Control of Electrospun Jets Instabilities: In Pursuit of Perfect Continuous Nanofiber Alignment

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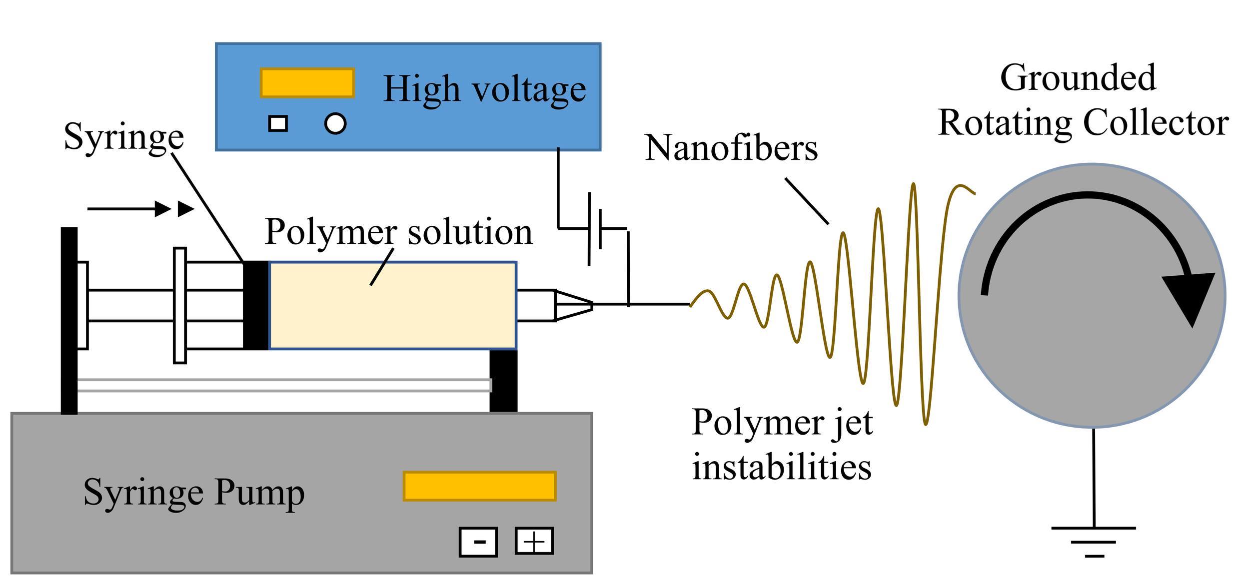
Project Objectives and Goals

- Increase the alignment and decrease the diameters of electrospun nanofibers to improve their mechanical properties and expand their applications.
- Analyze the jet instabilities during the electrospinning process .
- Study the parameters of the electrospinning process and their effect on fiber alignment and diameter. This will enable the nanomanufacturing of continuous, ultra-fine, highly-aligned nanofibers, which are critical for advanced applications.

