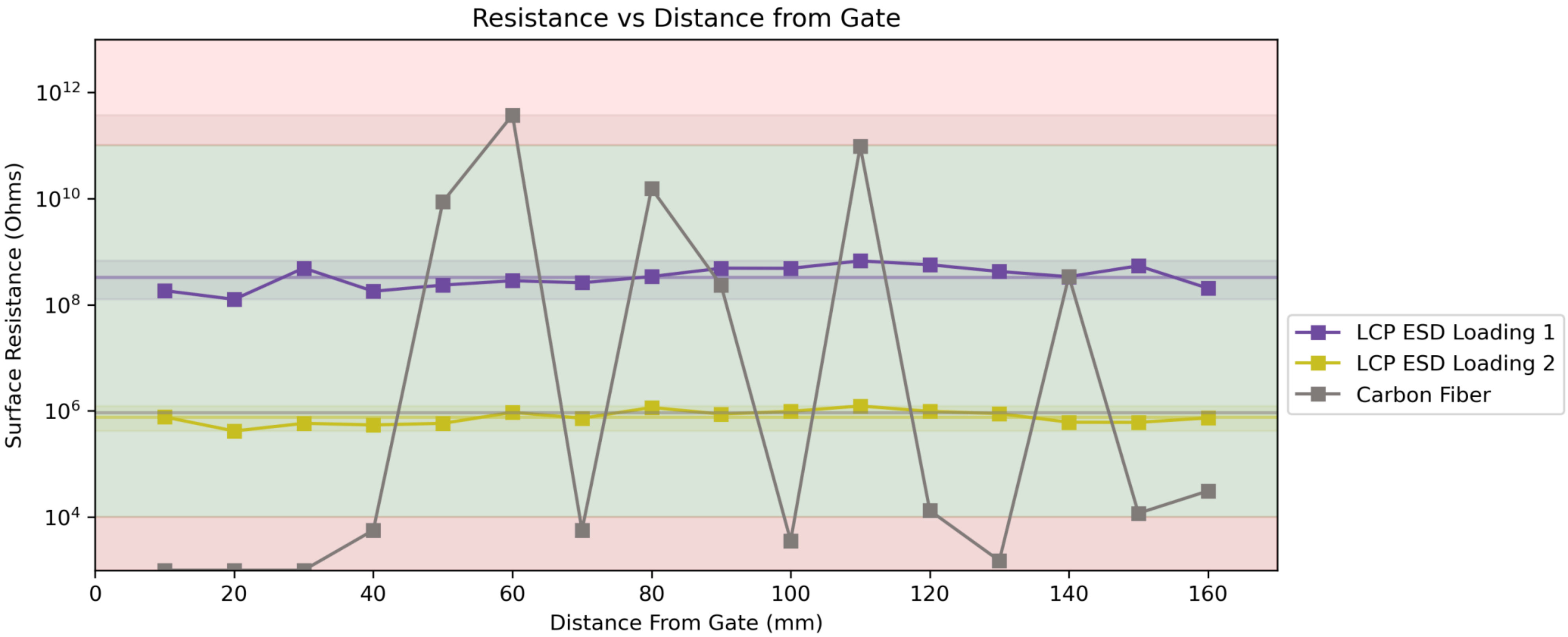
CF

DISCRETE CNT

Position	Resistance (Ohms)
Top	9.73E+08
Middle	1.12E+08
Bottom	2.20E+08
Log Trans. Mean	**2.88E+08**
Log Trans. Range	**8.69E+00**

