Crossflow Electrospinning

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Electrospinning (ES) is a widely utilized technique for creating fibrous and high surface area materials (*Fig 1*). The Montana Tech Nanotechnology Laboratory (MTNL) has patented an ES device that greatly reduces the fingerprint of a tabletop ES unit.[1] The electrospinner described is a handheld device that produces an electrostatic field inside the device barrel.[2] Once polymer enters the device barrel, it is stretched by the electrostatic force from the spinneret toward a ring electrode located on the outside of the device barrel. Airflow is then used to force the fibers beyond the end of the device onto any surface regardless of surface charge or conductivity.[3] This electrostatic air-driven (EStAD) ES device enables deposition onto biological surfaces without charge and enables deposition of conductive fibers onto any surface.[4] Here, we continue to develop the EStAD technology to increase the applicability and versatility of the device.

This abstract presents an innovative adaptation of the handheld electrospinner that employs ionized air directed orthogonal to the direction of fiber creation to produce freestanding electrospun fiber mats on arbitrarily charged surfaces. The crossflow ES system (*Fig 3*) addresses this issue by incorporating ionized airflow that directs the nanofiber along the barrel with charged air, disrupting electrostatic forces accumulating at the walls of the apparatus and enabling the creation of freestanding fiber mats independent of the substrate charge.

Parametric analyses of the crossflow ES system will be presented, including deposition and reliability under various humidity conditions by monitoring fiber diameter and fiber mat weight. We will demonstrate deposition onto non-charged surfaces using the crossflow device and deposition of conductive polymers onto non-charged surfaces. The uniformity of fiber mat weight and fiber diameter will also be examined in these cases under constant humidities. We hypothesize that the freestanding fiber mats will exhibit increased uniformity, enhanced structural integrity, and increased resilience due to reduced interference from the internal charge of the apparatus. Applications of this technology range from advanced tissue engineering scaffolds to flexible sensor deposition, along with fabrication of on-demand conductive nanowires.

[1] J. L. Skinner, J. M. Andriolo, J. P. Murphy, and B. M. Ross, "Electrospinning for nano-to mesoscale photonic structures," Nanophotonics, vol. 6, no. 5, pp. 765–787, Aug. 2017, doi: 10.1515/NANOPH-2016-0142/ASSET/GRAPHIC/J_NANOPH-2016-0142_FIG_002.JPG.
[2] G. Taylor, "Electrically Driven Jets," Proc R Soc Lond A Math Phys Sci, vol. 313, no. 1515, pp. 453–475, 1996.
[3] L. G. Huston, E. A. Kooistra-Manning, J. L. Skinner, and J. M. Andriolo, "Combined electrostatic and air driven electrospinning for biomedical applications," Journal of Vacuum Science & Technology B, vol. 37, no. 6, p. 062002, 2019, doi: 10.1116/1.5122659.
[4] J. L. SKINNER, E. A. Kooistra-Manning, GREGORY, Jessica M., and L. G. Huston, "Device for polymer materials fabrication using gas flow and electrostatic fields," PCT/US202035478, 2020

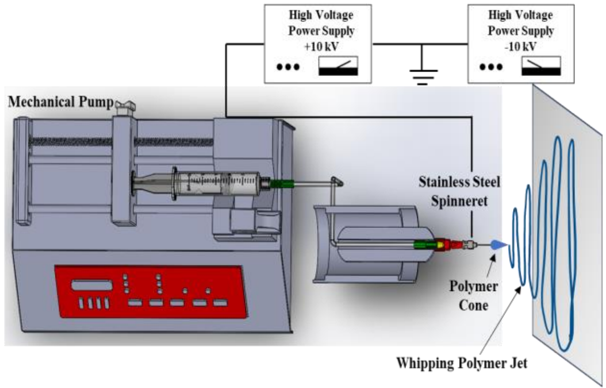

Fig 1. Graphic of a traditional ES setup. A traditional ES system consists of a mechanical pump used to deliver solvent-dissolved polymer through a metallic spinneret held at a high voltage relative to a conductive collection surface. As a polymer jet is emitted from the cone apex, it approaches the collection electrode in a chaotic whipping motion that results in solvent evaporation and fiber or droplet deposition.

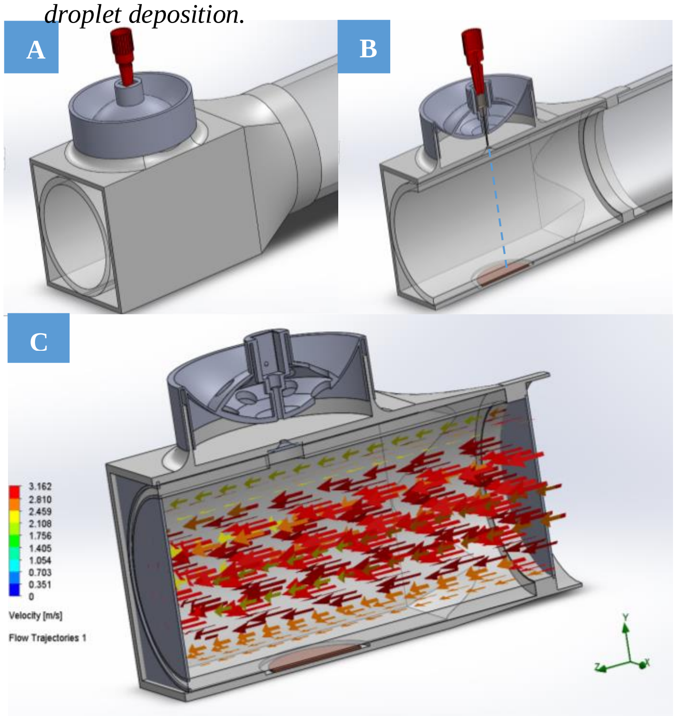

*Fig 3. **(A)** CAD (computer aided design) rendering of crossflow apparatus assembly. **(B)** A cross sectional view of crossflow apparatus with copper electrode placed opposite the spinneret and dotted line showing spinneret to electrode path **(C)** The crossflow apparatus assembly with 3 m/s airflow simulation from right to left demonstrating the air that carries away electrospun fibers.*

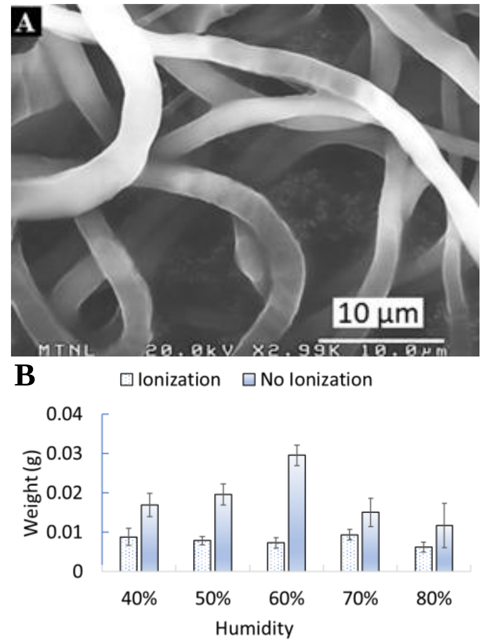

*Fig 2. **(A)** SEM showing electrospun fibers produced by the EStAD under ionization and 70 % humidity. **(B)** Data demonstrating improved reliability of fiber mat weights deposited under ionization over a range of humidities.*