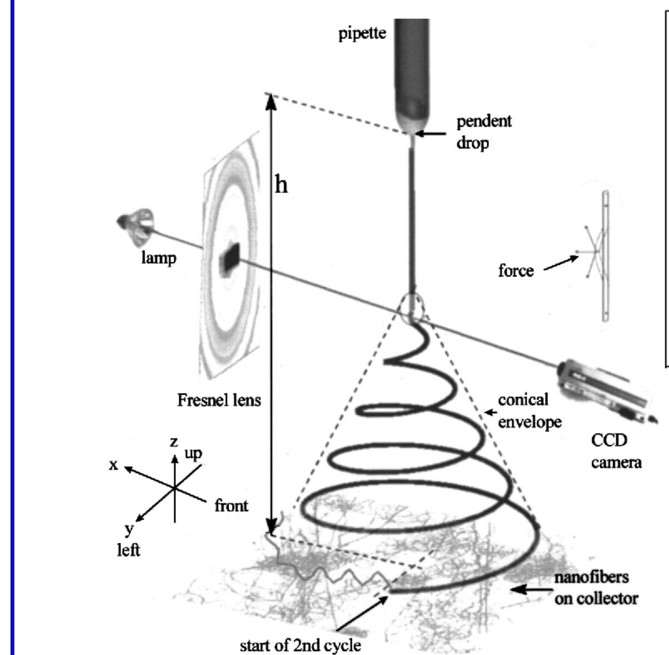
Background

Ultrafine continuous nanofibers (NFs) are at the cutting edge of structural materials and advanced composites R&D due to their recently discovered unique properties, including simultaneously ultrahigh strength and toughness. Due to their excellent and unique mechanical properties, nanofibers can be used in numerous multi-functional applications such as structural composites, biomedicine, filtration, catalysis, electronics, agriculture, and protective clothing, to name a few. The electrospinning process produces continuous NFs by jetting polymer-based solutions in high electric fields. The field causes the polymer to overcome surface tension, ejecting a fine jet that bends and whips unstably, thinning the jet, and depositing nanoscale fibers randomly on a conductive substrate. Many applications would benefit from aligned continuous nanofibers, however persistent jet instabilities currently prevent high alignment.

