Ionic Polymer Metal Composites for Sensing and Actuation Produced with Cellulose Nanofibrils

AUTHORS:

Mehdi Tajvidi, Colin Noonan, Ali (Parham) H. Tayeb, Mohsen Shahinpoor, Seyed Ehsan Tabatabaie

PRESENTED BY:

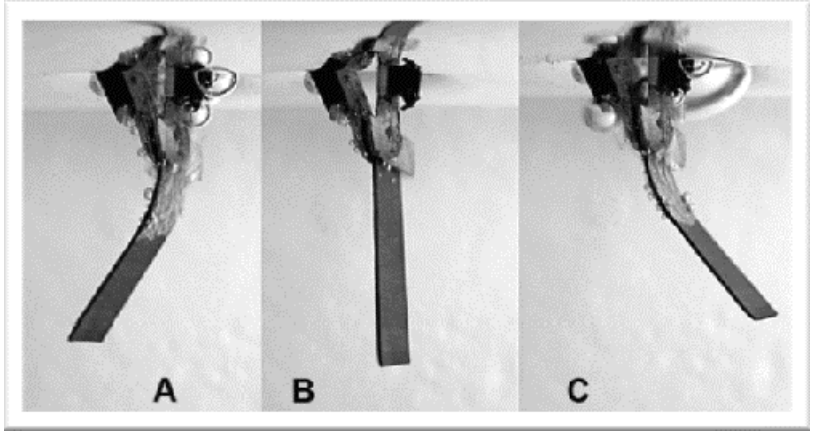
Mehdi Tajvidi

Assistant Professor of Renewable Nanomaterials

School of Forest Resources, University of Maine

Ionic Polymer Metal Composites (IPMC)'s

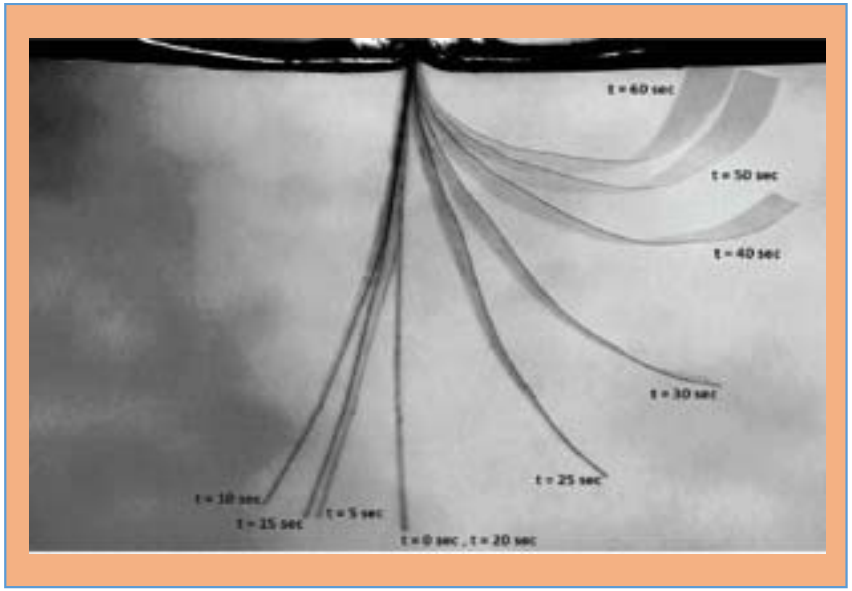
- Can be used for soft robotic actuators, flexible sensors, and artificial muscles from micro-to-macro size levels.



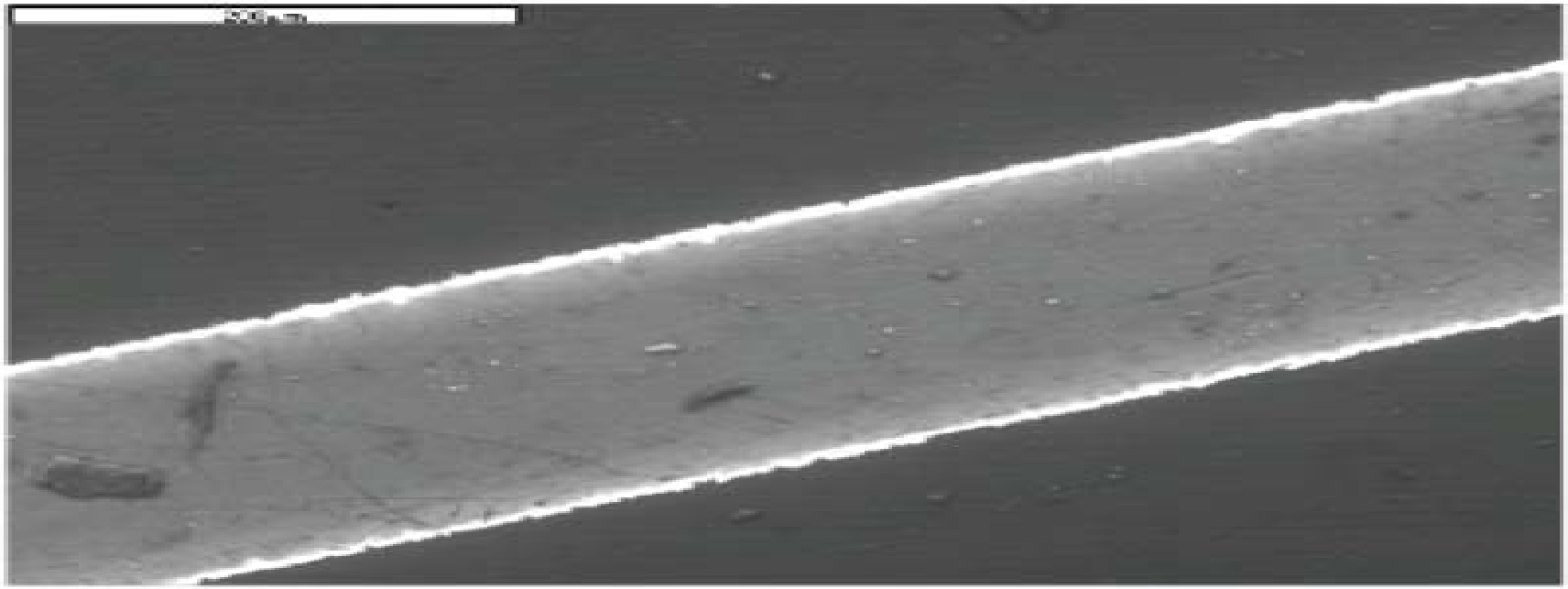
- Light weight
- no mechanical parts
- low voltage
- microns thin
- Large displacements
- Low power consumption (milliwatts)
- Macro or micro level

Problems with IPMC's

- Nafion is not eco-friendly
- Complex manufacturing process



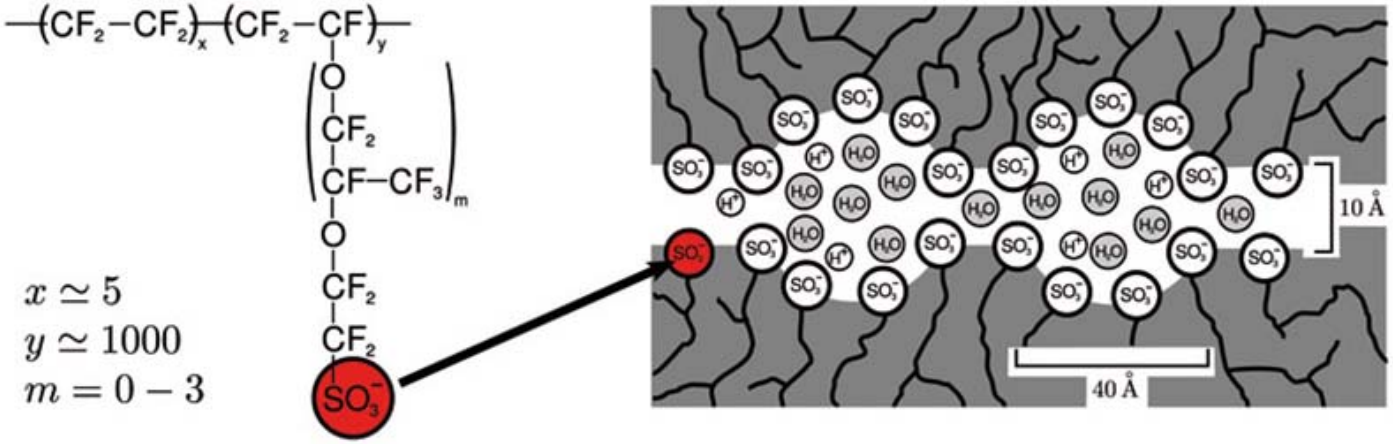
IPMC Structure



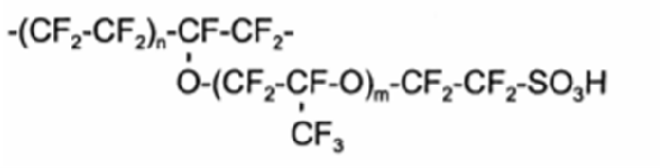
Nafion (170-200 microns), or ionic exchange material, with micro thin layer of platinum (10-15 microns)

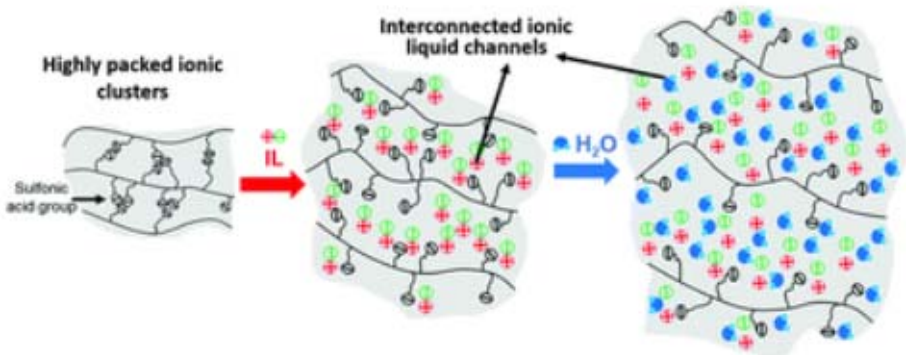
Nafion®

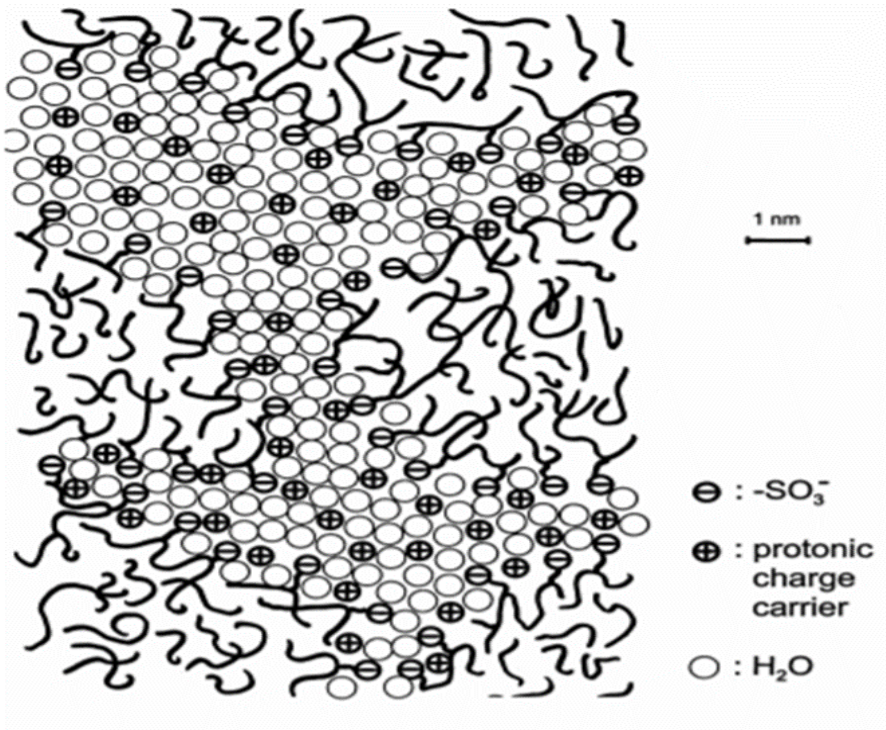
- Polyelectrolyte
- Hydrophobic perfluoroinated backbone
- Hydrophilic sulfonic acid functional groups

