# Demonstrating Effective Use of A Base Plate Electrode for Electrospinning of Polyvinylpyrrolidone Nanofibers

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## ABSTRACT

Electrospinning is an incredibly useful and simple fiber manufacturing process. The purpose of my investigation is using the novel techniques of reversing the voltage biasing and introducing a base plate electrode to enhance the accuracy and areal density of the deposition of fiber mats.
Using a solution of polyvinylpyrrolidone (PVP) and ethanol, trials were run with and without the base plate electrode. Then their areal densities were compared. With these changes to the standard process, other variables can be tested with more control over the deposition. In the future other researchers can use this innovative method to more easily study effective electrospinning in the pursuit of highly desired up-scaled production.

## INTRODUCTION

Electrospinning is the process of extracting small diameter fibers from a flowing solution by way of electrostatic acceleration.

**Extremely applicable technique:**

- ❖ Exceptionally fine filters
- ❖ Catalyst manufacturing
- ❖ Nano 3D printing
- ❖ Building substrates for medical tissue transplants

**Ways for improved process:**

- ❖ Understanding each variable involved
- ❖ Modeling interdependencies of the variables
- ❖ Increased control of deposition and production

## GOALS

- ❖ Repeat reliable trials using parameters established in previous research
- ❖ Develop a quantifiable method to compare the effect of adding a base plate electrode to a standard no-base setup
- ❖ Establish groundwork for future experiments using this innovative setup

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## PHYSICS OF ELECTROSPINNING

- ❖ Large potential creates electric field
- ❖ Induces attractive force on charged particles in polymer
- ❖ Equilibrium of electrostatic attraction and surface tension
- ❖ Stable ohmic zone and larger turbulent zone

## METHOD

10mL of an 8% PVP solution was prepared and stirred for 2 hours
10 Trials were run, with both a base plate and no-base plate setups, at the following parameters:

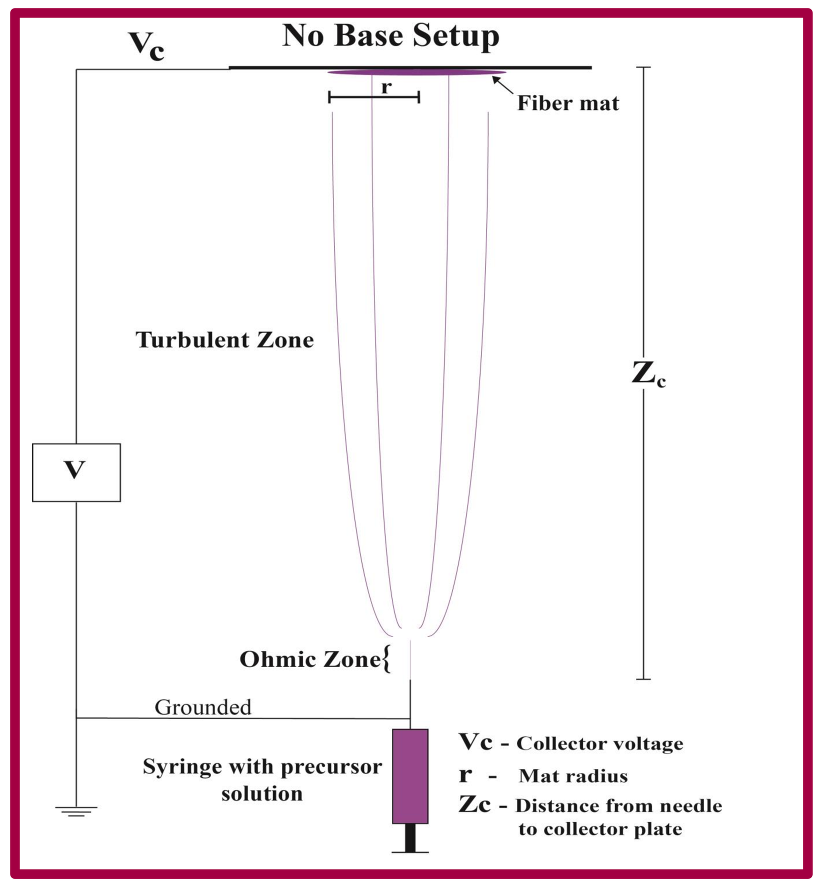
- ❖ Flow rate, Rf, of 1 mL/h
- ❖ Needle distance, Zc, 15.24 cm
- ❖ Collector Voltage, Vc, 20 kV