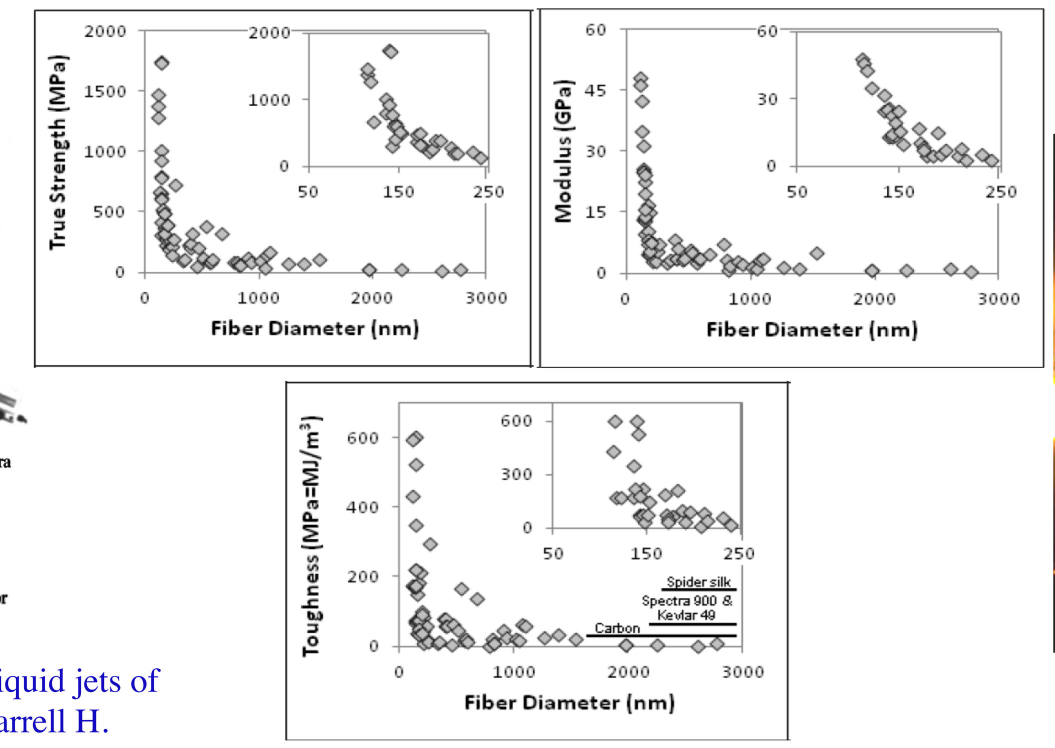


Electrospinning set up

Data and Results

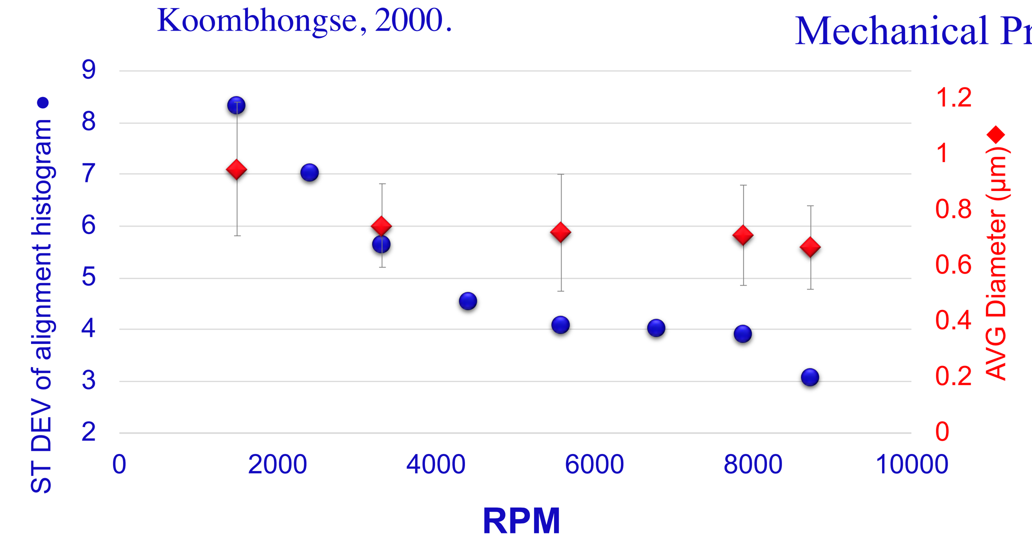


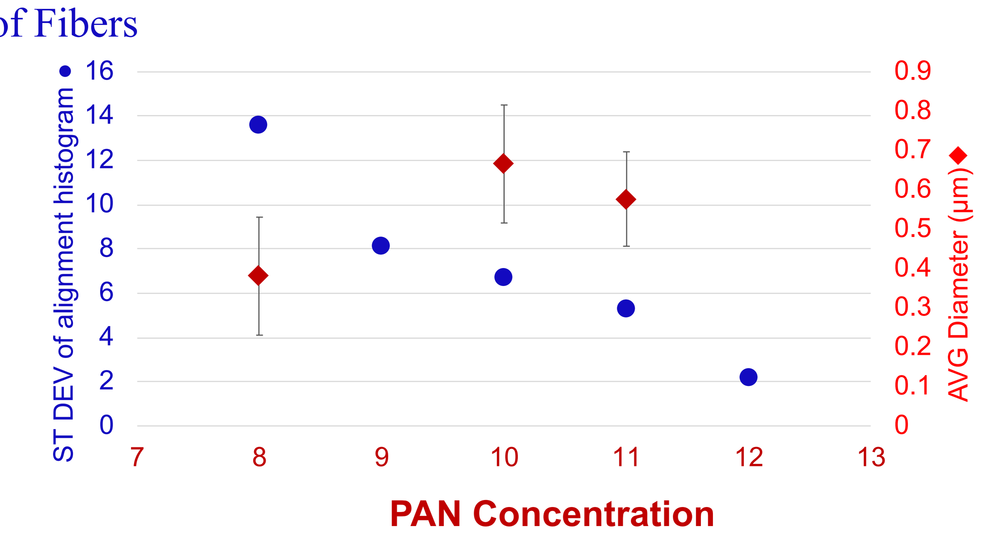
Bending instability of electrically charged liquid jets of polymer solutions in electrospinning, Darrell H. Reneker, Alexander Yarin, H. P. Fong, Sureeporn Koombhongse, 2000.