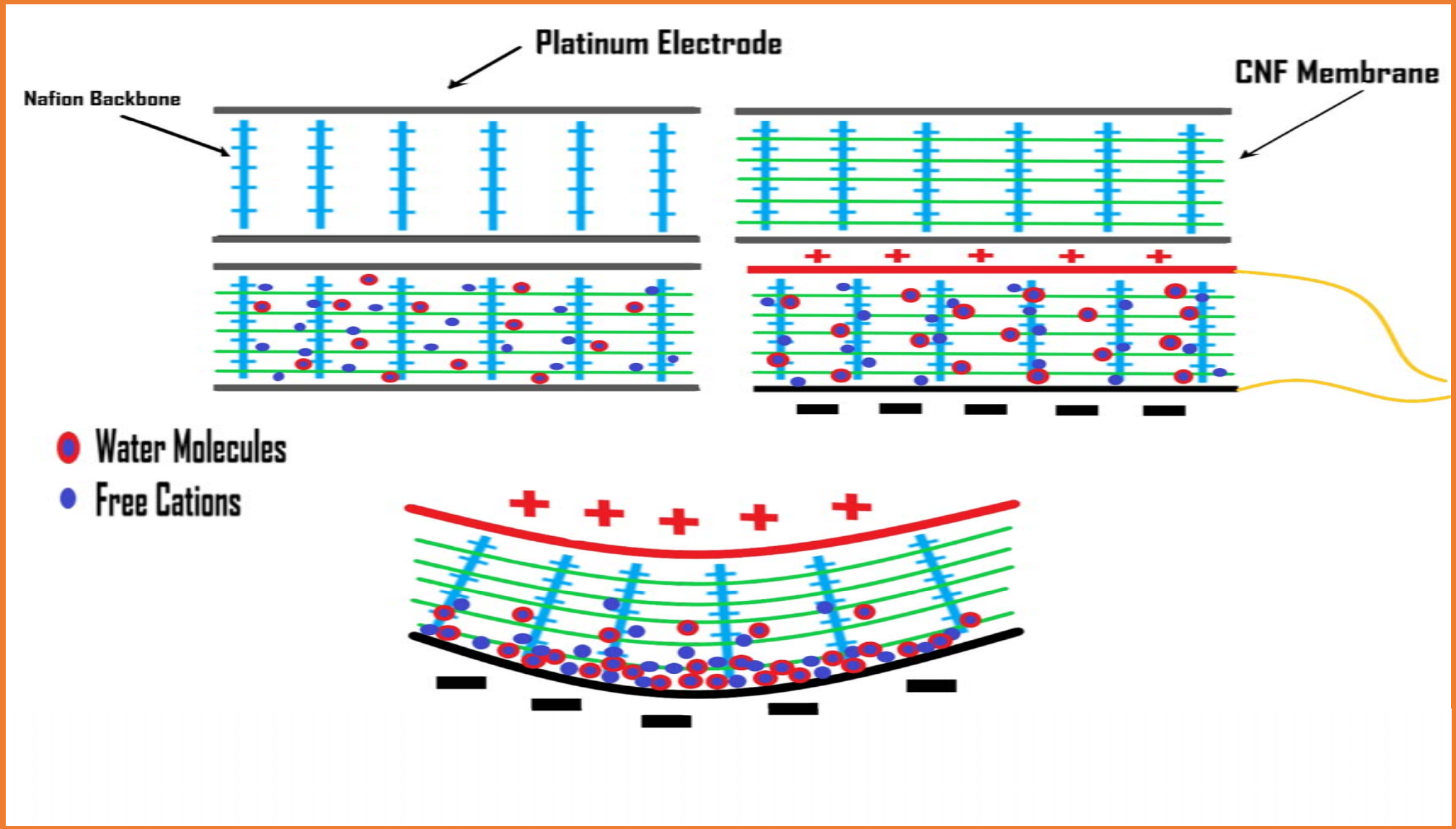


Nafion's Ionic clusters

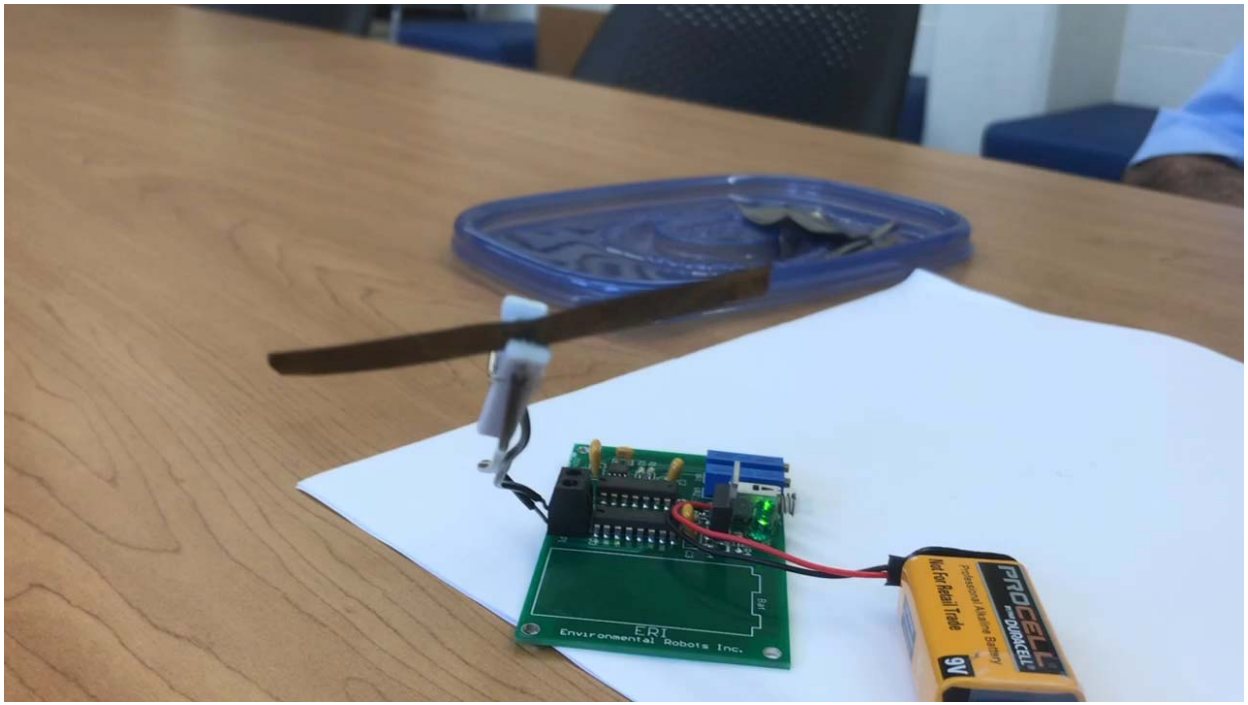


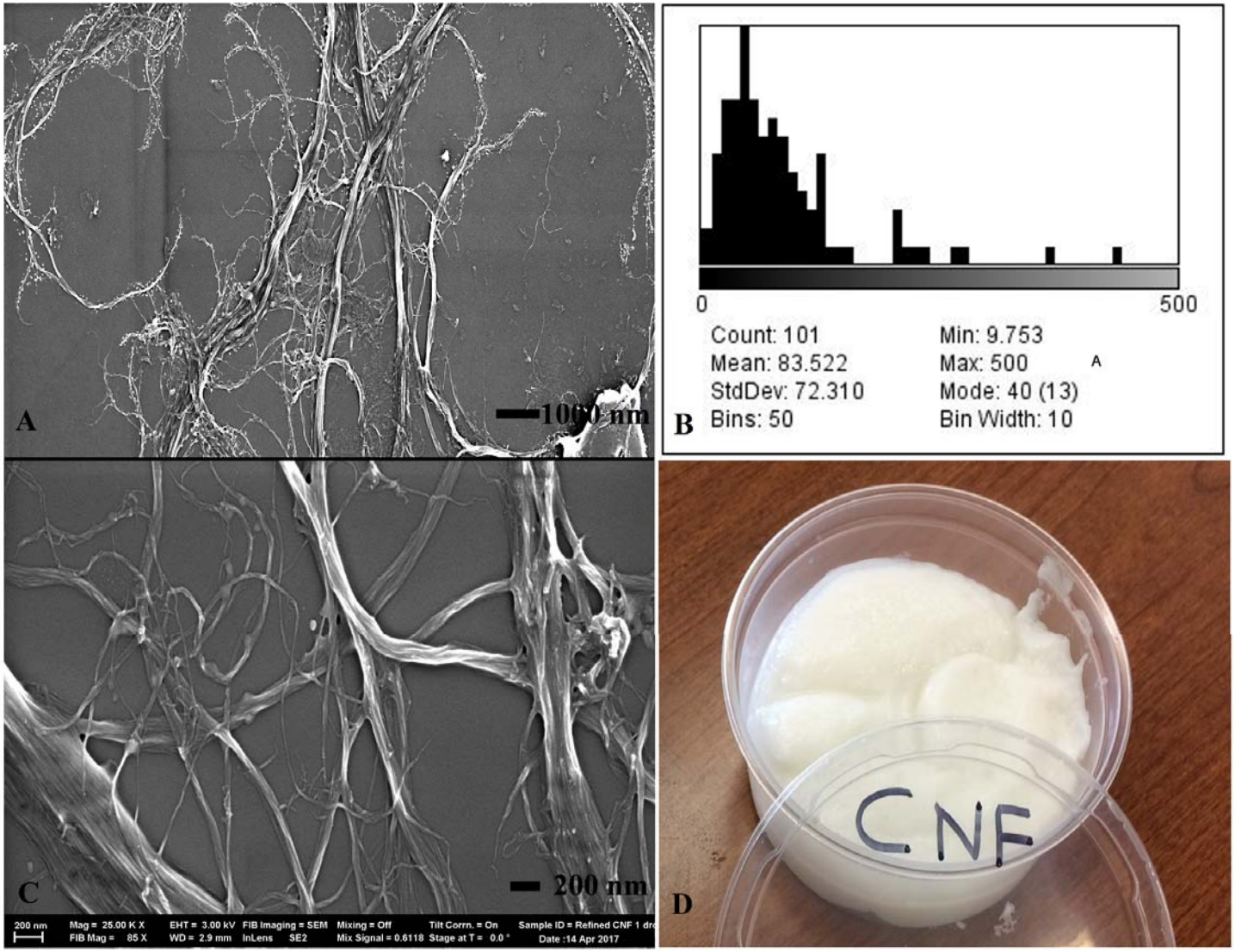





Platinum Electrode
Nafion Backbone
CNF Membrane
Water Molecules
Free Cations

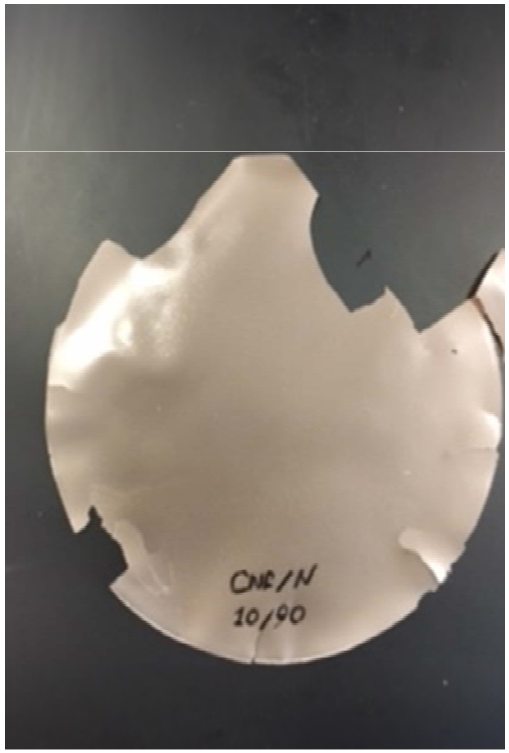
IPMC flexing under applied voltage

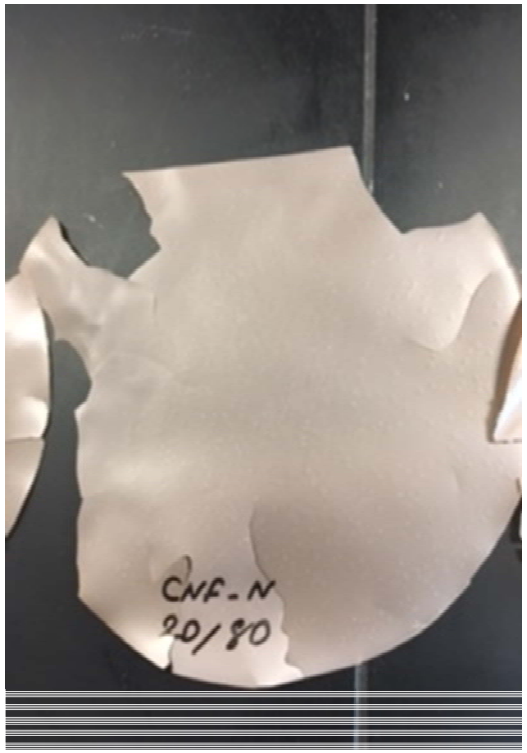


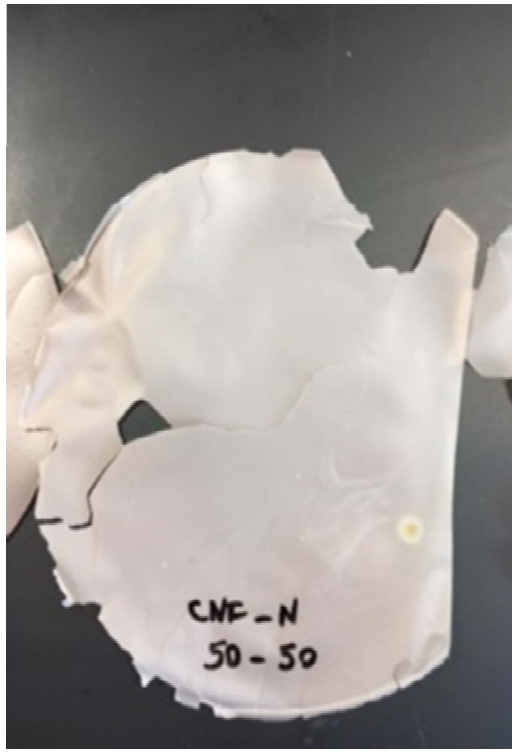

A
1000 nm
B
0
500
Count: 101
Mean: 83.522
StdDev: 72.310
Bins: 50
Min: 9.753
Max: 500
Mode: 40 (13)
Bin Width: 10
A
C
200 nm
200 nm Mag = 25.00 K X EHT = 3.00 kV FIB Imaging = SEM Mixing = Off Tilt Corrn. = On Sample ID = Refined CNF 1 dr
FIB Mag = 85 X WD = 2.9 mm InLens SE2 Mix Signal = 0.6118 Stage at T = 0.0 ° Date :14 Apr 2017
D
CNF

