Electrostatic Enhanced Compact Aerosol Concentrator Development

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Electrostatic Collection Technology

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- Technical Point of contact Dr. J. Bottiger, Dr. E Steubing
Electrostatic Collection Technology

...versatile technology capable of interfacing to many detection modalities...

Charging
- Corona-charging
- Optimum Charge Saturation

Sample Deposition
- Electrostatic Focusing & Deposition

Liquid
- Self-cleaning Hydrophobic Membrane
- Wetted Column

Surface
- Electrostatic Sorting for Particle Enrichment
- Gentle Low Velocity Deposition on Tape

Assay or Antibody Detection System requiring small volume samples (< ml)

Spectrographic Detection System
Electrostatic Enhanced Compact Aerosol Concentrator Development

...Roadmap...

FY 03
- Experimental Electrostatic Capture Module

Hydrophobic Membrane

FY 04
- Inline Aerosol Concentrator
- Wetted Column Electrostatic Capture Module

FY 05
- Compact Electrostatic Aerosol Concentrator Prototype
Electrostatic Enhanced Compact Aerosol Concentrator Development

...Description of Current Effort...

- Moderately concentrated aerosol drawn through experimental capture duct
  - simulates the output of a cyclone concentrator
  - monodispersed aerosol consisting of fluorescent beads
  - sheath air employed to confine aerosol stream

- Electrostatically charged by corona array

- Particles electrostatically focused directly into small liquid volume
  - beads deposited on solid surface in initial experiments

- Component configuration modified to optimize collection efficiency

- Performance determined by fluorescent imaging techniques
Electrostatic Enhanced Compact Aerosol Concentrator Development

...experimental set-up for optimizing electrostatic capture configuration...

Orthogonal Collection Approach

[Diagram of the orthogonal collection approach with labeled parts: Inlet Probe, Sheath Air, Aerosol, Corona Array, Outlet Probe, Outlet]
Electrostatic Focusing of Particles Into a Liquid Using Corona Charging & Transport

Operation Schematic for Orthogonal Collection Approach

- Aerosol Flow
- Duct
- Corona Tip Array
- Corona
- Defection Electrode
- Particles Being Deflected Into Collection Liquid

- Sheath Air
- Current Control Circuit
- Corona Ground
- Collection Liquid
- Hydrophobic Mesh
- Focus Electrode

Particles Being Deflected Into Collection Liquid
Electrostatic Enhanced Compact Aerosol Concentrator Development

...experimental set-up for optimizing electrostatic capture configuration...
Compact Electrostatic Aerosol Concentrator

...compact, low power, high flow rate...

- Direct aerosol concentration without energy consumptive inertial separation process upstream
  - Pressure drop orders of magnitude lower than inertial separation collector
  - 7 unit array samples 210 LPM with 1 watt fan

- Particles charged by radial array of corona tips

- Particles deposited onto small liquid wetted column located on the axis of the aerosol duct

Fan 4.5 in. Dia.

Electrostatic Capture Module x7
Electrostatic Focusing of Particles Onto Liquid Wetted Column Concept

Corona Tip Array

Aerosol Flow

Aerosol Duct 0.75 in. dia.

Conical Corona

Particles Being Deflected Into Collection Liquid

Collection Liquid In

Collection Liquid Out

Liquid Wetted Column
Electrostatic Focusing of Particles Onto Column Experiments

Test Setup

- 2.5 mm diameter nozzle
- Corona Array
- 1.5 mm dia. dry column
- ITO coated glass focus electrode
Electrostatic deposition of smoke onto a 1.5 mm diameter dry column @ 1 liter per minute aerosol flow rate through 2.5 mm diameter nozzle

- Excess deposition beyond column occurs when deposited particles form an insulating layer preventing newly arriving particles from discharging to the column ground.
- The particles then repel each other causing them to be deposited on the surrounding surface.
- This will not occur in the actual implementation of the technology where the aerosol density is orders of magnitude lower than that of the smoke used to visualize the aerodynamic characteristics of the collector.
Electrostatic Focusing of Particles Onto Column Experiments – AEROSOL DATA

Electrostatic deposition of 2.3 μm beads onto a 2 mm diameter dry column with 3 mm diameter nozzle @ 1 liter per minute aerosol flow rate