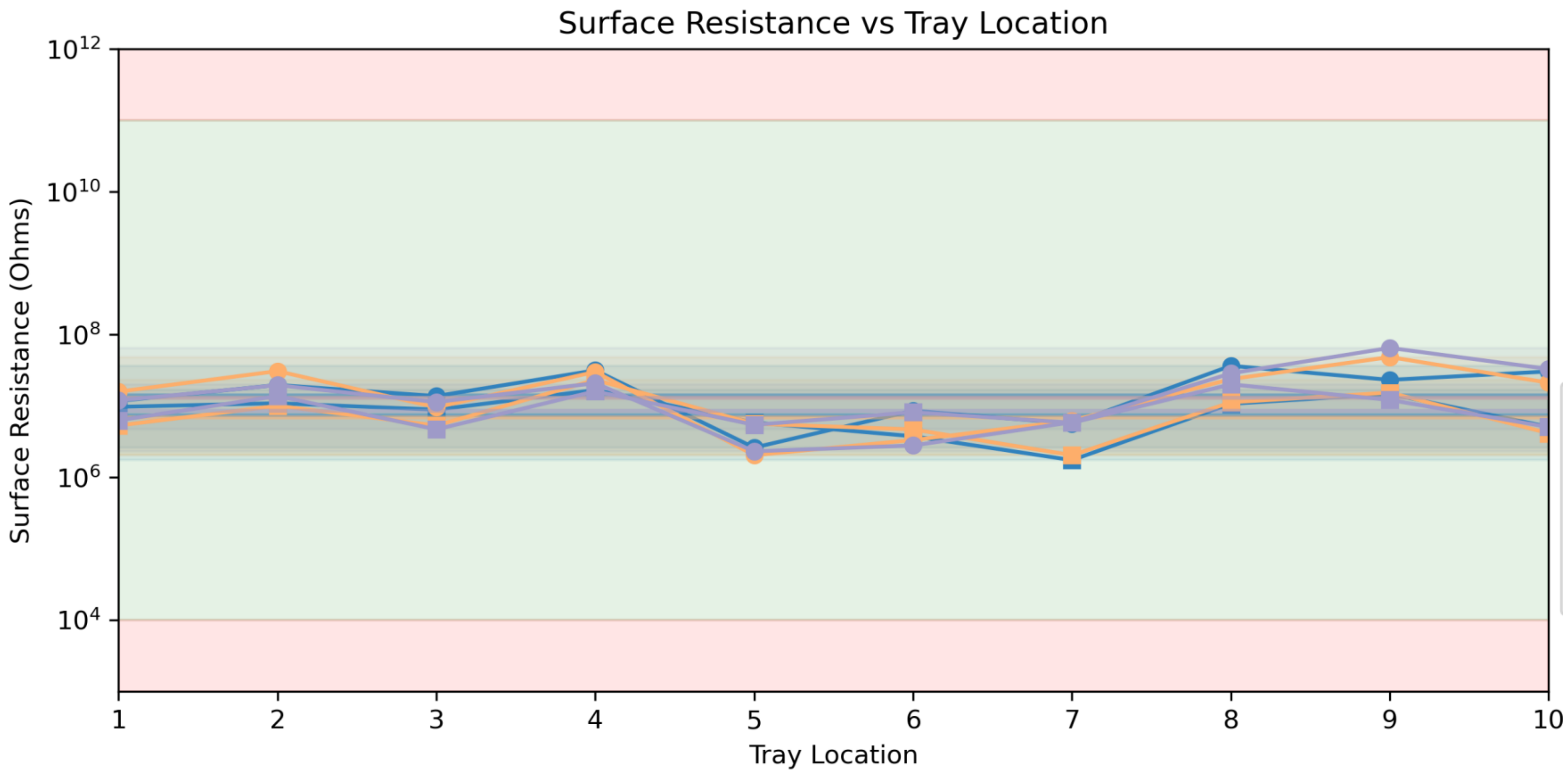
dCNT

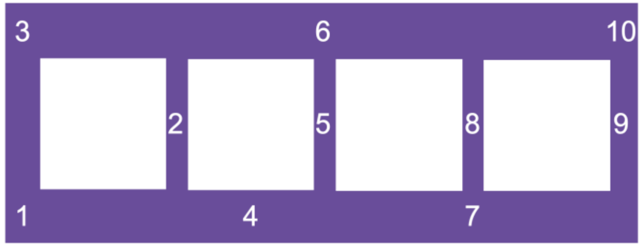
LCP GFR35 Results | Surface Resistance



Dogbone ID	Side	Log Trans Mean	Log Trans Range
LCP ESD Loading 1	Core	3.26e+08	5.30e+00
LCP ESD Loading 2	Core	7.58e+05	2.97e+00
Carbon Fiber	Core	9.32e+05	3.74e+08

