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 ultra-high 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.

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.

Data and Results

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

Abdelrahman Elsayed¹, Lucas Barry¹, Alexander Sinitskii², Yuris Dzenis¹ (PI)
University of Nebraska-Lincoln, ¹Dept. of Mechanical & Materials Engineering, ²Dept. of Chemistry

• Study the parameters of the electrospinning process
• Analyze the jet instabilities during the electrospinning process
• Increase the alignment and decrease the diameters of electrospun NFs by jetting polymer-based solutions in high field conditions and depositing nanoscale fibers on a conductive substrate. Many applications would benefit from aligned continuous nanofibers, however persistent jet instabilities currently prevent high 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 area density. (another type of defects in non-manufactured 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.

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 diameter 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.

Acknowledgments

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