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Exploring Polyvinyl Alcohol (PVA) as an Electrospinning Material

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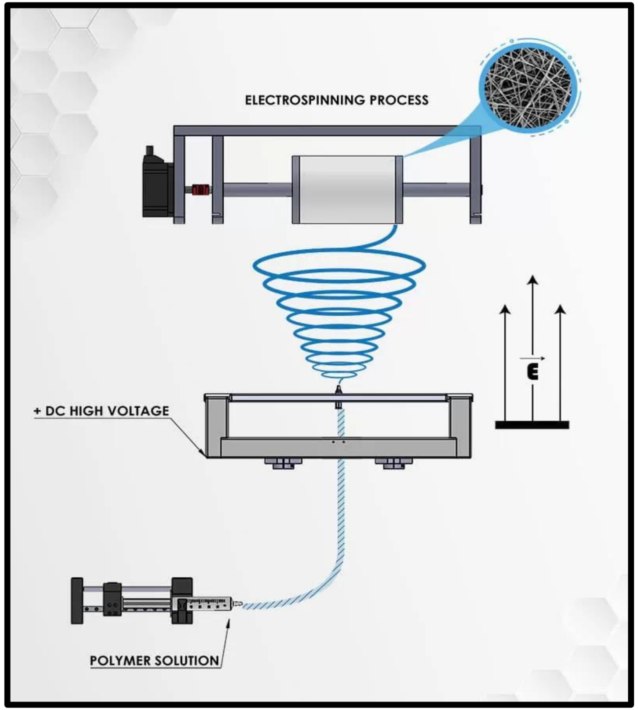
What is Electrospinning?

- An advanced manufacturing process that uses high voltage to draw thin polymer jets into solid fibers
- Produces nanoscale fibers with high surface area and tunable properties
- Fibers are collected on a grounded surface after solvent evaporation
- Allows control over fiber diameter, alignment, and porosity



Electrospinning Setup

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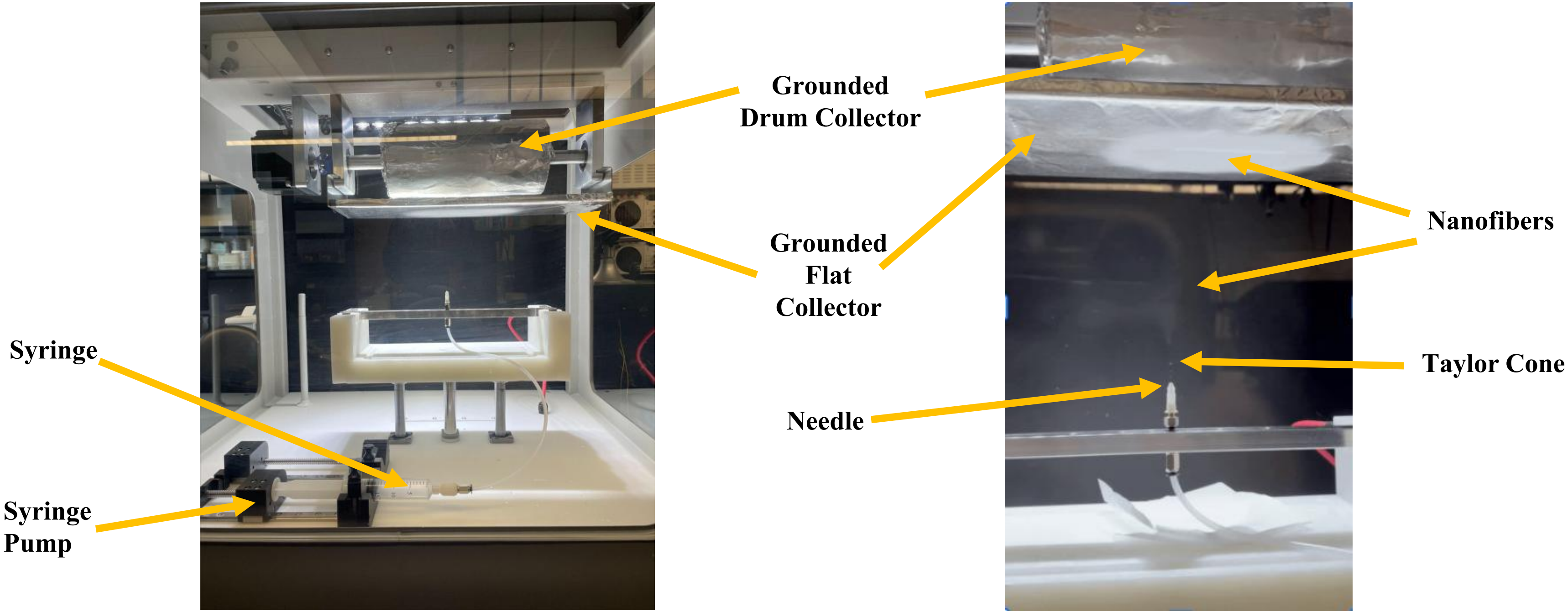
UofL Electrospinning Setup

