Combined Electrostatic and Air Driven Electrospinning for Biomedical Applications

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Electrospinning (ES) is a facile process for producing polymer fibers with high surface-area-to-volume ratios. Traditional ES fabrication involves an electrostatic force that pulls polymer from a grounded spinneret tip to a charged metallic deposition surface held at a high voltage. Typically, ES devices can be used to deposit fibers directly onto a multitude of surfaces by placing an external electrode on or behind the substrate. An existing portable ES device has been shown to produce results similar to benchtop ES machines and was capable of ES directly onto human skin that was grounded with an external electrode.[1] The present study was directed at reducing external electrode dependency and improving efficiency and transportability of ES, which can be beneficial for numerous biomedical applications such as producing anti-microbial bandages or forming layers directly onto skin to promote wound protection and drug delivery.

In this work, a low-power, portable ES device that incorporated directed airflow was assembled for rapid deposition of polymer fiber materials onto surfaces regardless of material electric charge (**Figure 1**). The device provided a 40X reduction in volume compared to a traditional table-top unit and was easily assembled and disassembled for repeated transport and use. Both high-voltage and grounded electrodes were encased within the system and provided the electrostatic force necessary to pull polymer from the spinneret tip before viscous forces from directed airflow routed the fibers towards the intended substrate, regardless of substrate charge. This effectively allowed for deposition of fibers onto surfaces that have been inherently problematic for traditional ES configurations.

Poly(ethylene oxide) (PEO) was selected for the ES solution as it is an established biocompatible and biodegradable polymer.[2] The portable electrospinner presented has demonstrated deposition of fiber mats onto both conductive and non-conductive substrates. **Figure 2** shows direct deposition onto porcine skin to demonstrate feasibility of use on humans. Finite element analysis and computational fluid dynamics simulation is also being used to guide development and optimization of the portable electrospinner (**Figure 3**). Future studies will evaluate effectiveness of antibiotic releasing fibers generated by the portable electrospinner on *Staphylococcus aureus*, a bacterium known to cause severe skin infections. On-demand deposition of an antibacterial polymer layer directly onto such an infection could prevent further spread and life-threatening side-effects.

[1] **Mouthuy P-A, Groszkowski L, Ye H.** Performances of a portable electrospinning apparatus. *Biotechnology Letters* 37: 1107–1116, 2015.
[2] **Chen G, Guo J, Nie J, and Ma G.** Preparation, characterization, and application of PEO/HA core shell nanofibers based on electric field induced phase separation during electrospinning. *Polymer* 83: 12-19, 2016.

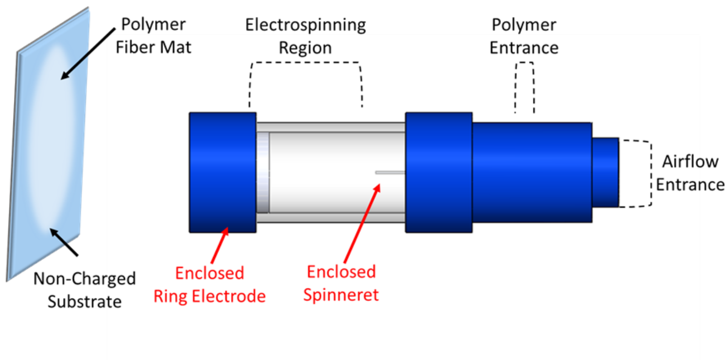

Figure 1. SolidWorks rendering of the portable ES tool. Electrospun fibers are directed from the spinneret tip toward the ring electrode by electrostatic force. Viscous forces from air flow further direct the fibers onto the substrate.

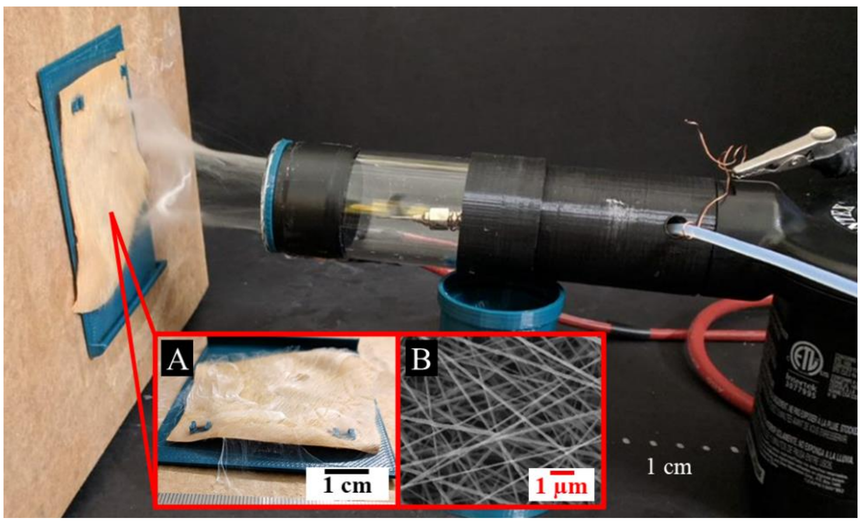

Figure 2. Image showing the portable ES device depositing fibers onto porcine skin. **A** Closer image of porcine skin coated in electrospun fibers. **B** Scanning electron micrograph of fiber mat deposited using the portable electrospinning device. Fibers had a smooth surface with an average diameter of ~250 nm.

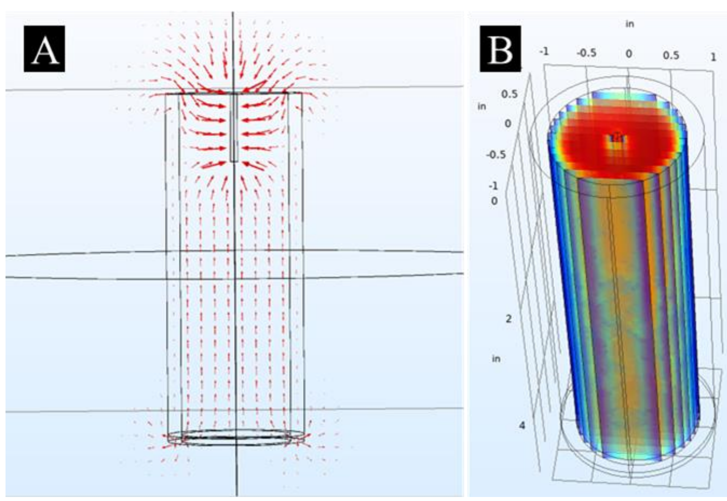

Figure 3. A Finite element analysis (FEA) results of the electrostatic field strength within the portable ES device is shown with a vector field plot resulting from an applied voltage of 15 kV. **B** Computational fluid dynamics results of air flow through the portable ES device are shown as velocity magnitude in m/s.