Portable Electrospinner with Ionized Airflow to Improve Performance Across Environments

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Solution electrospinning (ES) fabrication requires delivery of a solvent-dissolved polymer by mechanical pump to a metallic spinneret held at a high voltage relative to a collection surface. Once polymer forms a bead just outside the tip of the spinneret, voltage initiated on the collection surface (electrode) causes surface charge buildup at the surface of the polymer bead. At critical value, the polymer bead is deformed into a cone. At the apex of the cone, a micro- or nano-scale polymer jet is pulled by electrostatic force toward the deposition surface, resulting in deposition of polymer fibers or beads. During flight, the polymer jet experiences a chaotic phase, whereby, solvent evaporation occurs.[1] Iterations of ES have produced high surface area materials with enhanced charge transport, light polarization, improved light absorption and photovoltaic properties, improved crystallinity, and even scaffolds for cell growth and guided cell differentiation.

One major limitation to wide adoption of electrospun materials is the ES hardware itself, which typically requires high voltage, electric isolation, and charged, and flat deposition surfaces. The Montana Tech Nanotechnology Laboratory (MTNL) developed a portable ES device that minimized the fingerprint of traditional ES, while diversifying the applications to which ES could be applied.[2-4] Past researchers who have developed portable ES devices required the deposition surface (whether that was an object or living thing) be placed in the path of the electric field. This results in disruption of the electric field, unreliable deposition, and a potential shock hazard. The device invented by MTNL places a ring electrode inside of a hand-held ES system, and incorporates airflow (Fig. 1).[2-4] In this setup, electrospun fibers are formed between a needle and ring electrode, and then forced by airflow through the center of the ring and on to a deposition surface beyond the end of the device; thereby completely encasing the electric field and enabling deposition onto any surface, regardless of charge (Figs. 2-3), and providing improved reliability. In addition, the mobility of the device enables coating of complex (round or uneven) surfaces rather than flat (Fig. 2C).

In this work, we aim to achieve higher precision during fiber deposition in environments with varying humidity to improve fabrication and operational reliability of electronic or photovoltaic devices or medical bandages fabricated on-demand in the field. We have modified the portable electrospinner to include ionized airflow to remove charge buildup in the device caused by changing humidity (Fig. 4). Future studies will monitor reliability by electron microscopy and material performance.

[1] "Electrospinning for nano to mesoscale photonic structures," J. L. Skinner, et al., *Nanophotonics*, 2016, [2] "Combined Electrostatic and Air Driven Electrospinner for Biomedical Applications," L.G. Huston, et al., Journal *of Vacuum Science and Technology B*, 2019. [3] "Air Driven Electrospinning of CNT Doped Conductive Polymer Fibers for Electronics," E.A. Kooistra-Manning, et al., *MRS Advances*, 2020, [4] US. Patent Ap. No. PCT/US202035478 EU Ap. No. 20812979.1.

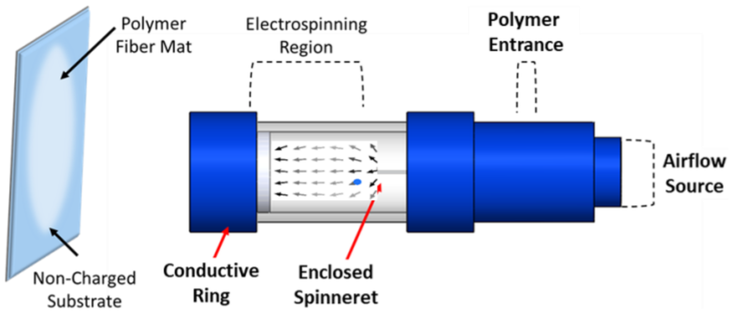

Fig. 1. Portable ES device developed by MTNL. The hand-held electrospinner encloses the electric field and incorporates airflow to enable deposition onto any surface regardless of charge or shape.

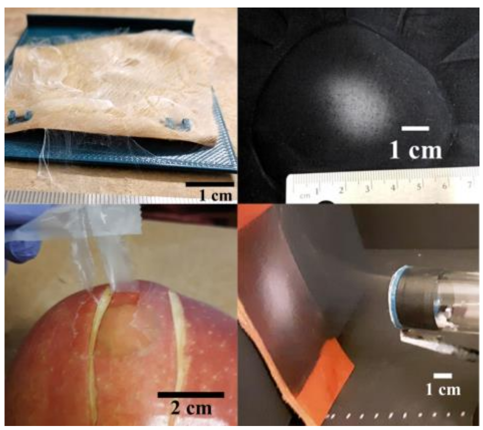

Fig. 2. ***A*** *Electrospun fibers deposited by the MTNL portable ES device onto fetal porcine skin* ***(A)****, on fabric* ***(B)****, onto an apple* ***(C)****, and on dampened rawhide* ***(D)****.*

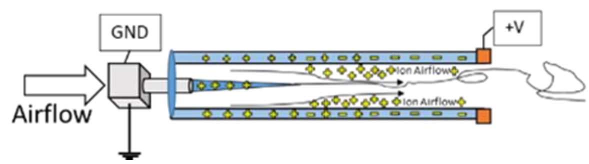

Fig. 4. Graphic showing ionized airflow in the portable ES system. Ionized airflow prevents charge buildup on the barrel, thereby minimizing lateral perturbances of the electrospun fibers and improving directed deposition.

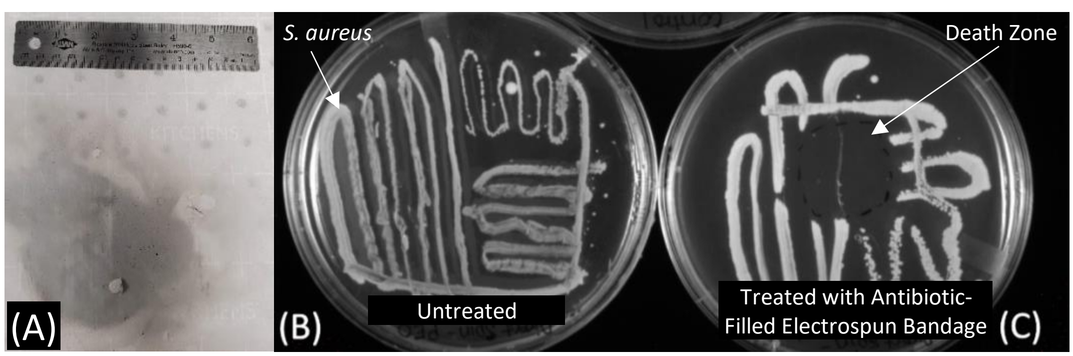

Fig. 3. The portable electrospinner has been used to demonstrate deposition of conductive fiber mats ***(A)****, and antibacterial bandages that successfully killed Staphylococcus aureus* ***(B-C)****.*