Inovenso NE300 Electrospinning System



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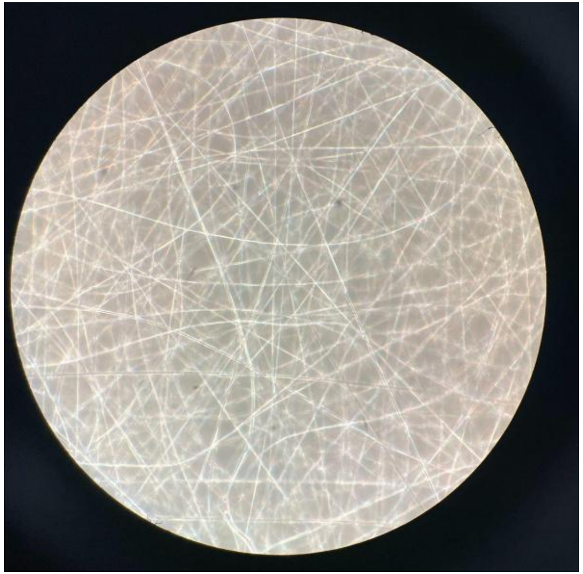
Why it Matters

Electrospinning Advantages

- Electrospun fibers have a high surface area
- Mimic structures found in biological tissue like collagen
- Can be engineered for things like biosensors, flexible electronics, and smart fabrics



Electrospun PVA nanofibers at 1000x magnification

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Project Overview

- Investigate how working distance and molecular weight affects polyvinyl alcohol (PVA) fiber formation
- Four distances: 30 mm, 80 mm, 130 mm, and 180 mm
- For each, adjust voltage and flow rate to identify optimal conditions
- Use SEM to analyze how distance influences fiber quality, diameter, and porosity
- Electrospinning was conducted under ambient humidity, which ranged from 62-67%

Electrospinning PVA dissolved in water

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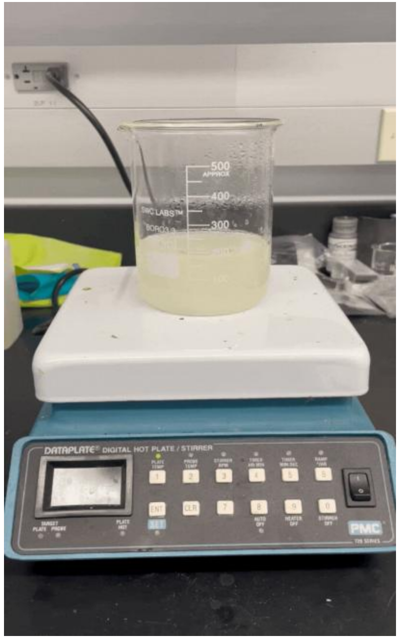
PVA Spinning Solution

- Polyvinyl alcohol (PVA) is water-soluble, biocompatible, and widely used
- We used one PVA with a molecular weight of 13,000–23,000 Da (25 wt%) and another at 105,600 Da (4.545 wt%)
- Both were dissolved in Reverse Osmosis (RO) water
- Goal is to develop a safe, reproducible baseline process for PVA electrospinning



Mixing PVA powder with water

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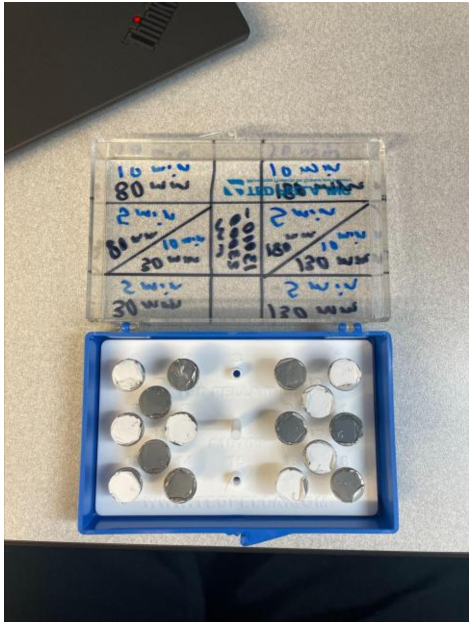
Optimization Approach

- At each distance, voltage and flow rate are systematically varied for each solution
- Criteria for optimization are a stable Taylor cone, minimal bead formation, and uniform fiber deposition
- "Best recipe" for each distance was chosen for SEM analysis