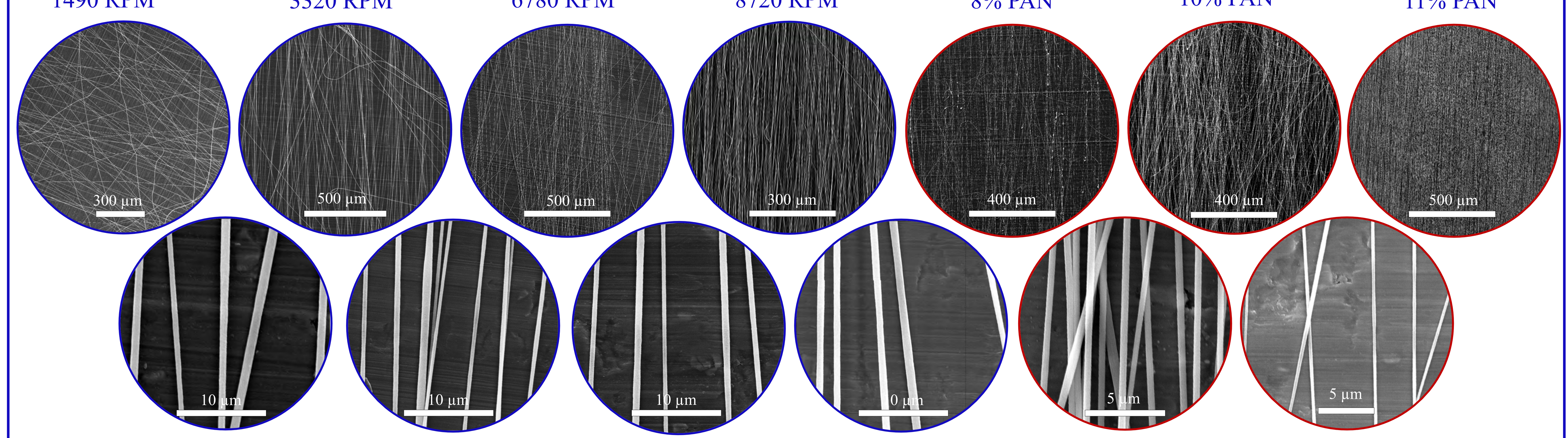
Demonstrated Size Effects in Mechanical Properties of Fibers