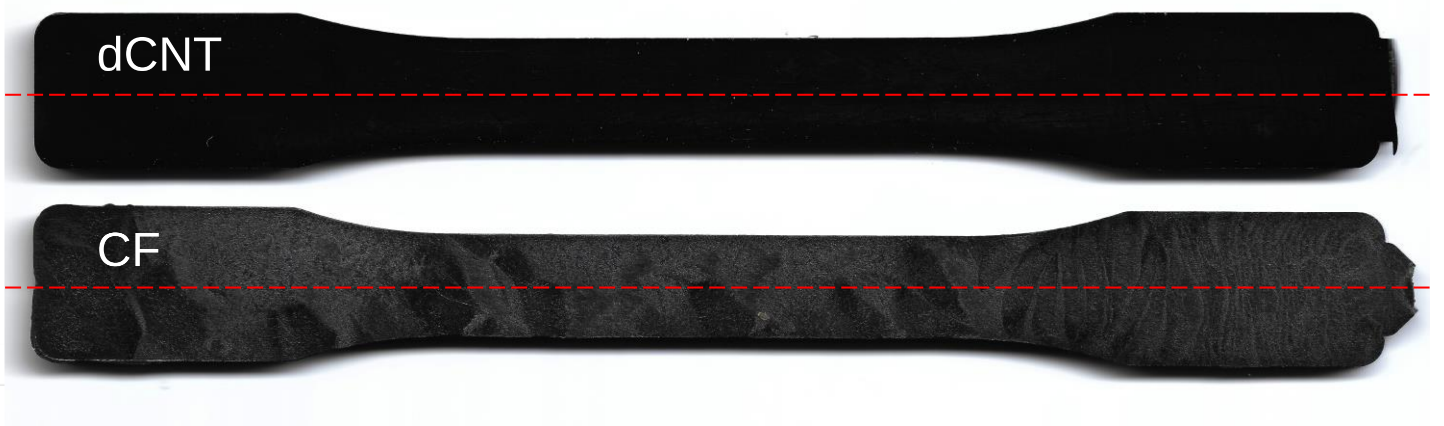
LCP GFR35 Results | Injection Molded Trays

