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Design and Collection Efficiency of a New Electrostatic Capillary Collector for Fine and Ultrafine Particulate Matter

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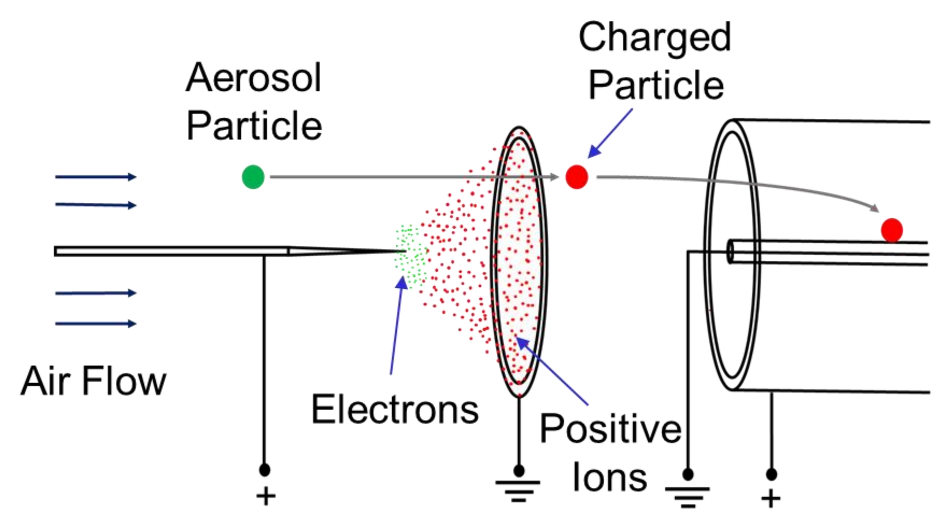
ABSTRACT

- Collection of ultrafine particulate matter having aerodynamic diameter less than 2.5μm (PM2.5) is used for sensing potentially harmful chemical and biological aerosols
- We introduce a novel Electrostatic Capillary Collector (ECC) that collects aerosol particles in size range from ultrafine to PM2.5 directly onto an analysis substrate
- Electric Potential applied between ring and concentric needle ionizes molecules to create positive ions
- Particles collide with positive ions and get positively charged as they enter the device
- Charged particles change their path due to electric field and collect on a capillary surface



INTRODUCTION

The ECC collects ambient air particles on a capillary substrate which can be used for in-situ analysis

MOTIVATION

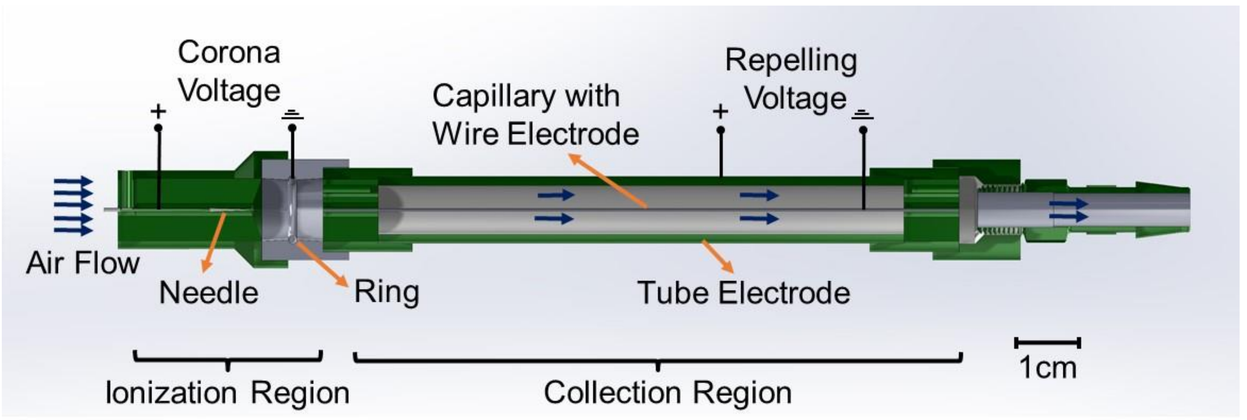
- Long exposure to fine and ultrafine particulate matter (particles < 2.5μm diameter) due to air pollution is associated with respiratory and cardiovascular diseases.
- The composition of fine and ultrafine particles in air changes with pollution sources and environmental conditions in a short time
- Sampling of these particles to understand their sources and their analysis in-situ is essential for regulatory control strategies