> 99% of 2.3 μm Particles Removed From Aerosol by Electrostatic Collection
Electrostatic deposition of room air onto a 2 mm diameter dry column with 3 mm diameter nozzle @ 1 liter per minute aerosol flow rate

> 90% of 0.5 m Particles removed from Aerosol by Electrostatic collection
Electrostatic deposition of 2.3 µ fluorescent beads onto a 2 mm diameter dry column with 3 mm diameter nozzle @ 1 liter per minute aerosol flow rate

Top of Column
Deposition predominantly on column collection surfaces
Small amount on the focusing electrode surface

Side of Column

Focus Electrode
Half this density of particles observed on focusing electrode surface with the electrostatics turned off.
Corona Charging Technology

...developed on independent program involving electrostatic deposition of pharmaceuticals ...

- Corona charging advancements
  - Developed new corona charging technique superior to currently available technology
  - High efficiency (demonstrated >99%) uni-polar charging
  - Current controlled corona eliminates ion density variation due to tip erosion
  - Array of Corona tips generates uniform corona

- Corona wind management
  - “wind” blows particles toward collection port
  - controlled by tip array

- Charging
  - Corona-charging
  - Optimum Charge Saturation
Advantages of corona charging

- Predictable particle charging
- Charging obeys Pauthenier equation
- Field charger
- Uses maximum E-Field for capture
- Designed for theoretical efficiency for respirable particle size

Corona Tip Array
Self Cleaning Liquid-Air Interface

...withstand differential pressure with efficient particle transport...

- Teflon treated nylon mesh retains liquid in collection channel
  - Debris tolerant
  - 40% open area
  - Low cost - standard Teflon fabric treatment
  - thermal imbedment assembly

- Self Cleaning
  - over pressurize channel to purge liquid past mesh to rinse contaminants off surface
  - liquid seal re-established when pressure is reduced

Results in clog-free, low-maintenance continuous operation
Electrostatic Surface Deposition

...Benefits...

- Superior to impaction methods
  - Better control of deposition parameters
    - Smaller size sample
    - Potential to deposit mono layer
  - Less likely to damage pathogen
    - Gentle Low Velocity Deposition
  - Lower pressure drop
    - Lower power
    - Quieter aerosol collection fan

- Tape transport from collector to detector
  - Rapid, automated, precise location
  - Tape configuration:
    - Disposable - reel to reel
    - Reusable - loop
    - Materials - polymer, ceramic, metal
Electrostatic Sorting

...sample enrichment by electrostatic deflection of selected particles...

- **Description of operation**
  - Stream of particles electrostatically charged by corona created at the exit of nozzle
  - Particles interrogated by UV laser
  - resulting laser induced fluorescence used to determine particles of biological origin
  - Selected particles focused onto small diameter target
  - rejected particles deflected to annular surface surrounding target

- **Features**
  - High S/N ~ 50,000:1
  - High switching speeds > 10Khz
  - High efficiency (>99% @ 2um)
Electrostatic Sorting

...feasibility experiment...

Tube conveying particles
- 1-2 liter per minute airflow
- 1 mm dia nozzle
Corona formed at tip
Collection electrode
- 1mm diameter post
Rejection electrode
- Copper with 1mm gap
Solid State Switch

Experimental electrostatic sorting mechanism

Experimental result showing deposition of HP cyan toner (3um-9um) particles onto collection electrode

Experimental result showing deposition of HP cyan toner (3um-9um) particles onto rejection electrode
Electrostatic Sorting

...deposition onto tape concept ...
Benefits of Electrostatic Collection

- Affords plug and play detector integration for standardized air sampling module
  - Deposition into liquid for assay and antibody based detection
  - Solid surface deposition for spectrographic detection
  - Electrostatically focused aerosol stream for advanced particle sorting techniques

- Electrostatically focus particles into $\mu$l liquid volumes
  - Interfaces to advanced detection technologies
  - Clog free hydrophobic membrane
  - Capable of low temperature operation

- Electrostatic surface deposition superior to impaction methods
  - Better control of deposition parameters
  - Less likely to damage pathogen
  - Lower pressure drop reduces fan power & noise