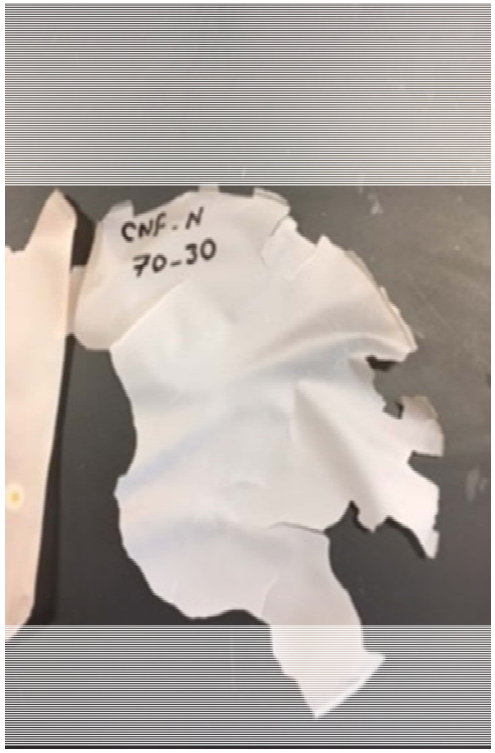
Making Membranes

- Preliminary Films





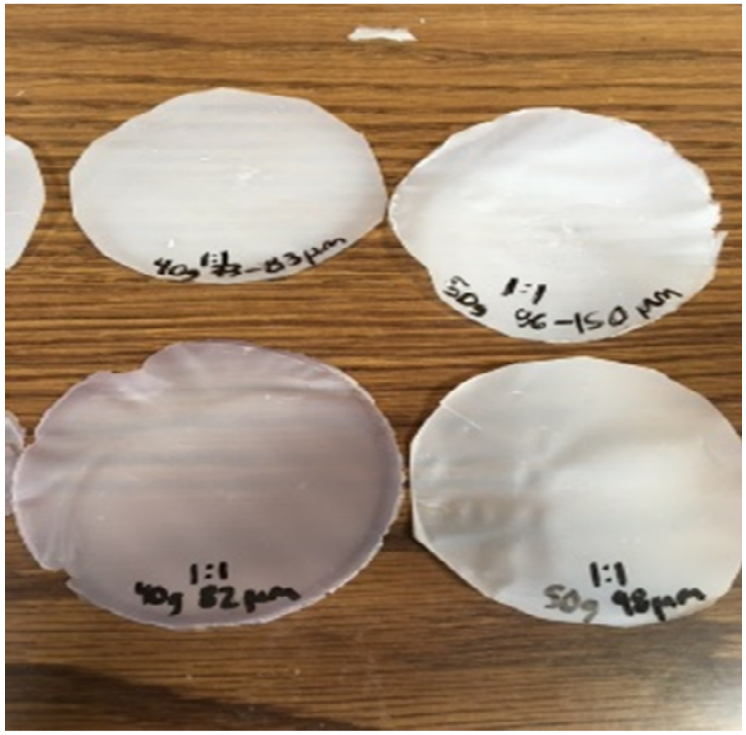


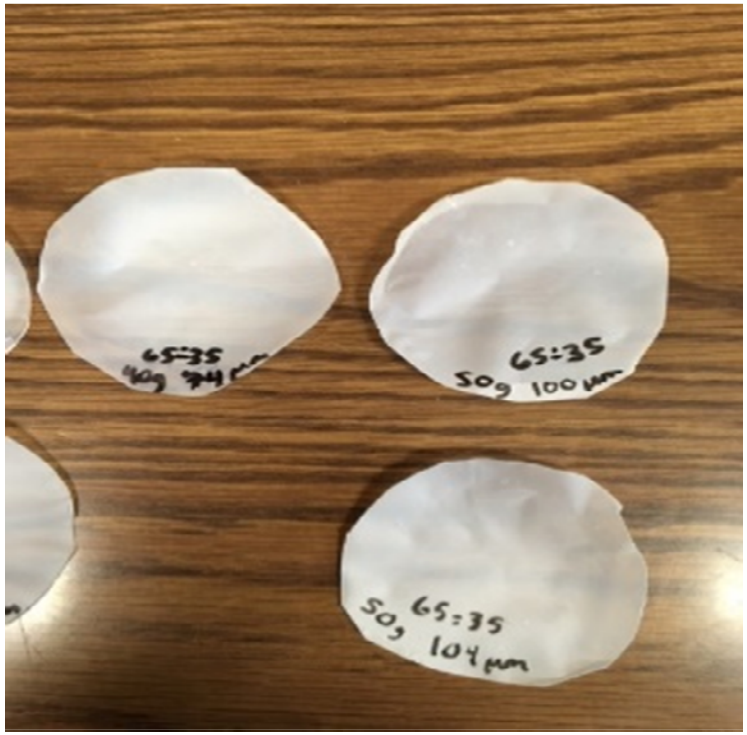


Next generation membranes

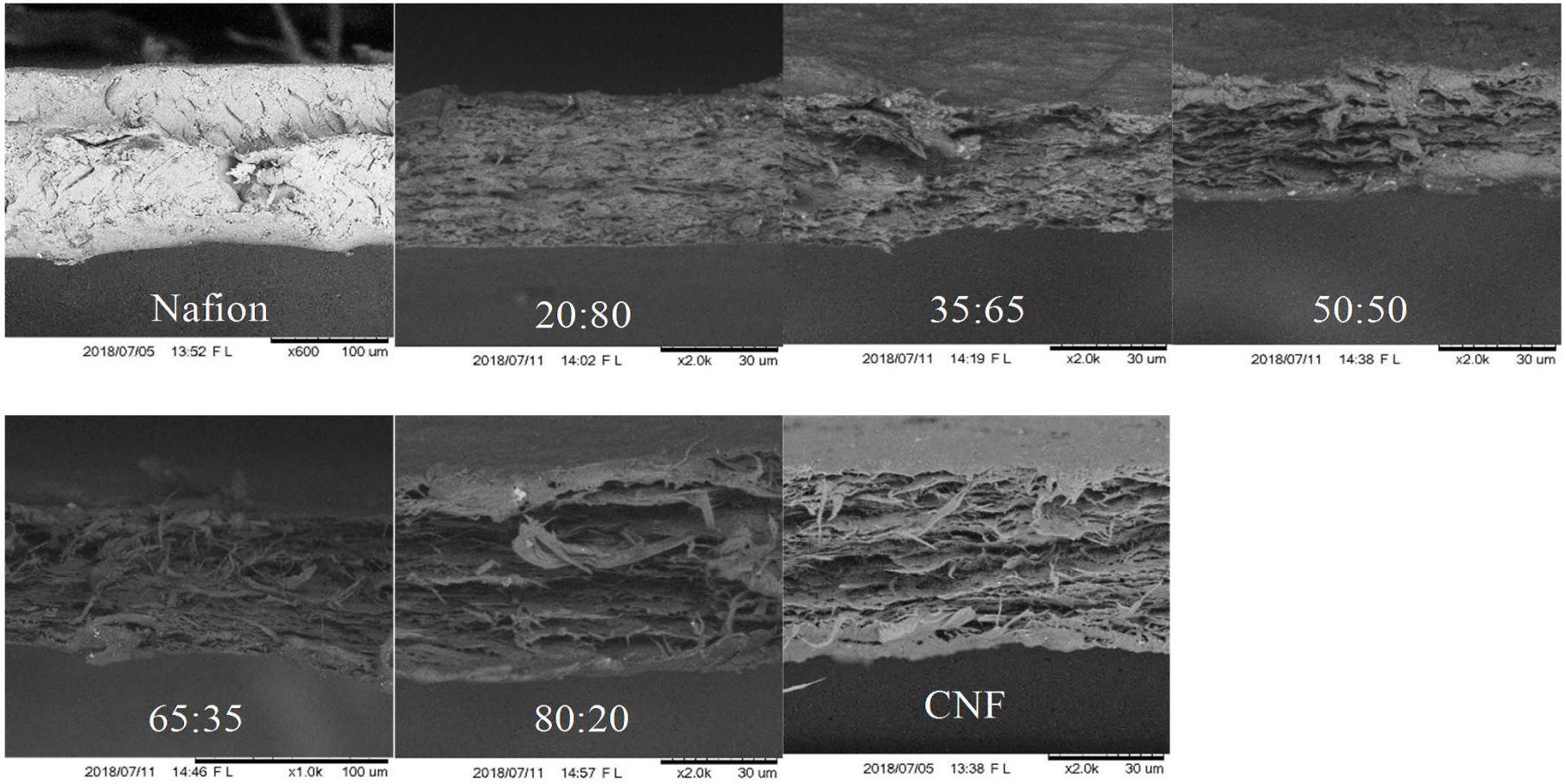
Ranged from 0.15- 0.60 grams and 30-150 microns

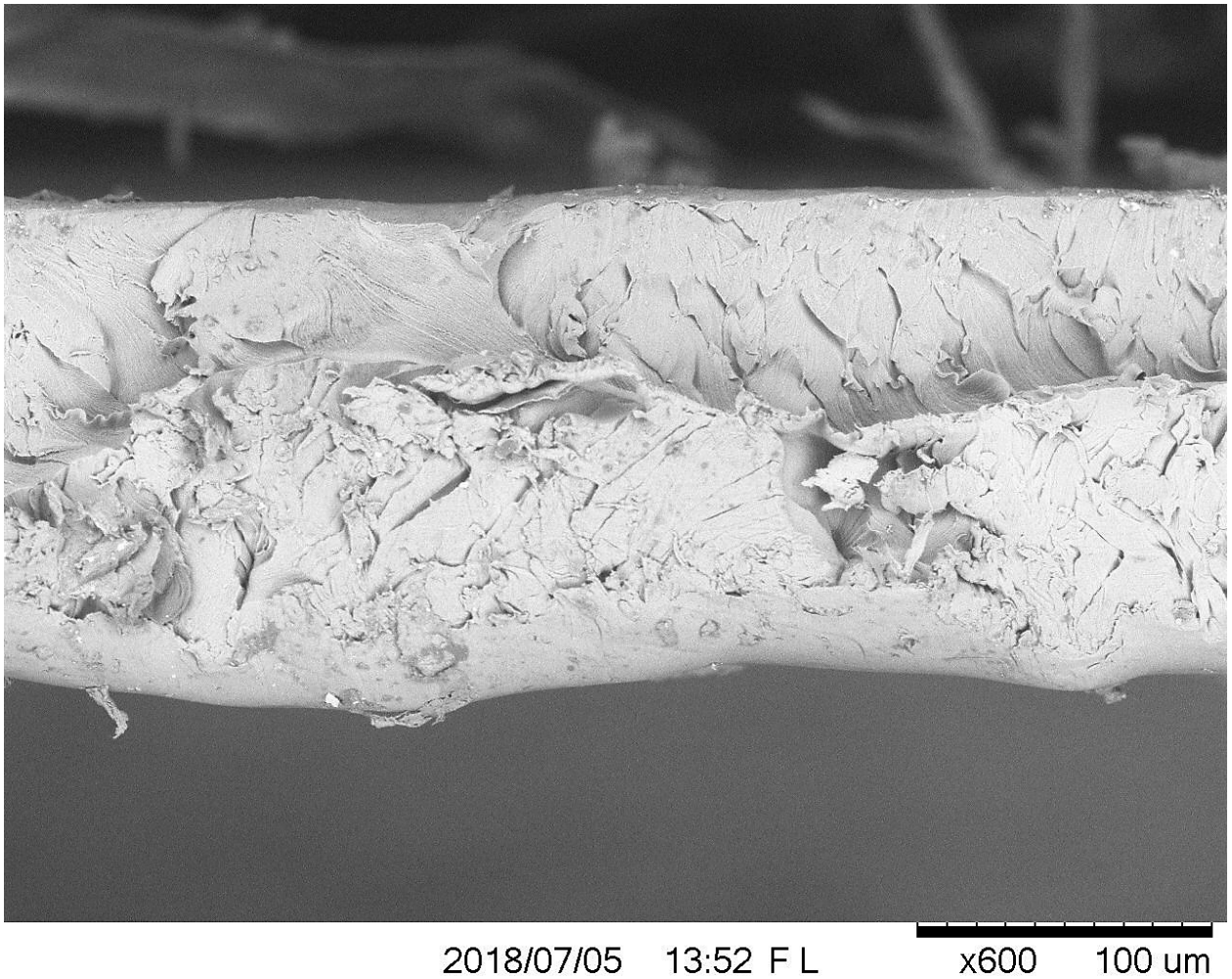
- 100 % Nafion
- 20:80 CNF:Nafion
- 35:65 CNF:Nafion
- 50:50 CNF:Nafion
- 65:35 CNF:Nafion
- 80:20 CNF:Nafion
- 100% CNF