PROJECT OBJECTIVES

- To design and prototype a sampling device for fine and ultrafine particles to be integrated to an analysis system.
- To optimize device operating parameters to achieve maximum collection of particles on analysis substrate
- To test the device for collection efficiency

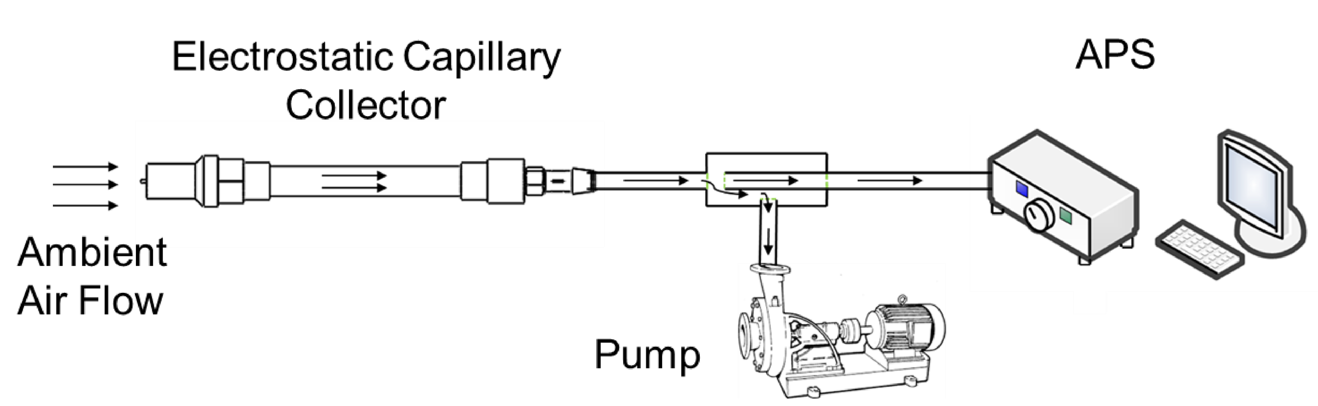
EXPERIMENTAL SETUP

DEVICE DESIGN



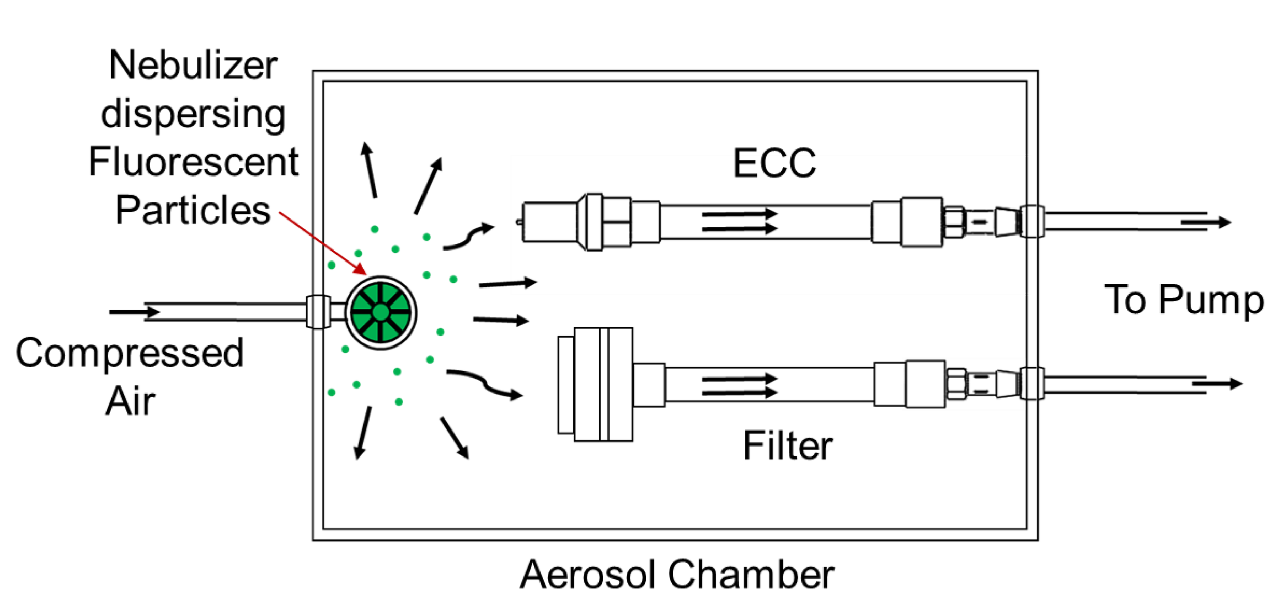
- Corona voltage generates positive ions to charge particles as they enter ionization region