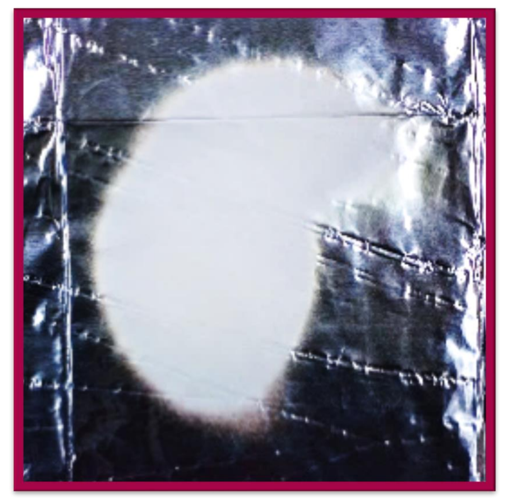
Then measurements were taken of:

- ❖ Yield mass, Y [g]
- ❖ Mat radius, r [cm]
- ❖ And other notes about the trial as well

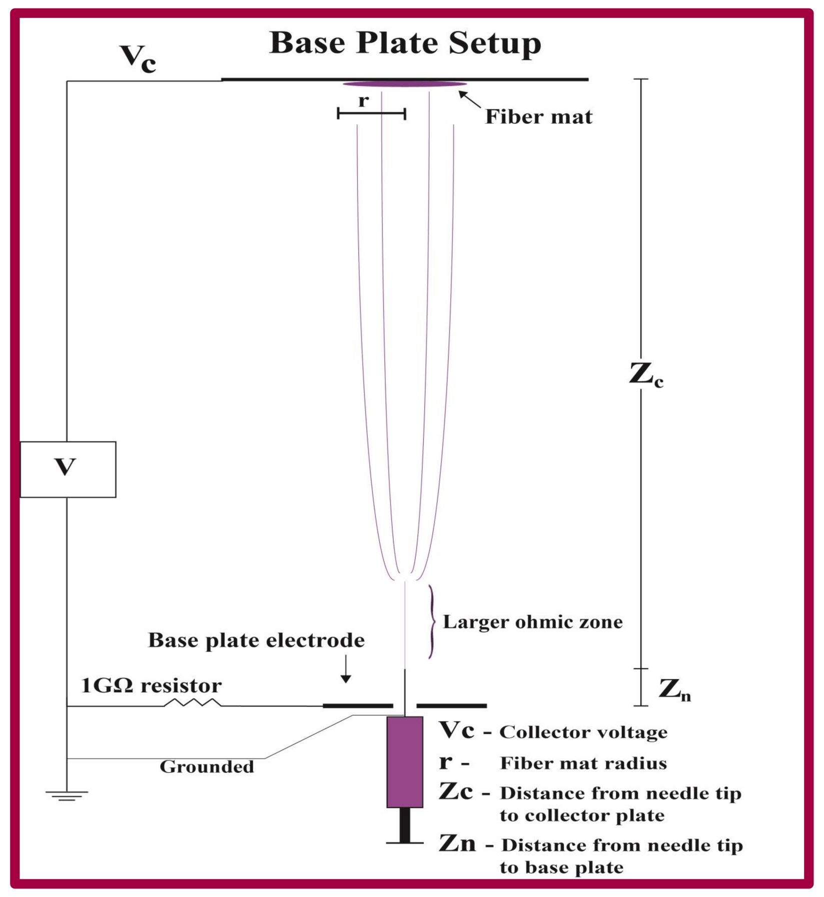
The areal density was calculated according to the equation:

$$\text{Areal Density} = \frac{Y}{\pi r^2}, \quad [\text{g/cm}^2]$$

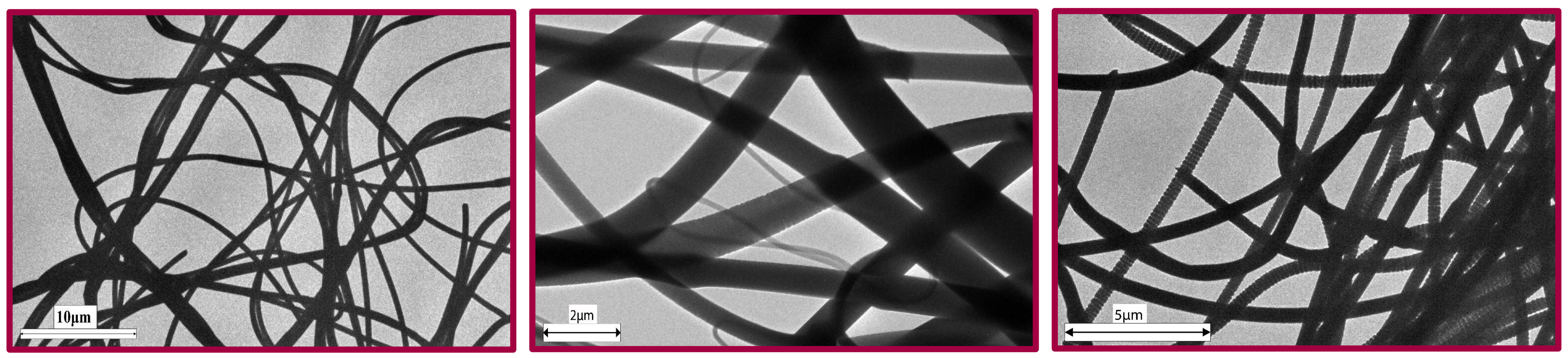


**No base r≈5.2cm**
This deposition mat had poor uniformity without a base plate. The edges displayed larger fringing as well.




**Base plate trial r≈4.0cm**
This deposition with the base plate addition shows impressive uniformity. The radius grew with time, which merits further study.




TEM images of fibers. Consistent fibers with minimal disturbances (left). Drastically different fiber diameters (middle) "crinkle fry" fibers (right)

## FIBER CHARACTERIZATION

The figures above are TEM images of fibers. The images indicated that there were inconsistent fiber diameters and structures. The first image shows a section of ideal fibers with similar diameter and consistency. The middle is an example of varying diameters, sometimes even on the same fiber. And the right image displays fibers with a "crinkle fry" structure. Further analysis is required to determine if these factors significantly affect the performance of the electrospun fibers. If so, experiments, as noted in the future work section, can be performed to minimize these defects.

## RESULTS

**Areal Density of Fiber Mats**

- ❖ The addition of a base plate electrode gave an average increase of 11x the areal density of deposition on the collector plate as compared to the no-base plate setup

**Focus of Deposition**

- ❖ The deposition was controlled in terms of shape, diameter, and placement on collector plate with the addition of the base plate.
- ❖ Confounding variables such as angle of needle and external E-fields are reduced

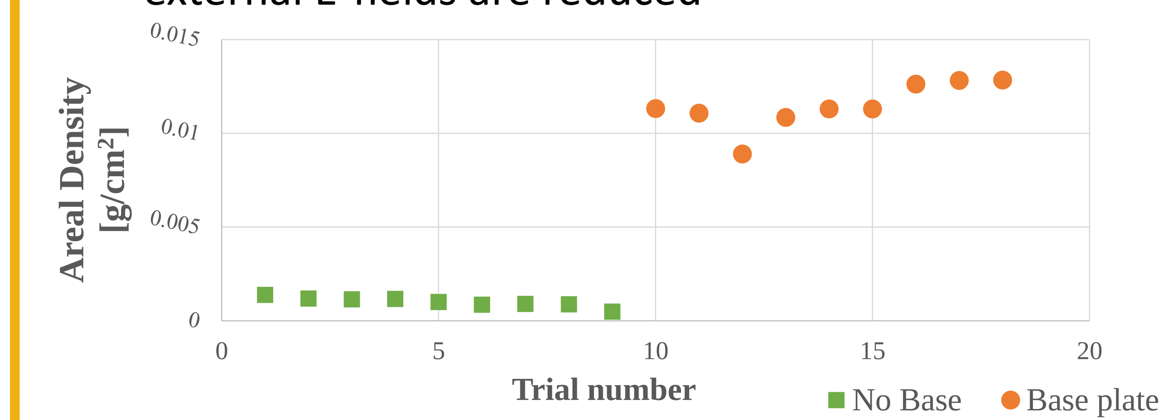



**Chart showing the difference in the areal densities of trials with and without the base plate**

## CONCLUSION

Besides the effective use of the base plate electrode, many important considerations regarding the electrospinning process were discovered. These included:

**Flushing of needles**

- ❖ Needles needed to be flushed with ethanol in-between each trial to prevent buildup of the polymer.

**Appropriate flow rate**

- ❖ Flow rates are not specific to other parameters, but there is a lower and upper limit that should be determined experimentally.

**Type of needle**

- ❖ A circular opening needle provided a better jet than a typical angled syringe needle.

## FUTURE WORK

**Mathematical models:**

- ❖ Deposition diameter ($\Theta_m$) as it relates to the collector potential ($V_c$)
- ❖ Deposition diameter ($\Theta_m$) as it relates to the needle distance ($Z_n$)
- ❖ Fiber diameter ($\Theta_f$) as it relates to collector Voltage ($V_c$)

**Optimization of parameters for similar goals:**

- ❖ Higher quality fibers as determined by statistically consistent fiber diameter
- ❖ Smallest or possibly specifically desired diameter range

**Working with other materials or additives**

- ❖ SPACT joint security fiber printing collaboration