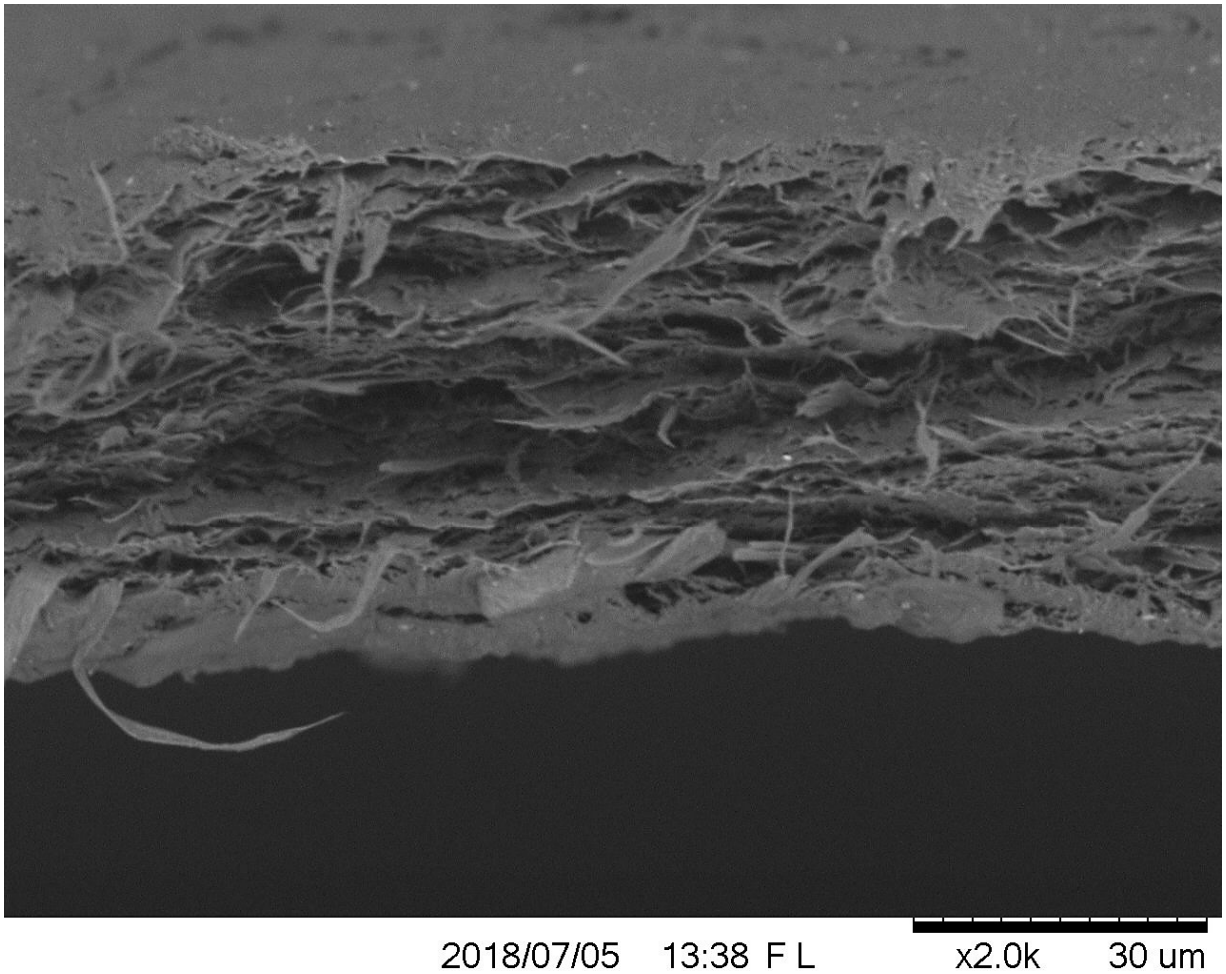
SEM Analysis





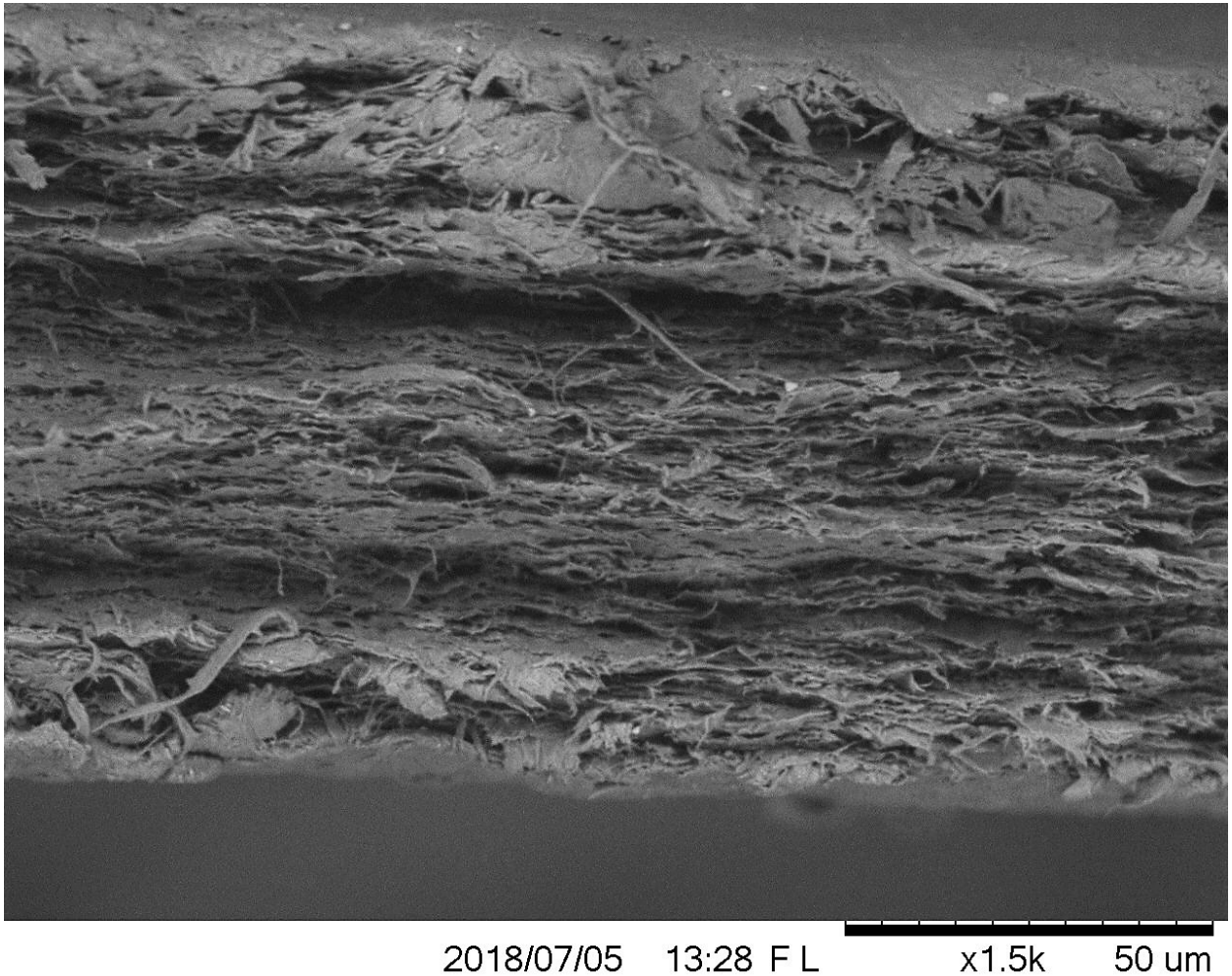
UV 0.4 Sample 10

Nafion 600x



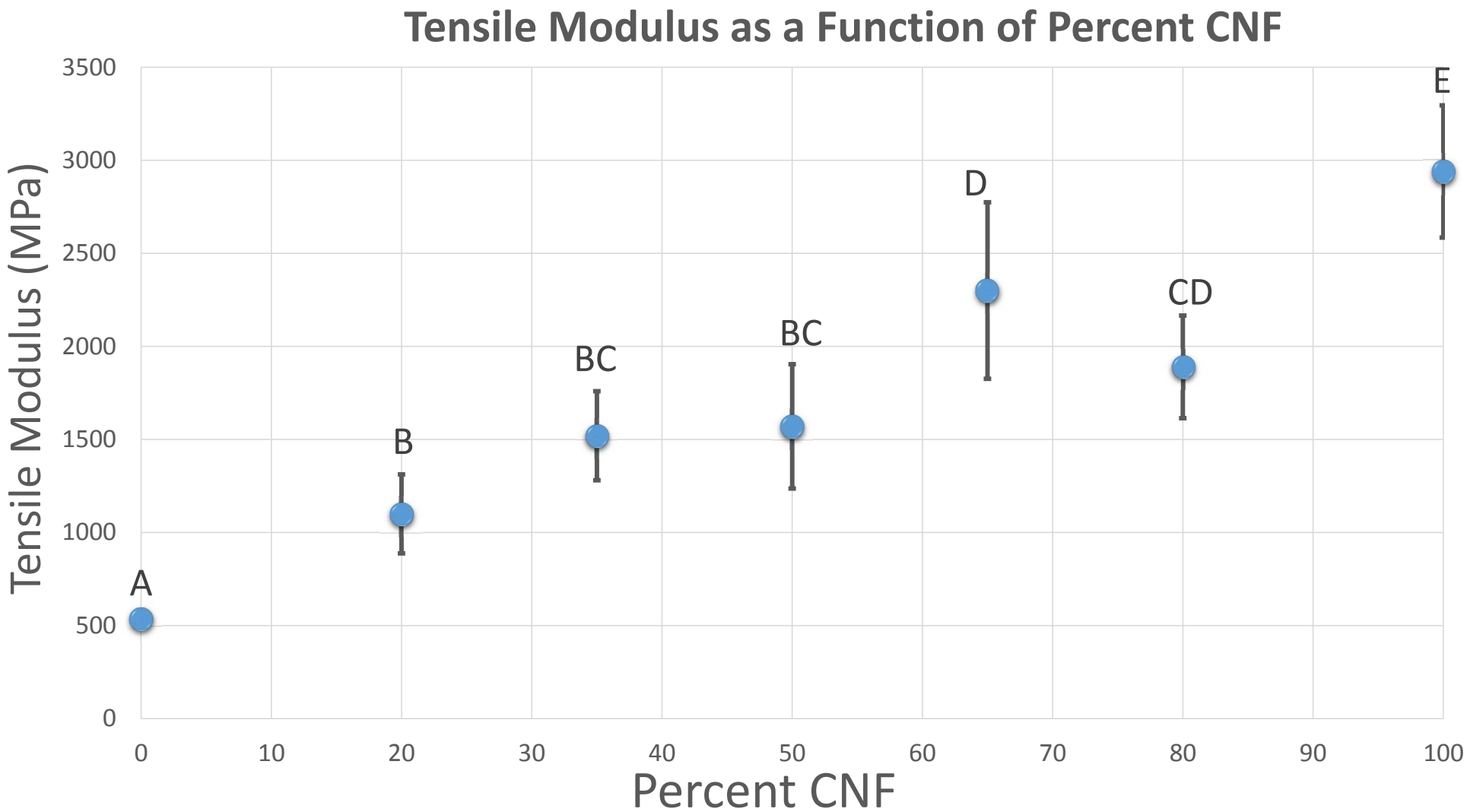
UV 0.4 Sample 10

CNF 2000X

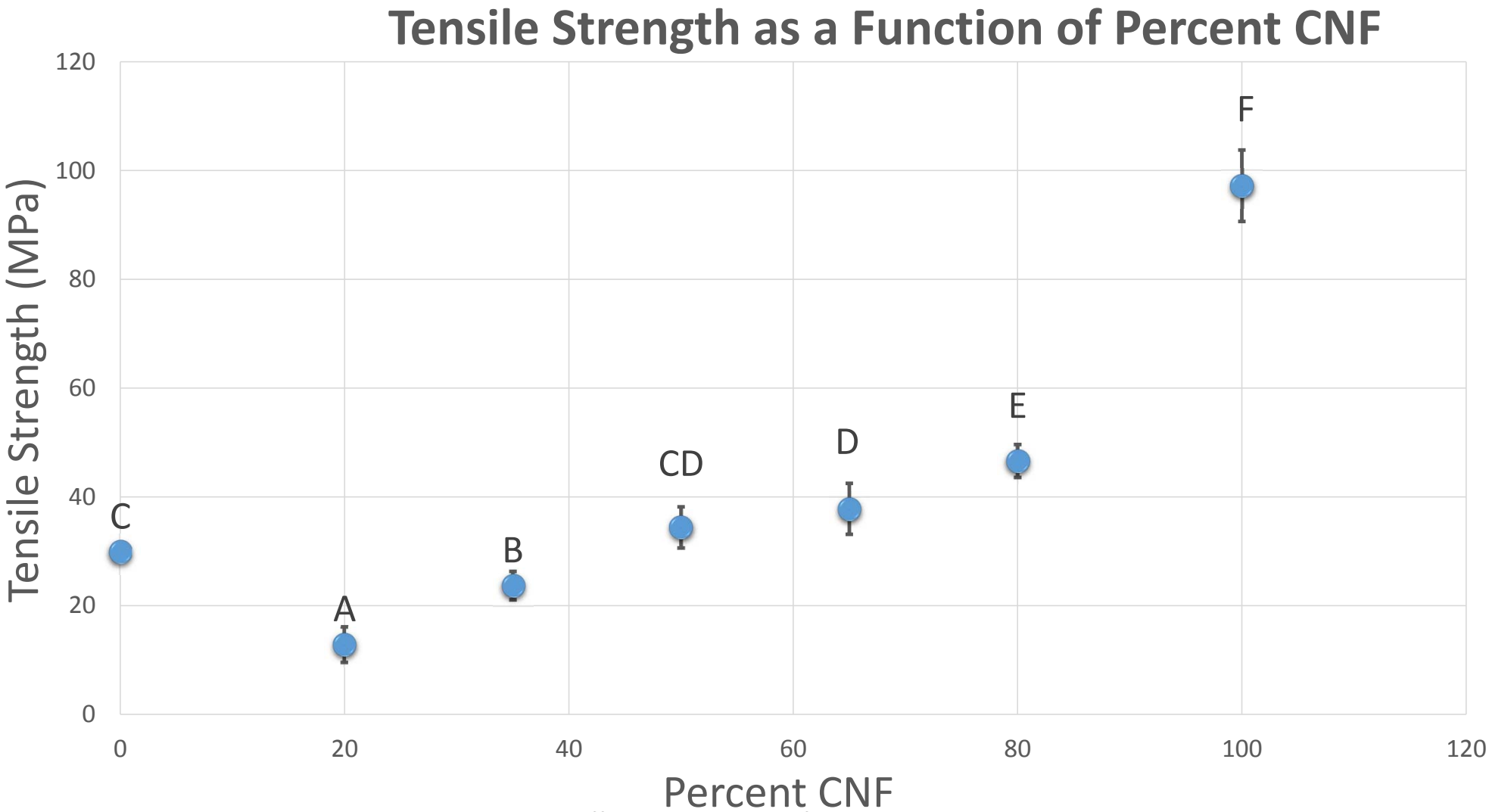


UV 0.4 Sample 10

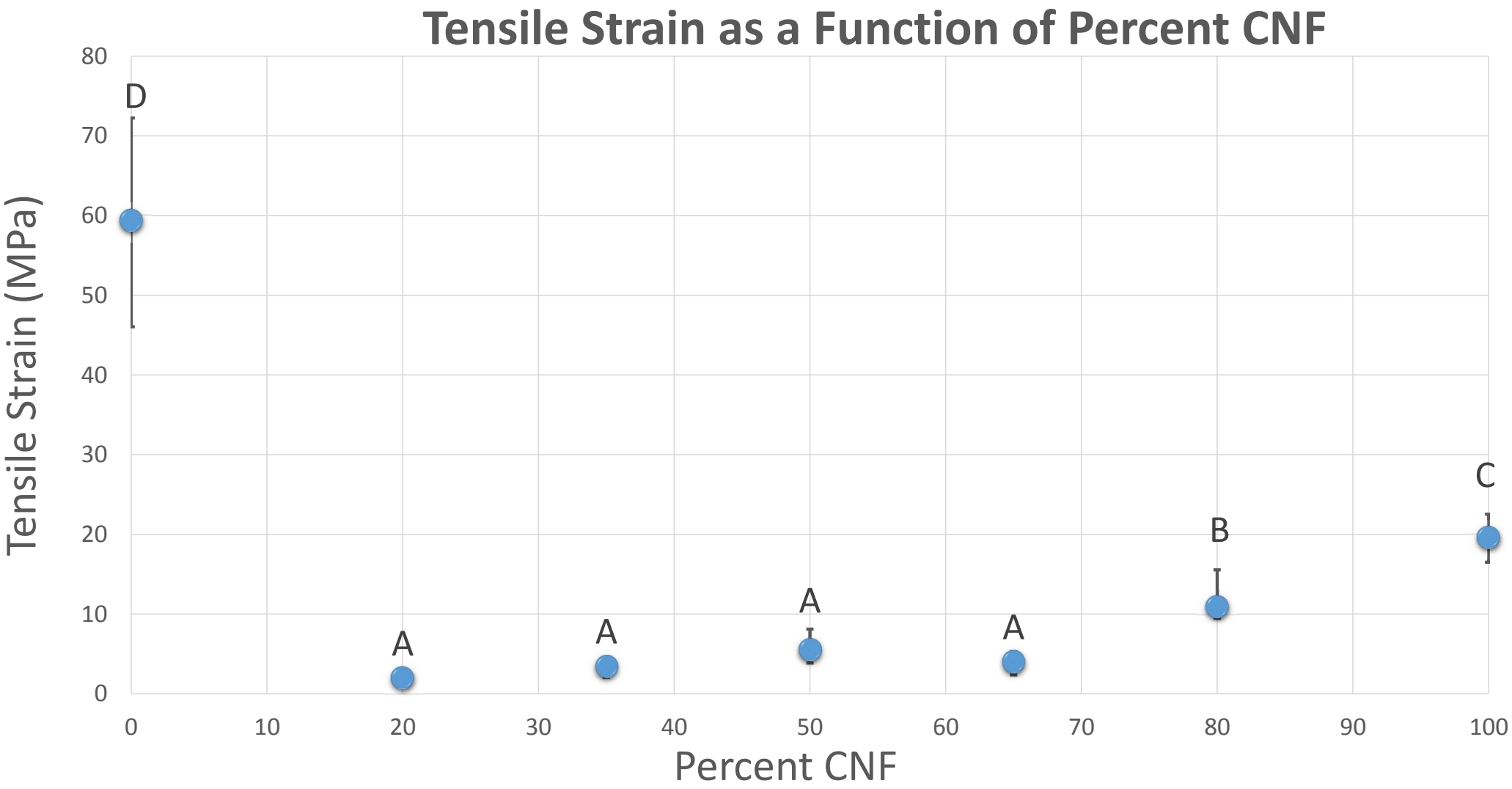
CNF:Nafion 50:50



