

Electrostatic Charge Elimination in Ionized Air-driven Electrospinning

H.W. Pearson-Nadal, C.T. Baumstarck, I.J. Gilfeather, J.M. Andriolo and J.L. Skinner

Montana Tech Nanotechnology Laboratory, Montana Technological University, Butte, MT 59701
Dept. of Mechanical Engineering, Montana Technological University, Butte, MT 59701
hpearsonnadal@mtech.edu

Traditional electrospinning (ES) is used to produce nanometer to micrometer sized fibers by introducing a liquid polymer to an electric field between a spinneret and collector. Upon experiencing the electric field, the polymer undergoes electrostatic surface forces, causing elongation of the beaded droplet toward the collection surface. During flight, solvent used during the polymer preparation process evaporates, thereby resulting in a dry, fibrous polymer mat being deposited on a conductive collection surface. In past work, the MTNL developed a hand-held ES device with an entirely encased electric field that incorporated air flow and enabled deposition on any surface, regardless of charge.¹ The electrostatic air-driven (EStAD) ES device is particularly attractive for on-demand use in the field for medical applications. In previous work, we have demonstrated deposition of antibiotic treatment bandages on *Staphylococcus aureus*, direct deposition onto epithelial tissues (skin), and even coating on rounded surfaces.²

While promising, broad utilization of the EStAD in the medical field will be dependent on reliability and repeatability of materials deposited by the device to ensure effective dosages and treatment. It is critical that we address concerns related to treatment delivery in a variety of environmental conditions. Humidity is a common concern when ES. In the case of the EStAD, unpredictable humidity conditions alter charges along the device barrel, resulting in polymer losses along the barrel and incalculable fiber morphologies that impact the therapeutic dosing and efficacy. In this work, we hypothesized that the relationship between humidity and air conductivity could be impacting charge distribution along the EStAD barrel. At lower humidities, air conductivity is decreased and results in an uneven distribution of charges. In addition, humidity alters polymer chemistry at the spinneret tip and may induce undesirable effects during flight such as branching which may result in unpredictable material properties. In this work, we employed active charge neutralization by incorporating ionized particles in the airflow stream used to direct fiber deposition beyond the end of the device. By flooding the barrel with charge, neutralization was observed at the barrel surfaces by a high-accuracy electrostatic sensor (**Fig 1**). Electron microscopy and image analysis (**Fig 2**) was used to show improved reliability of electrospun fiber mats across a range of humidities (40- 80%, **Fig 3**), thereby demonstrating the correlation between charge neutralization and fiber deposition behavior. The modification will provide enhanced reliability and encourages safe use in medical settings.

¹ (U.S. patent app. no. PCT/US202035478)

² Huston et al., Journal of Vacuum Science and Technology B, 2019

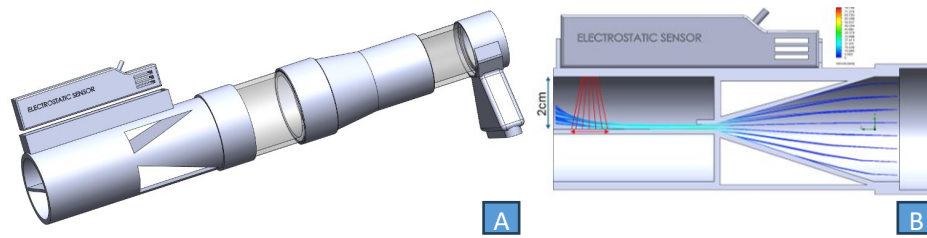


Fig 1. (A) CAD model of EStAD device equipped for ionized airflow and monitoring of surface charge along the barrel. Surface charge will be monitored by Keyence SK-050. **(B)** Electrostatic sensor detection range shown when placed in the ES apparatus with airflow at 4 m/s inflow.

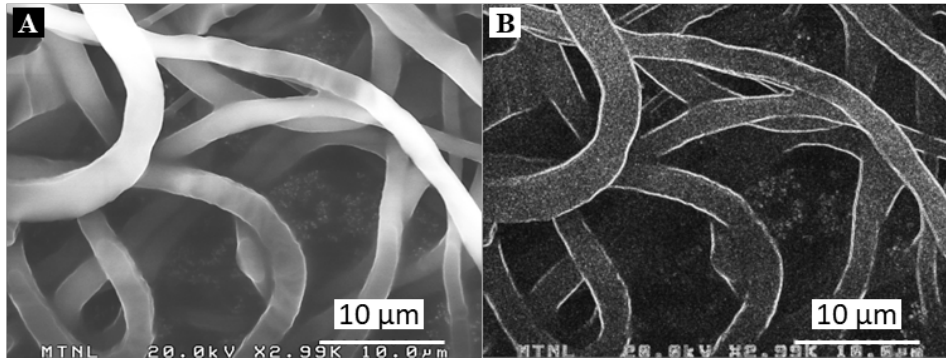


Fig 2. (A) SEM micrograph showing electrospun fibers collected during EStAD ES with ionization studies under humidity. **(B)** ImageJ image analysis software was used to contrast and quantify average fiber diameters per humidity condition.

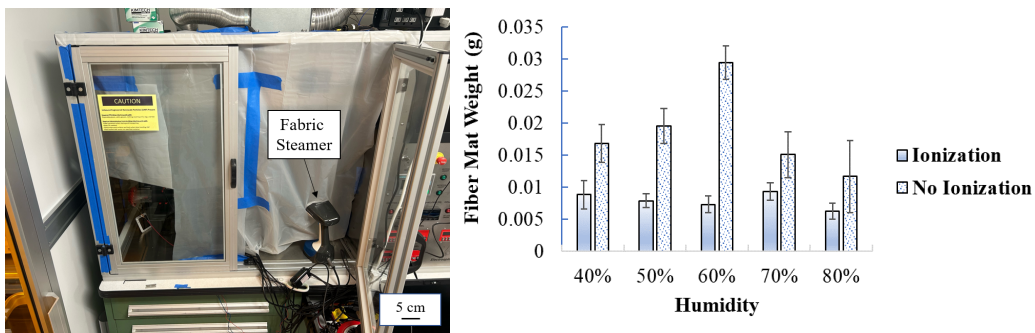


Fig 3. (A) Photograph of humidity chamber used to encase the EStAD device equipped with ionized air flow during humidity studies. **(B)** Results show statistically significant reliability in fiber mat weight when ionization is employed across humidities ranging from 40-80 %.