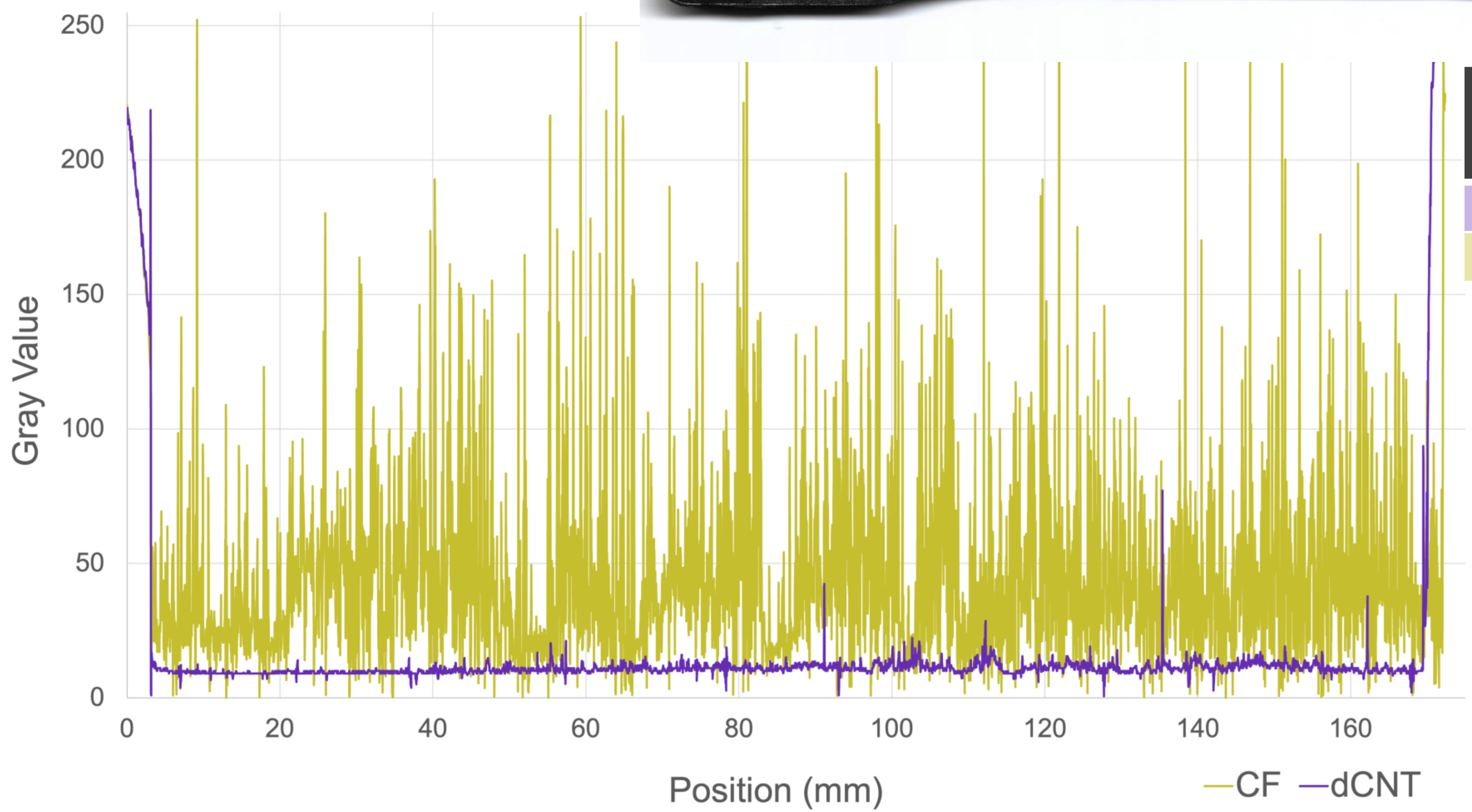




Tray ID	Side	Log Trans Mean	Log Trans Range
10-A	Top	1.40e+07	1.40e+01
10-A	Bottom	7.30e+06	9.59e+00
10-B	Top	1.29e+07	2.37e+01
10-B	Bottom	6.85e+06	1.13e+01
10-C	Top	1.28e+07	2.81e+01
10-C	Bottom	8.45e+06	4.27e+00