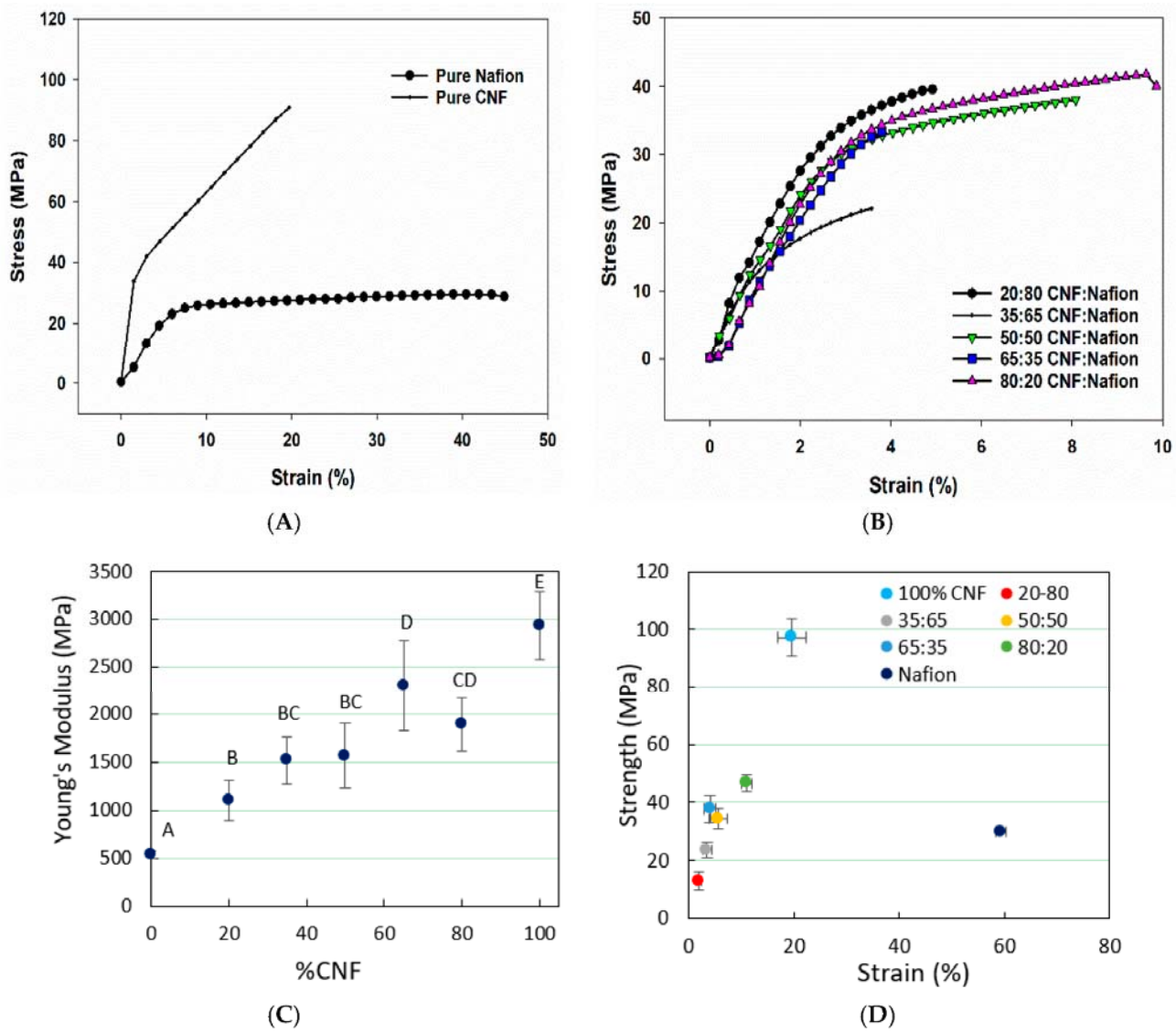
*Datapoints with similar letters have no statistical difference @95% confidence level



*Datapoints with similar letters have no statistical difference @95% confidence level

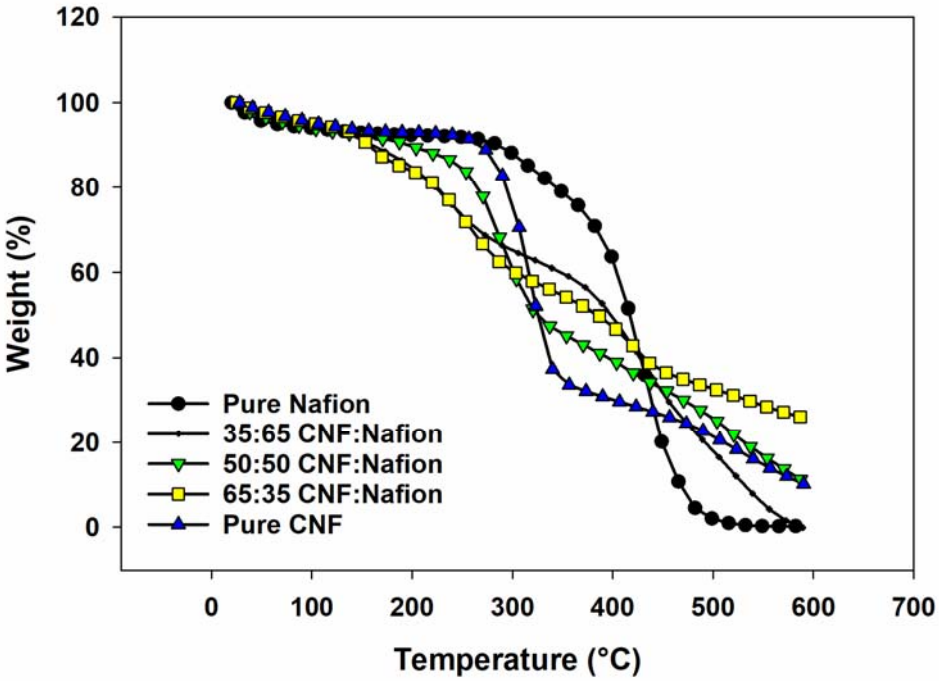


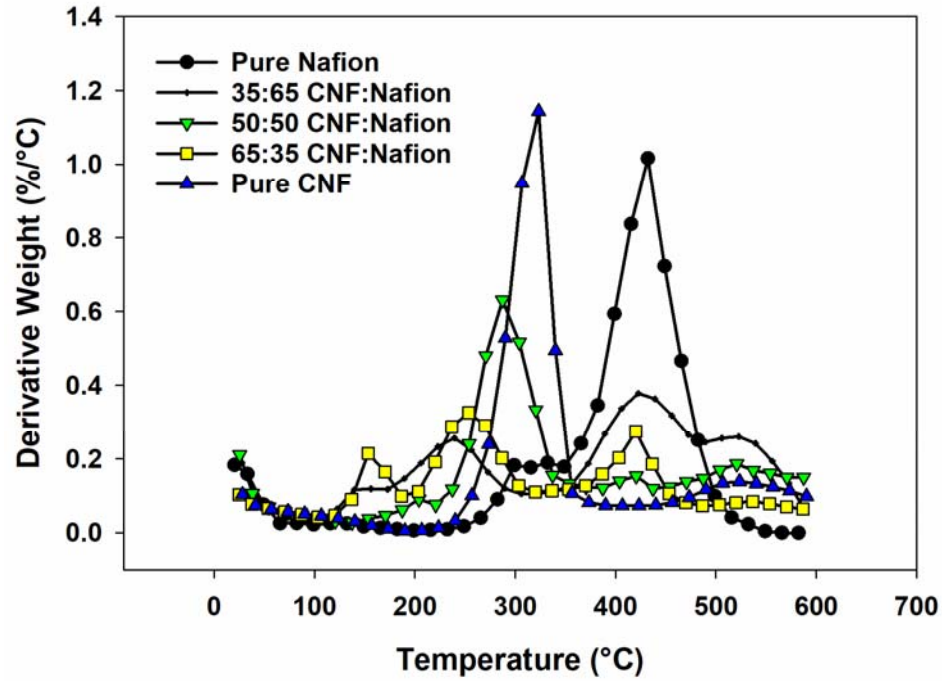
*Datapoints with similar letters have no statistical difference @95% confidence level



Typical stress-strain curves of pure materials and the hybrids thereof (A and B, respectively), tensile data obtained from CNF-Nafion® membranes with different CNF contents: (C) Young's modulus and (D) tensile strength-strain relationship.