Electrospinning jet instabilities

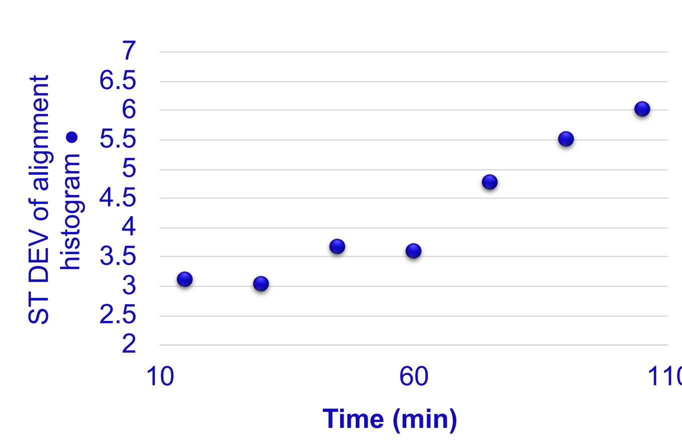


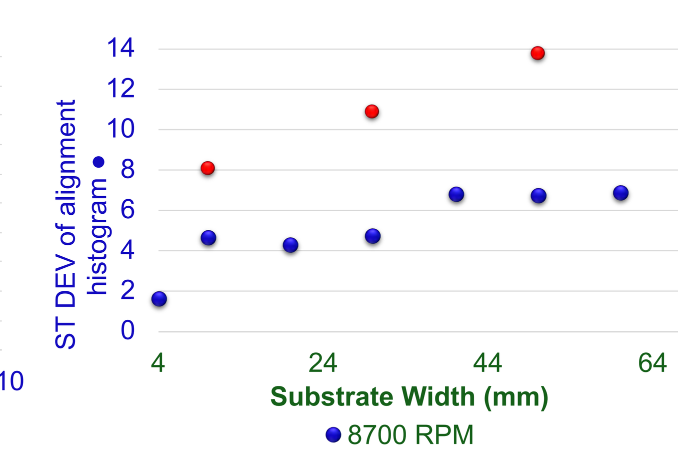


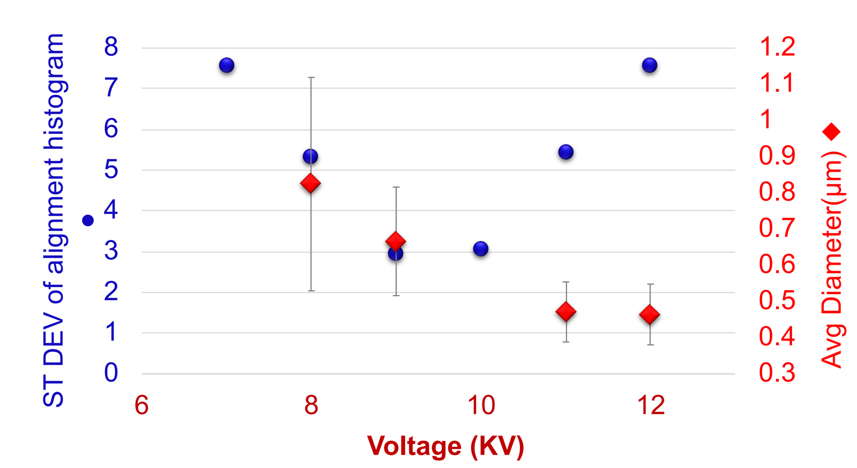
1490 RPM | 3320 RPM | 6780 RPM | 8720 RPM | 8% PAN | 10% PAN | 11% PAN

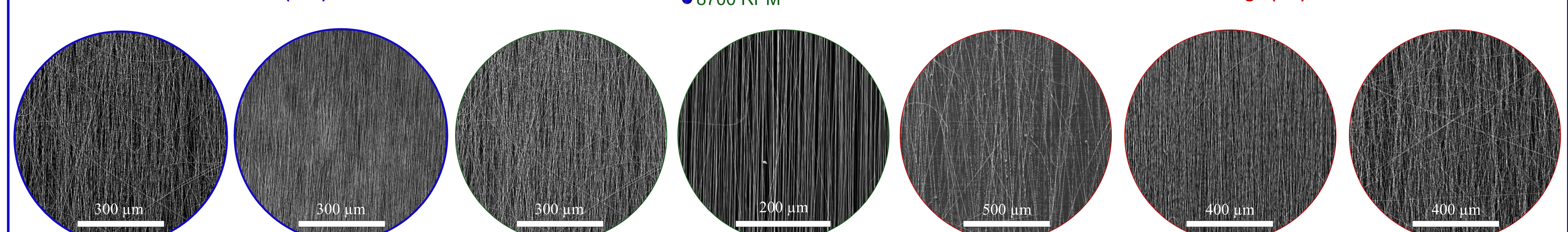


1490 RPM | 5570 RPM | 7875 RPM | 8720 RPM | 11% PAN | 8% PAN









105 Min | 30 Min | 60 mm | 4 mm | 8 KV | 9 KV | 12 KV

Conclusion

- The results showed nonlinear relationships between the process parameters and the degree of alignment.
- Increasing the RPM increases the alignment of the NFs and decreases their diameters.
- Increasing the concentration increases both the dimeter and the alignment of the NFs but decreases their area density.
- Increasing the accumulation time leads to decreased alignment, possibly because of increased air drag and/or charge buildup.
- Increased voltage causes decreased diameters but also increases electrospinning instabilities, thereby hindering the alignment.
- Best current result: very high but still imperfect nanofiber alignment.

Future Studies

- Analysis of the effects of electrospinning parameters on nanofiber alignment continues.
- We will build a computational model using the taken high-speed videography of the process to further understand the instabilities and quantify how they impact nanofiber alignment, diameter, and looping (another type of defects in nonmanufactured NF constructs).
- Investigate the impact of air flow and the charge buildup on the alignment.
- We aspire to demonstrate perfect nanofiber alignment.
- Use these results to Nano manufacture continuous nanofibers templated with graphene nanoribbons and Mxenes.

Acknowledgments

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References

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