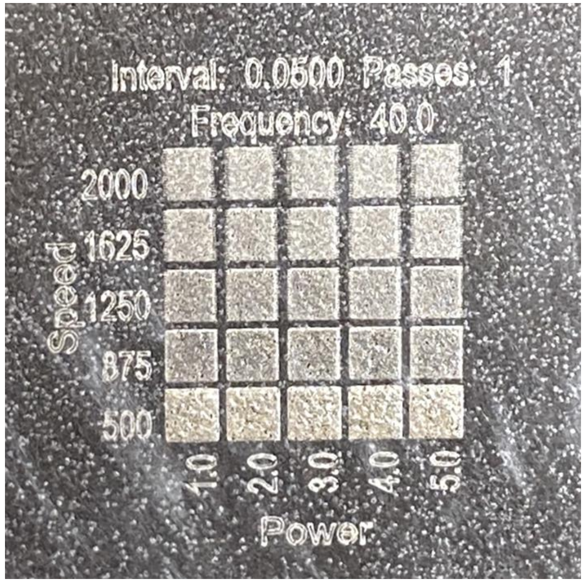
Surface Finish
Color Uniformity





Sample	Avg. Gray Value	Std. Dev.
dCNT	10.8	2.1
CF	43.8	29.2

Laser Marking
Film Contrast

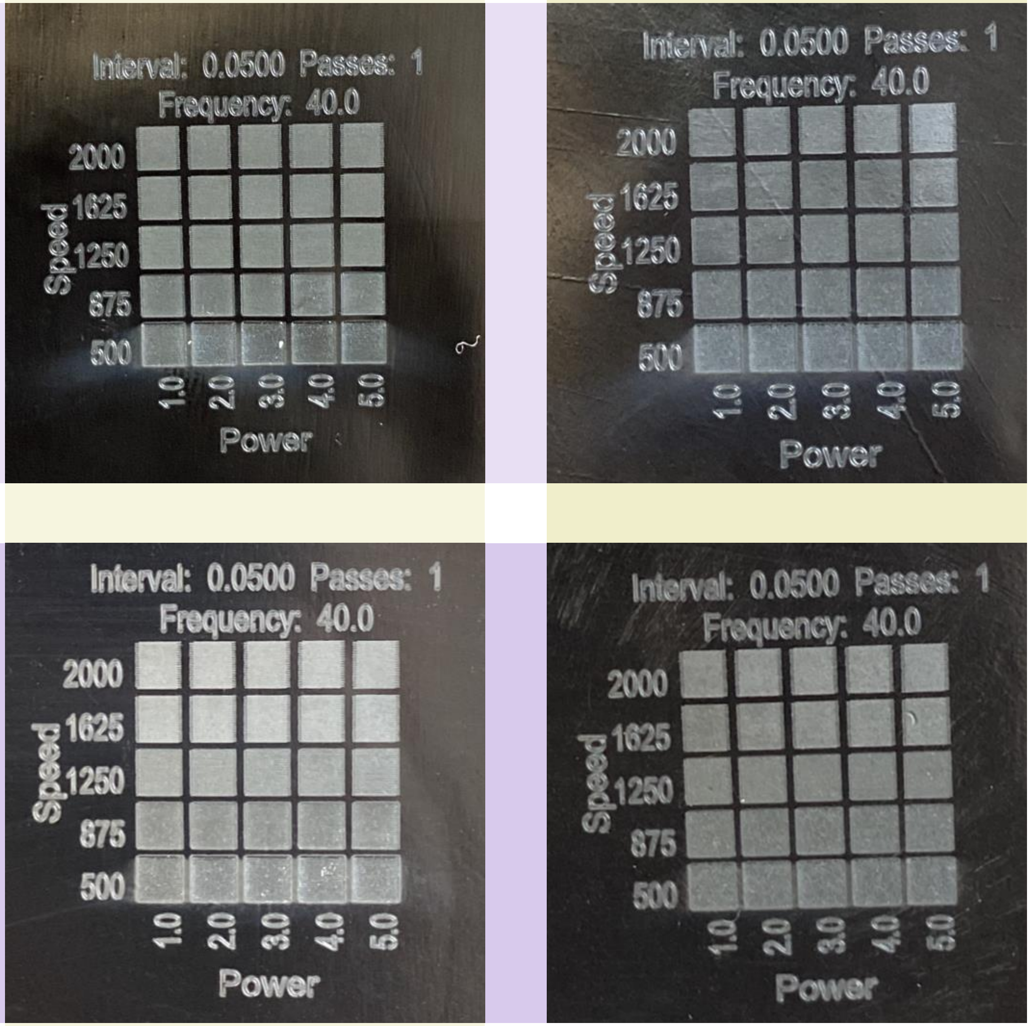


Control (PC-CF)

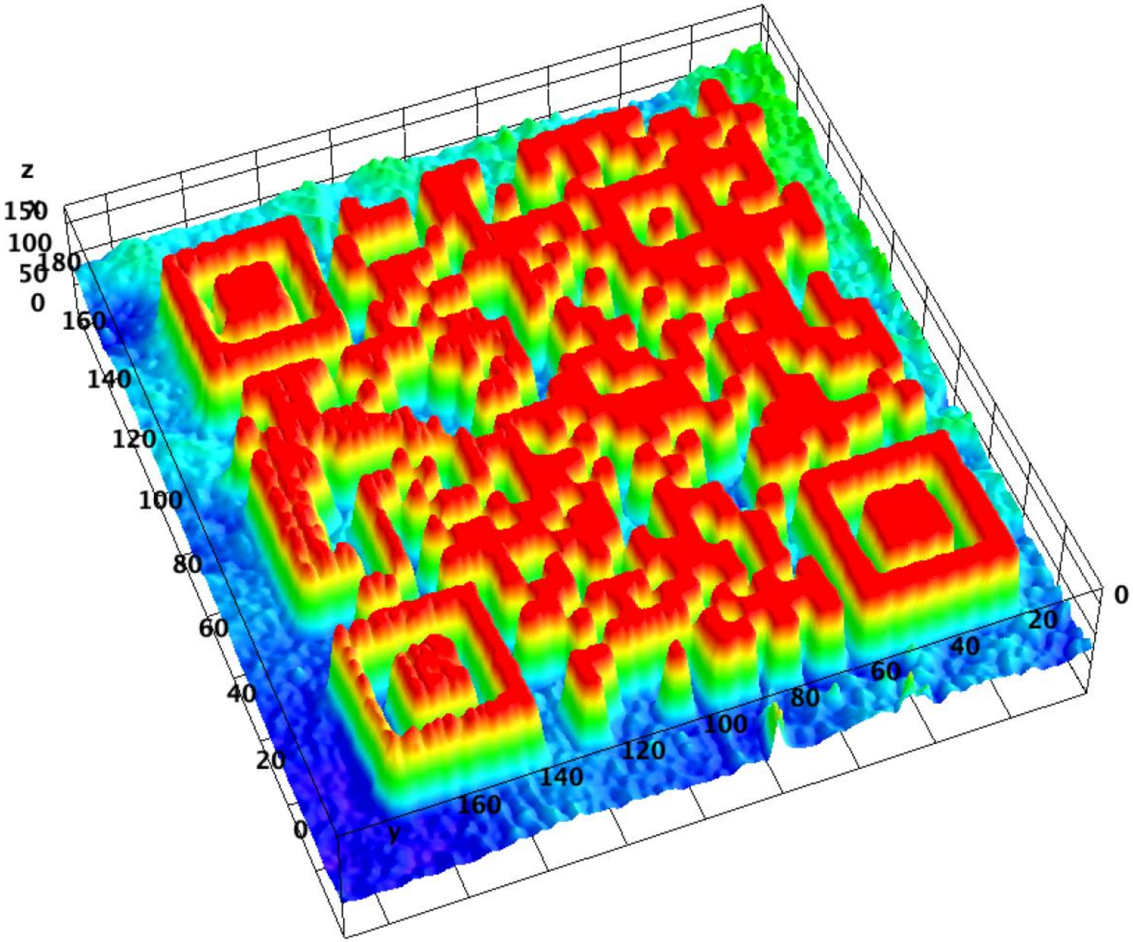
PC + dCNTs | PC + dCNTs + MCF

No LMC

2% LMC



Laser Marking
Film Contrast



THANK YOU