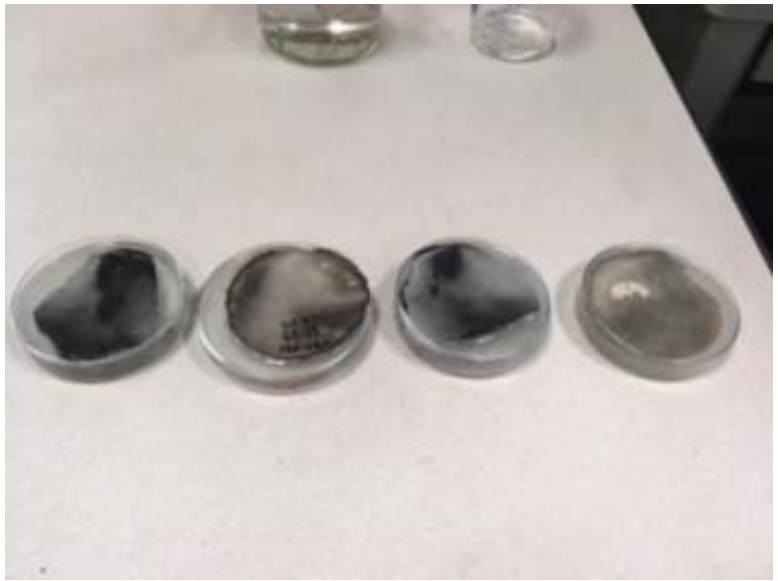
Thermogravimetric Analysis





Plating Process for Nafion

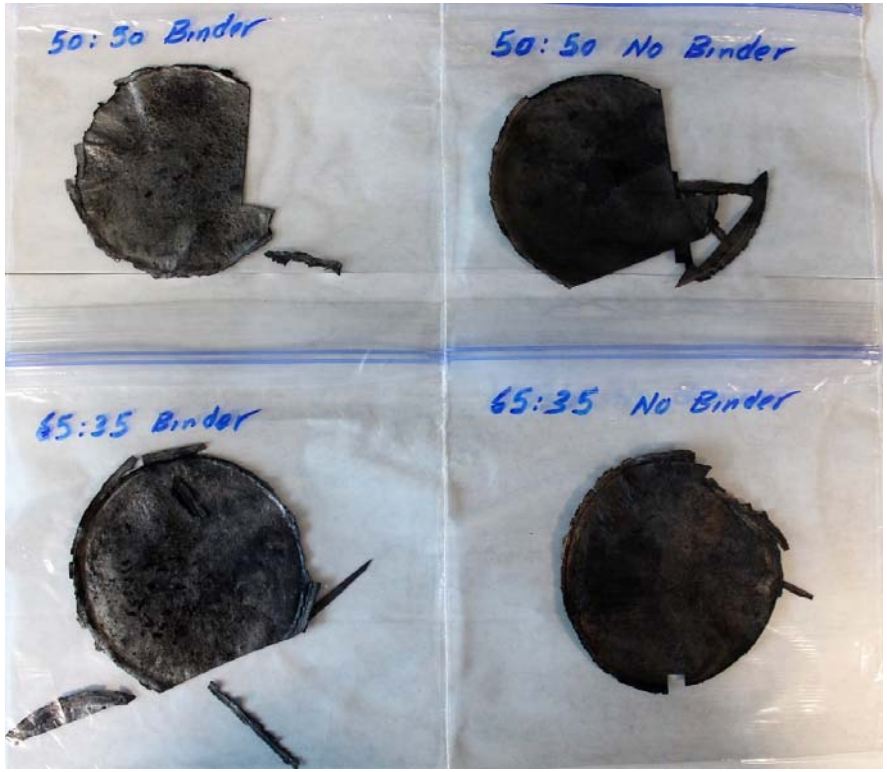
- Sanding of films to increase surface area density
- Acid boiling with HCL to clean and dope material with hydrogen ions
- Ion exchange of tetraamine platinum chloride hydrate (oxidation)
- Initial platinum compositing process using sodium borohydride to reduce platinum onto surface.
- Final surface reduction to lower resistance (usually done multiple times, 4)



First Plating Reduction

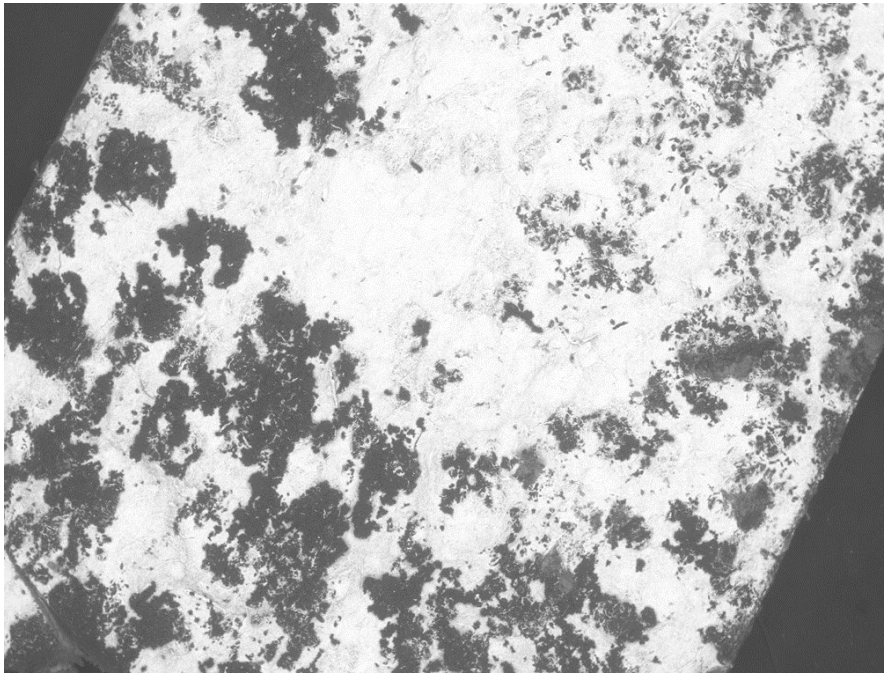
- High surface resistance into the Mega Ohms (need to have resistance closer to 5 ohms)
- Did not short
- Kept mechanical strength

Second Plating Reduction

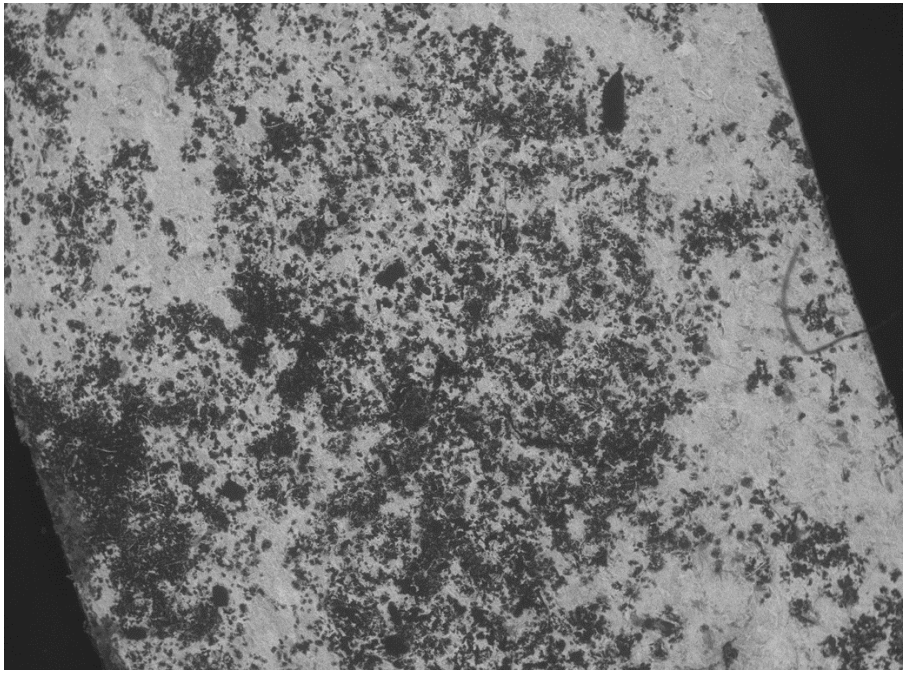


- Lower surface resistance
- Grey particles (platinum) were visible
- No substantial difference in properties between films
- Maintained mechanical strength