Stable Taylor Cone

Sample Collection and SEM Prep

- Collected on aluminum foil over grounded plate
- Used carbon tape to secure aluminum foil to the SEM stubs
- Samples sputter-coated with gold palladium (14.7 nm thick)
- Imaged at 10,000x magnification using SEM



Samples prepared for SEM inspection

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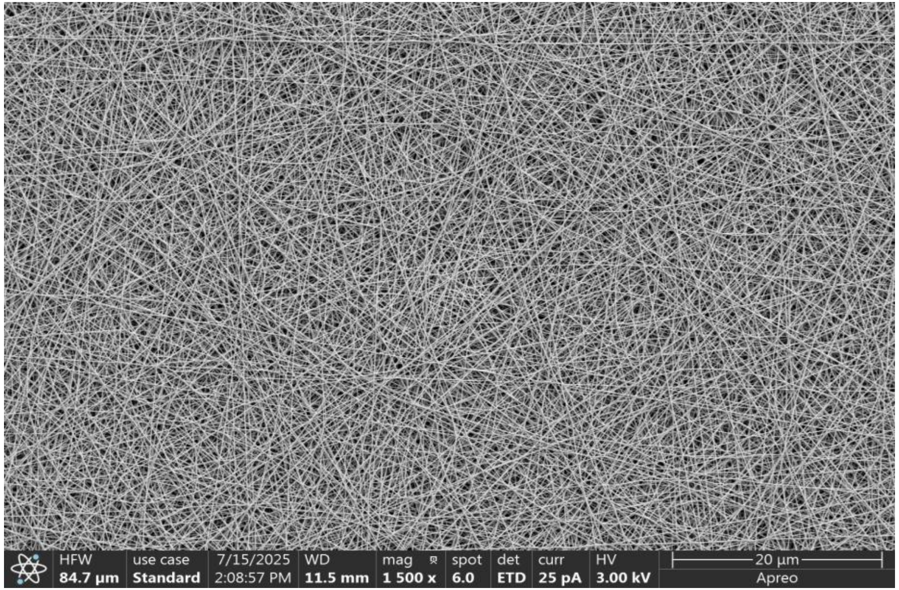
SEM Analysis

- Collect samples from each optimal condition
- Used SEM to evaluate fiber diameter and uniformity, surface coverage (fiber density), and presence of defects or beads
- ImageJ software was used for quantitative fiber analysis



13-23 kDa PVA solution under the SEM (1500x)

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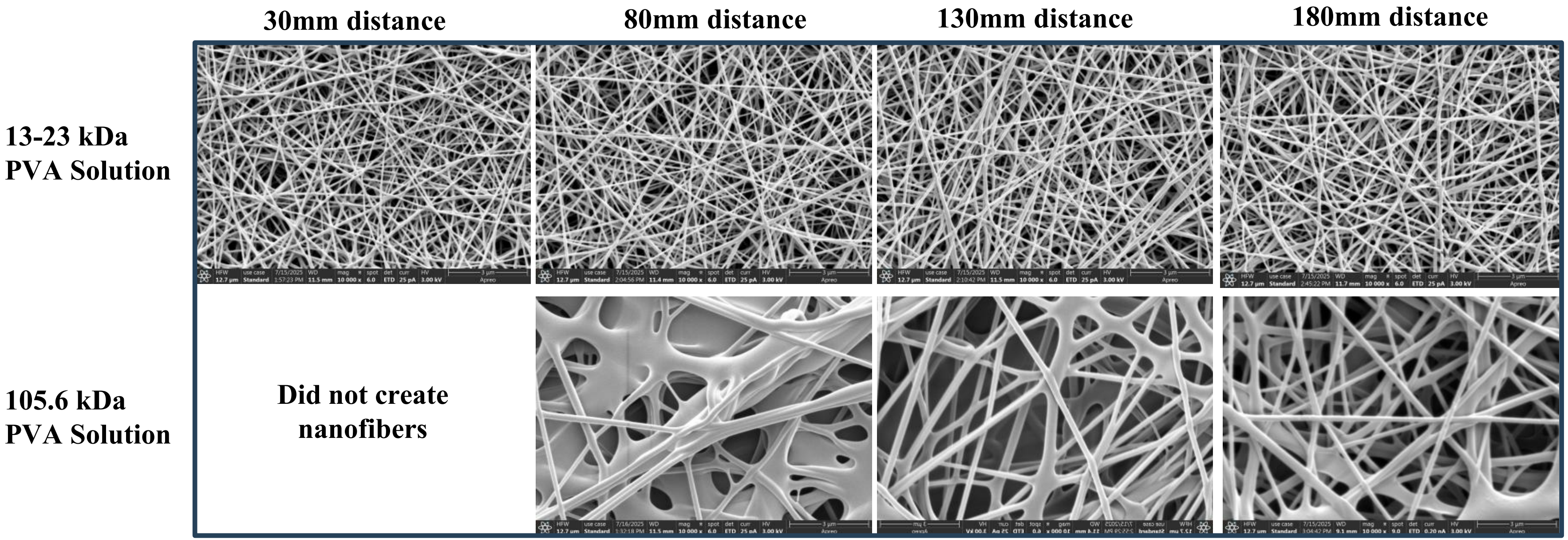
SEM Comparison



