Portable Electrospinning for Orthopedic Wound Treatment

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Electrospinning (ES) is a versatile polymer fiber manufacturing technique used for producing fibers with high surface area-to-volume ratio. Electrospun nanofibers have applications in filtration membranes, energy harvesting and storage devices, photonic devices, and biomedical devices and materials.[1] Solution ES requires the delivery of a solvent-dissolved polymer to a metallic spinneret held at a high voltage relative to a conductive collection surface. Upon electrification of the spinneret and polymer extrusion, the polymer droplet deforms to cone to reduce electrostatic surface forces. At the tip of the cone, a polymer jet is ejected.[1] From the polymer cone tip to the deposition surface, the polymer jet undergoes vigorous whipping motions that result in solvent evaporation and deposition onto the conductive collection surface.

A portable electrostatic and air-driven (EStAD) ES device has been developed to significantly reduce the fingerprint of ES fabrication. The EStAD shields all high voltage components from the operator and patient and is capable of deposition on nonconductive and complex surfaces. ES has many applications in the biomedical industry. The EStAD ES device provides a handheld system that can be used to deposit drug delivery devices and materials, tissue scaffolds, coagulant bandages, and/or sensors directly onto wound sites without patient-exposure to the electrostatic field. Using a traditional setup, biomedical materials deposited onto a biological surface require that surface be placed between the spinneret and deposition surface to intercept polymer fibers as they are being produced. The EStAD device uses a barrel through which polymer is stretched from the spinneret toward an isolated ring electrode set outside the barrel, before being guided past the end of the device by air flow.[2,3] This device has been used to demonstrate deposition of antibacterial fibers onto *Staphylococcus aureus* bacterial lawns, rounded produce surfaces, and across wound sites of porcine skin. In a recent modification, the EStAD has been equipped to incorporate ionization to improve reliability of the device over a range of humidity [4,5] that modify surface charge along the device barrel.

In this work, we demonstrate ionized portable ES and successful improvement to reliability over a range of humidities with air ionization. The CDC estimates that 3 % of patients experience post-op infection near the wound site following orthopedic surgery. We demonstrate deposition and monitor efficacy of antibacterial bandages deposited on simulated orthopedic wounds in agar.

[1] J. Xue, T. Wu, Y. Dai, and Y. Xia, "Electrospinning and electrospun nanofibers: Methods, materials, and applications," Chem Rev **119**(8), 5298–5415 (2019).
[2] E.A. Kooistra-Manning, L.G. Huston, J.L. Skinner, and J.M. Andriolo, "Air driven electrospinning of CNT doped conductive polymer fibers for electronics," MRS Adv, (2020).
[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 **37**(6), 062002 (2019).
[4] R.M. Nezarati, M.B. Eifert, and E. Cosgriff-Hernandez, "Effects of humidity and solution viscosity on electrospun fiber morphology," Tissue Eng Part C Methods **19**(10), 810–819 (2013).
[5] P.K. Szewczyk, and U. Stachewicz, "The impact of relative humidity on electrospun polymer fibers: From structural changes to fiber morphology," Adv Colloid Interface Sci **286**, (2020).

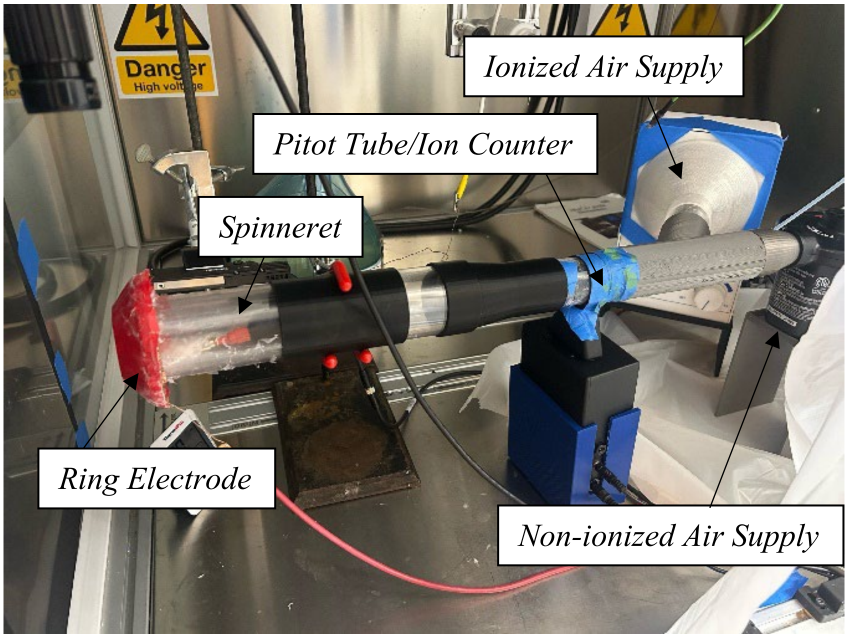

Figure 1: Experimental setup of the electrostatic and air-driven (EStAD) portable electrospinning device. The device includes both ionized, and non-ionized air supplies. An ion counter was used via a pitot tube attachment to monitor the ions entering the system.

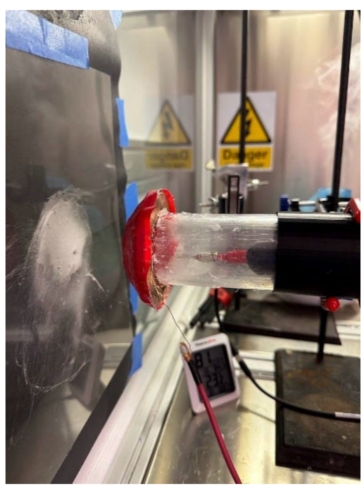

Figure 2: Fibers deposited via the EStAD device onto nonconductive polyethylene terephthalate (PET) transparency film.