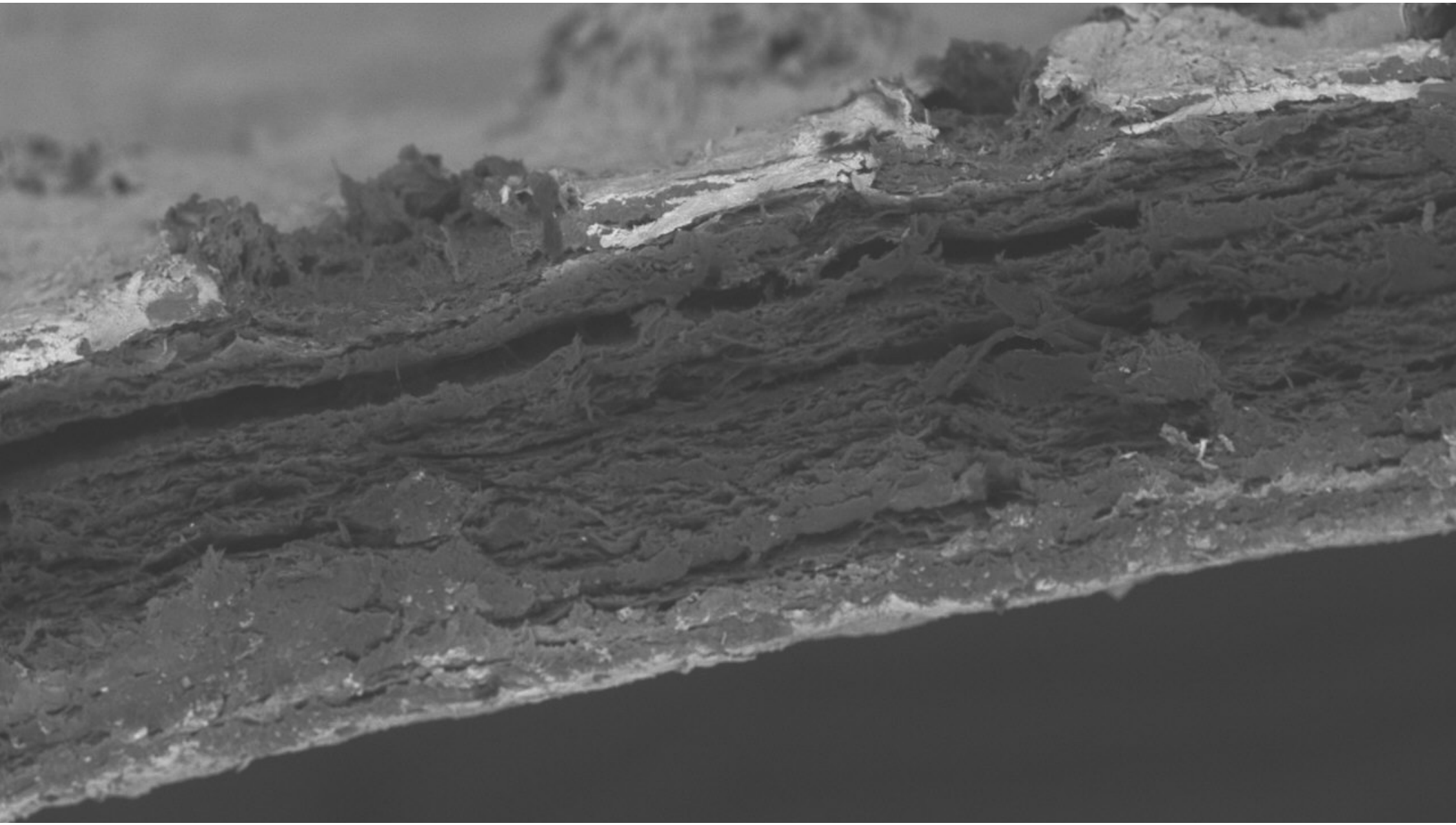
Second Plating Reduction

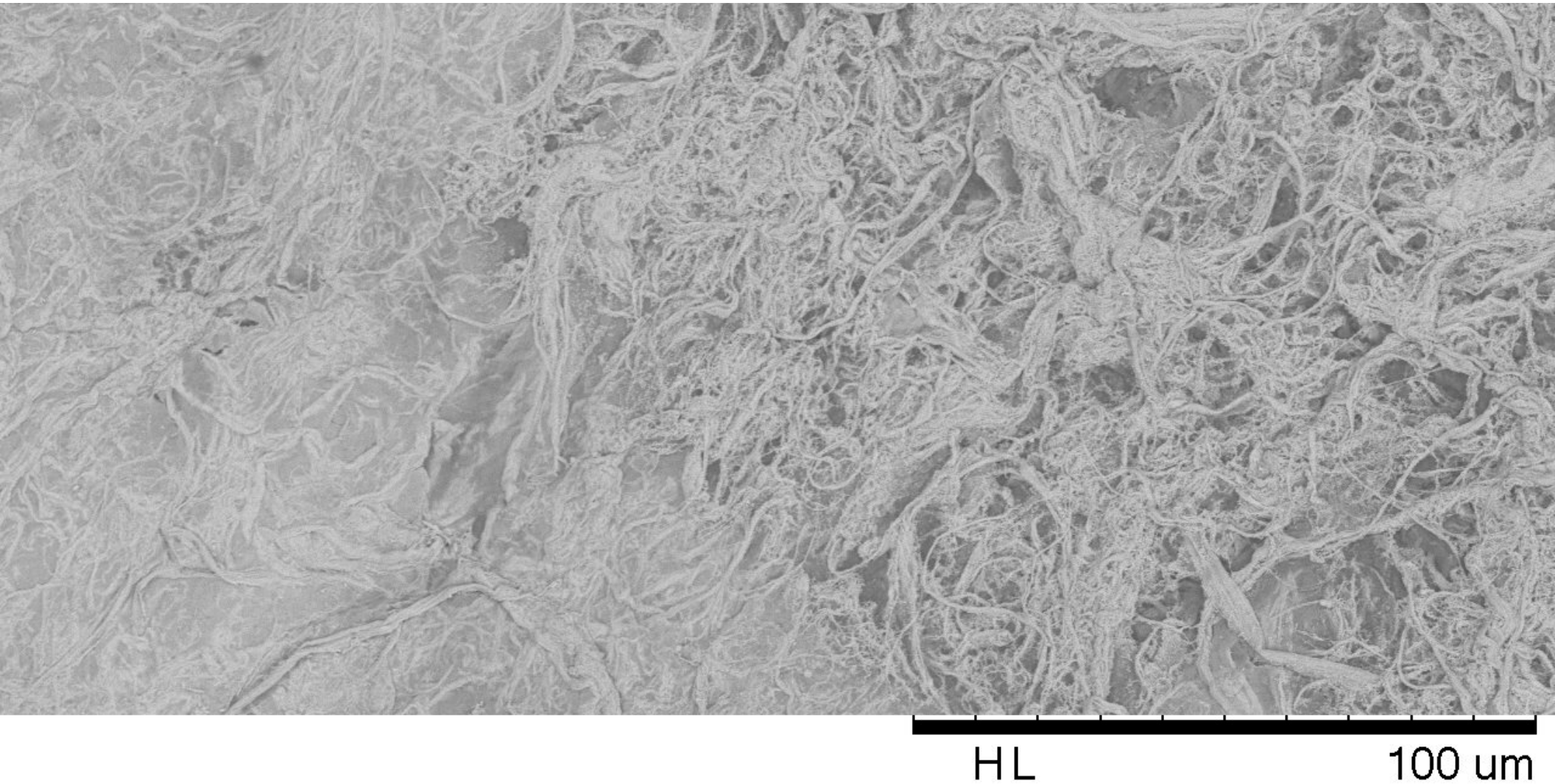


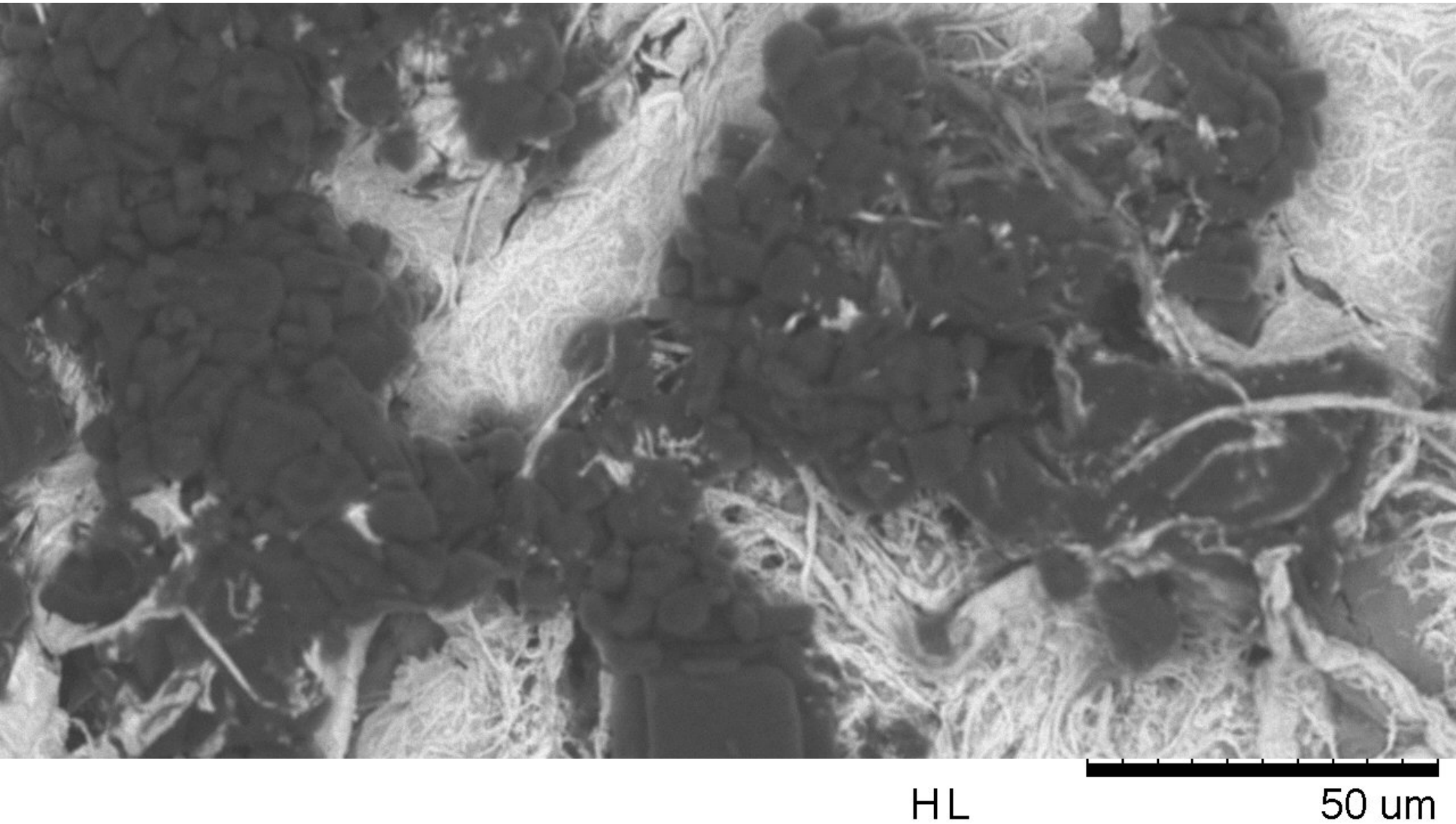
Rough side: 100-1000 ohm resistance



Smooth side: mega ohm resistance

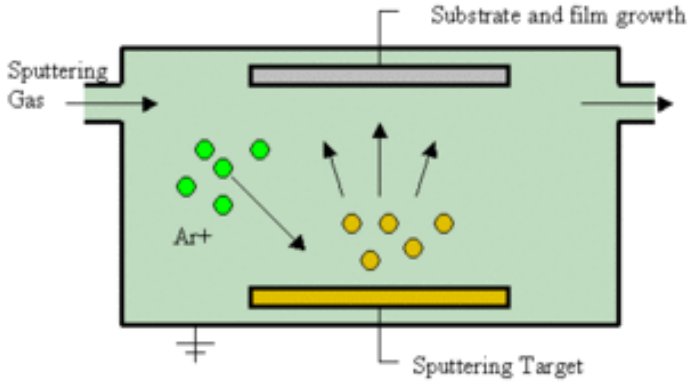


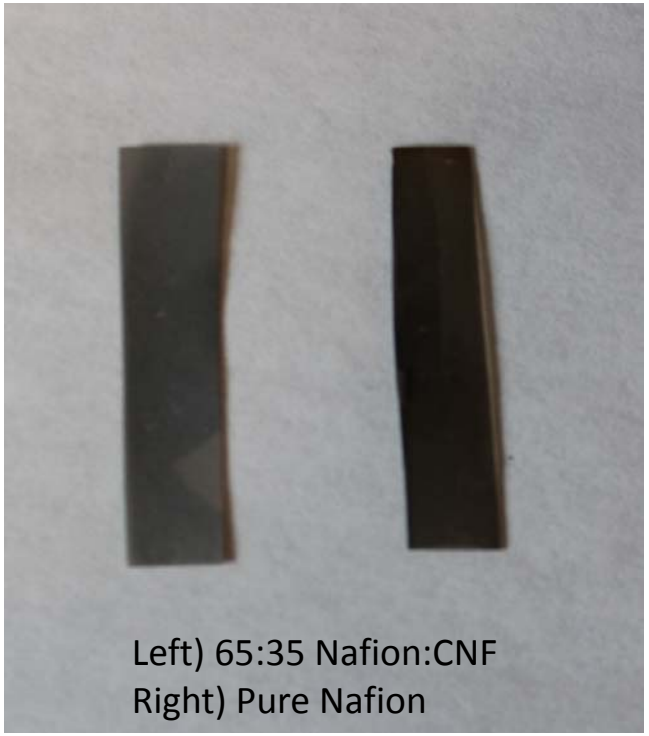

HL
100 um


HL
50 um

Sputter Coating

- Same process used in SEM coating
- Uses mixture of Gold and Palladium





Left) 65:35 Nafion:CNF
Right) Pure Nafion

Cheap alternatives: Copper Conductive Adhesive vs Conductive Ink

Copper Conductive Adhesive

- 25 µm of Copper
- 45 µm adhesive
- Too thick

Conductive Ink

- Ability to apply multiple coatings

Summary

- Hybrid membranes made from Nafion and CNF were produced
- Physical and mechanical properties of the membranes were satisfactory
- Plating process needs improvement
- Electric responsiveness is still weak
- There is potential for improvement

Thank you

FBRI
FOREST BIOPRODUCTS
Research Institute

National Science Foundation
WHERE DISCOVERIES BEGIN

MAINE

TAPPI

PRESENTED BY:

Mehdi Tajvidi

Assistant Professor of Renewable Nanomaterials

School of Forest Resources, University of Maine