- Electric field due to repelling voltage in collection region repels charged particles onto a fused silica capillary (OD 350μm ID 250μm)
- Device is attached to a pump to generate flow

OPTIMIZING OPERATIONAL CONDITIONS



- Air particles are sampled at varying corona and repelling voltages using Aerodynamic Particle Sizer(APS)
- The flow rate is varied from 2lpm to 4lpm and voltages applied are varied to achieve maximum collection

TESTING COLLECTION EFFICIENCY



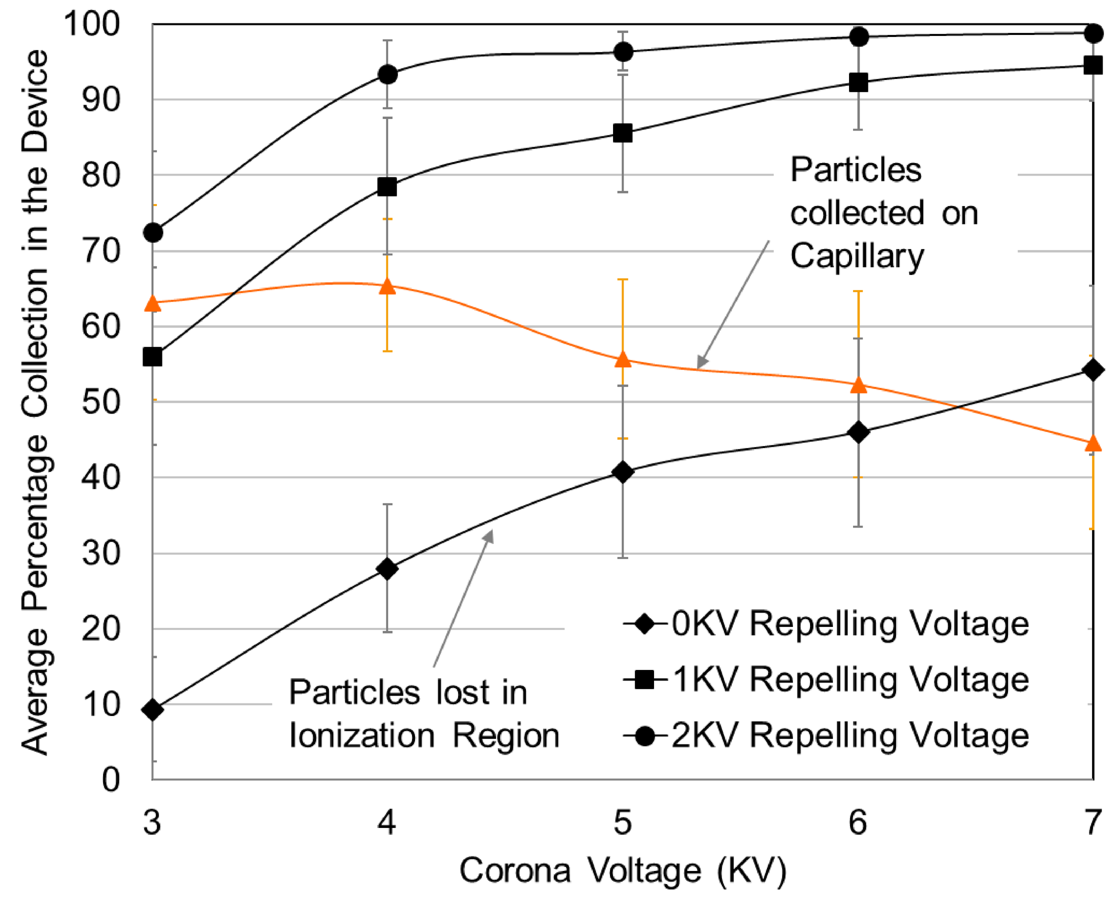
Monodispersed fluorescent polystyrene spheres are collected in ECC at optimized conditions and on a filter