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Quantitative Results

Input Parameters					Results				
13,000-23,000 Da Solution									
Working Distance (mm)	Voltage (kV)	Flow (mL/hr)	%Humidity	Temp (C)	Mean Diameter (nm)	SD (nm)	Min (nm)	Max (nm)	%Porosity
30	13	0.25	62	22.7	96.269	13.845	74.55	139.748	12.5
80	31	0.3	64	22.5	108.794	26.28	66.097	171.435	14.11
130	27.5	0.25	64	22.3	112.916	24.878	77.087	196.374	11.99
180	37	0.4	63	22.8	105.221	21.579	70.107	155.932	27.69
105,600 Da Solution									
Working Distance (mm)	Voltage (kV)	Flow (mL/hr)	%Humidity	Temp (C)	Mean Diameter (nm)	SD (nm)	Min (nm)	Max (nm)	%Porosity
30	8.8	3.28	67	22.7	N/a	N/a	N/a	N/a	N/a
80	18	1.85	67	22.7	301.409	141.987	105.482	829.465	25.93
130	26	1.8	66	23	274.945	111.983	110.547	638.776	27.61
180	34	2.38	66	23	306.834	199.914	170.692	1286.615	23.57

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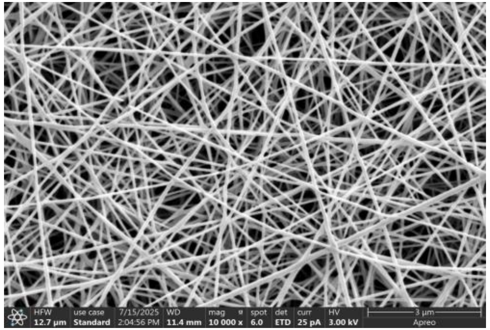
Observations and Discussion

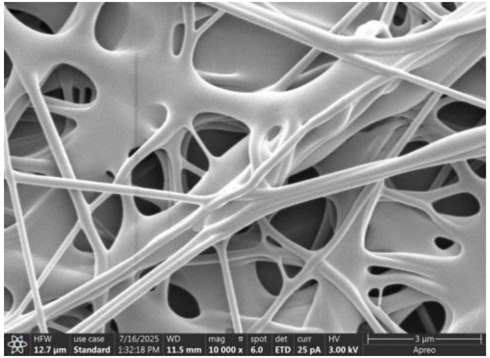
- Taylor cone looked the most consistent at 80mm and 130mm working distance
- Low MW produced <u>much smaller fibers</u>
- Working distance influences field strength and flight time, but didn't influence fiber diameter as much as expected
- Higher MW fibers appeared <u>more porous</u>, which is potentially useful for filtration or tissue scaffolds

80mm working distance (both under 10,000x magnification)

Low MW solution



High MW solution



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Conclusion and Future Work

- Electrospinning parameters affect fiber formation and stability
- Both molecular weights produced quality fibers under tuned conditions
- Working distance influenced jet behavior more than final diameter
- Controlling humidity might affect reproducibility and fiber uniformity
- Future work would be mechanical testing and alternate solution formulations

Personal Reflection and Broader Impact

Working on the Inovenso NE300 system

- Gained hands-on experience with electrospinning and SEM imaging
- Improved experimental design, data analysis, and problem-solving skills
- Learned how polymer properties affect fiber structure and process outcomes
- Built confidence working independently with advanced research equipment

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References

[1] Jiang, S., Schmalz, H., Agarwal, S., & Greiner, A. (2020). Electrospinning of ABS nanofibers and their high filtration performance. *Advanced Fiber Materials, 2*(1), 34–43. https://doi.org/10.1007/s42765-019-00026-7

[2] Nguyen, J., Stwodah, R. M., Vasey, C. L., Rabatin, B. E., Atherton, B., D'Angelo, P. A., Swana, K. W., & Tang, C. (2020). Thermochromic fibers via electrospinning. *Polymers, 12*(4), 842. https://doi.org/10.3390/polym12040842

[3] Inovenso. (n.d.). *Our technology*. https://www.inovenso.com/ourtechnology/

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