$$CE = \frac{I(Capillary)}{I(Filter)}$$

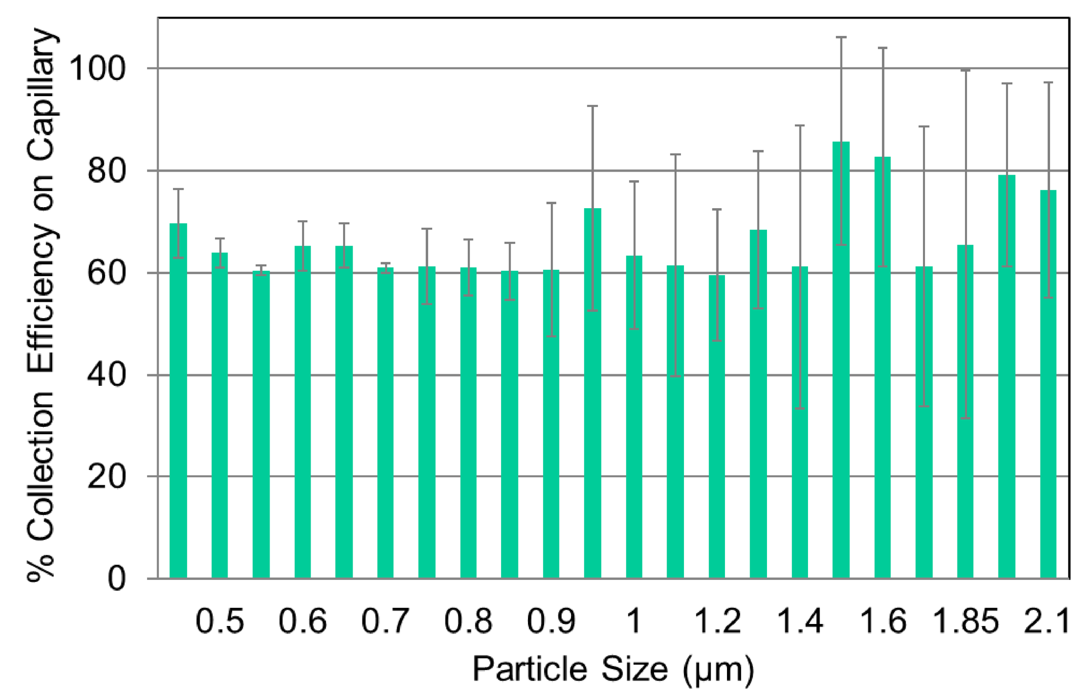
CE: Collection Efficiency

I(x): Bulk Fluorescence Intensity of particles collected on x

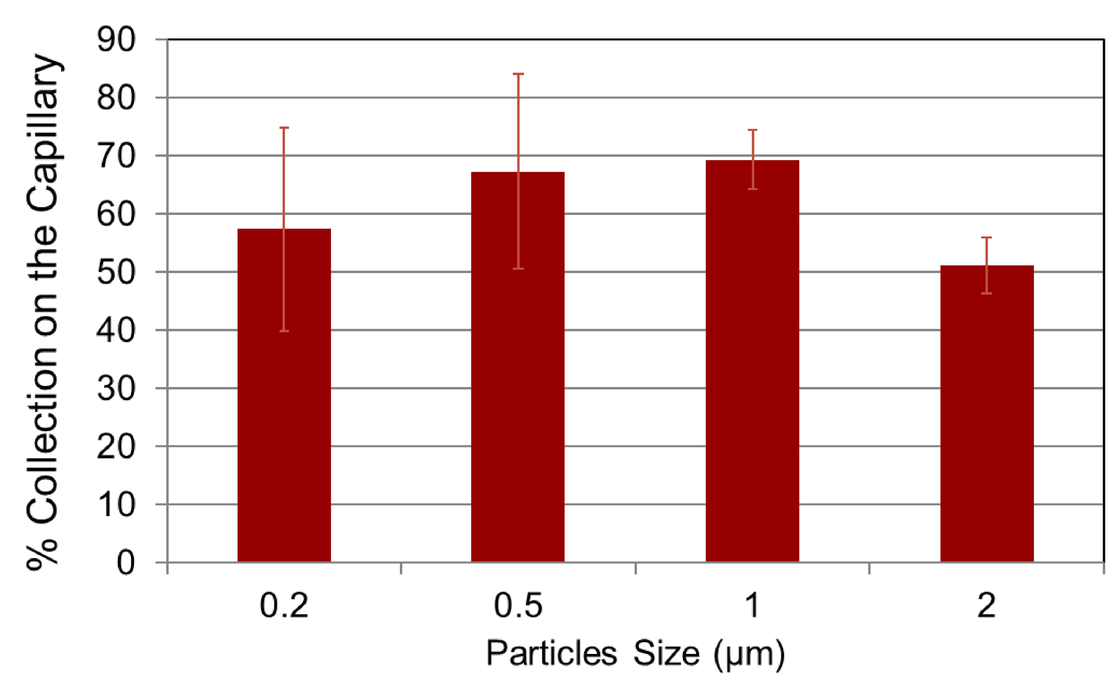
RESULTS AND ANALYSIS



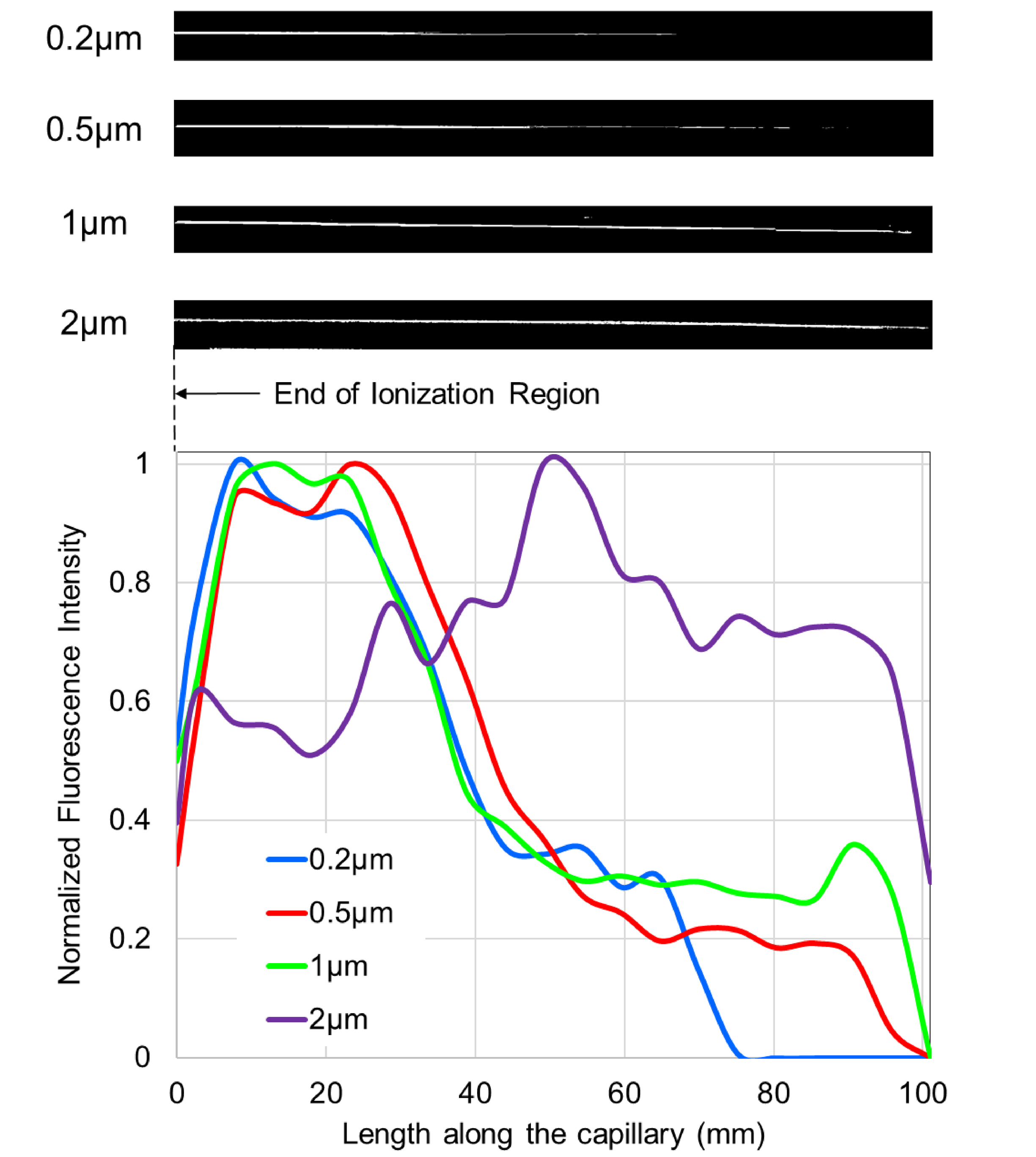
Optimizing Corona Voltage and Repelling Voltage: Maximum collection on capillary is found at 4KV Corona Voltage, 2KV Repelling Voltage at a flow rate of 3lpm



Collection for particle size range less than 2.5μm is calculated from APS measurements



Calculated collection on capillary is verified by measuring collection of fluorescent particles



Distribution of Fine/Ultrafine Particles Along the Capillary Length

- Epifluorescence Microscopy is used to image particles based on their fluorescence intensity
- Smaller sized particles collect near the ionization region
- As size of the particles increases, particles travel longer distances along the length of the device in collection region
- As the particle point of entry at the inlet is unknown, particle sizing based on their electrical mobility is difficult

CONCLUSIONS

- At the optimized operating conditions of the ECC, more than 50% of fine and ultrafine particles are collected on the capillary substrate having total surface area of 100mm^2
- Collected particles on the small capillary surface can be used for spectroscopic analysis in situ

FUTURE WORK

- Integrate in-situ analysis technique with ECC for source identification of sample.

ACKNOWLEDGMENTS

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