Measuring Nanoparticles

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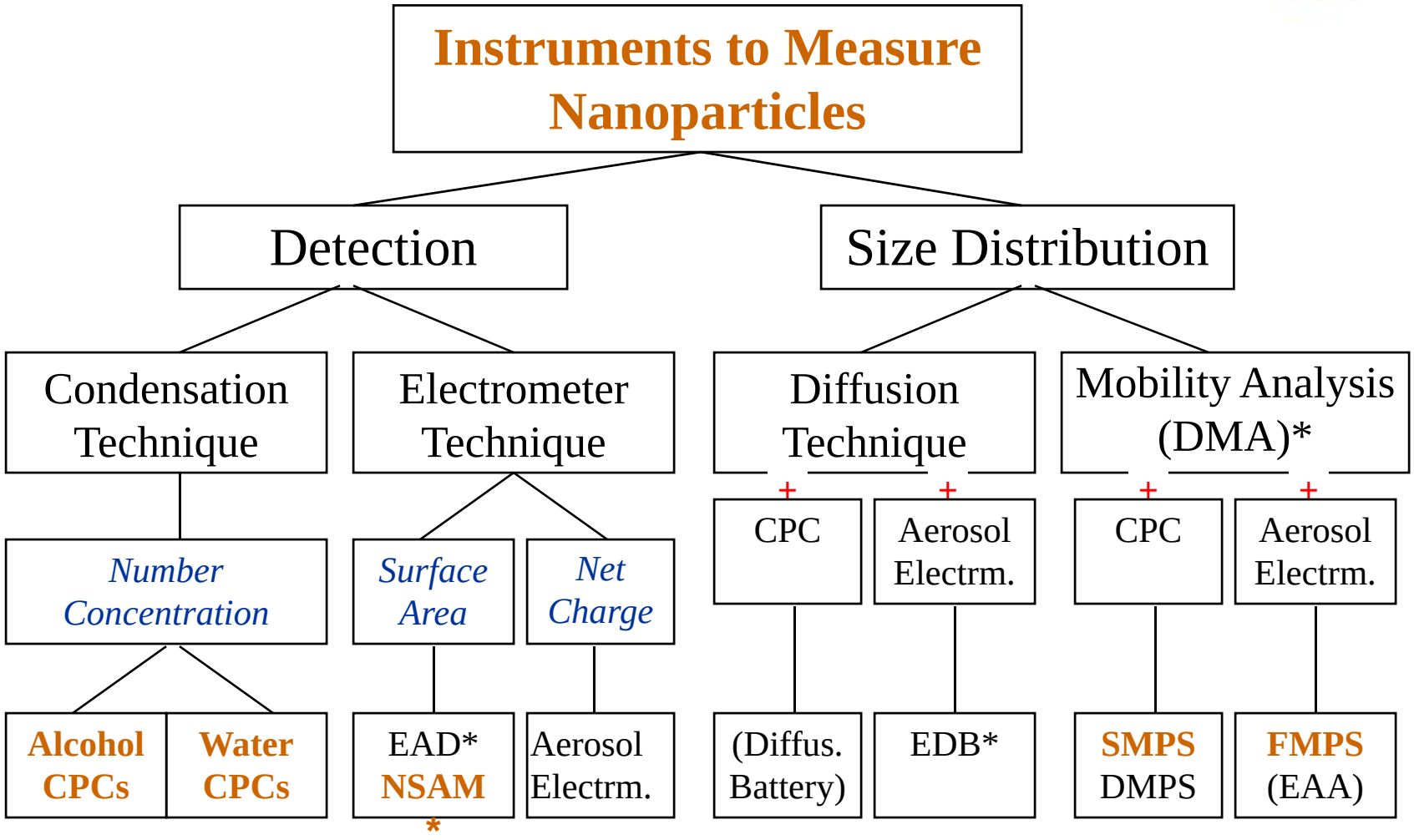
Outline

- Introduction
- Nanoparticle Characterization
- Aerosol Measurement Techniques
  - Brief outline
- Nanoparticle measurement
- Nanoparticle generation, transport
  - Agglomerates, Aggregates …
- Diagnosing Agglomerates
  - A new approach
- Moving Forward, “Scenario”

Overview Real-Time Instruments



** Plus charger!*

No claim for completeness!

Technologies for NanoParticle Characterization

Aerosol Detection -

"On-line" Measurements (not using "microscopes"), "Real time"

- Mobility of particles (charged)
  - Motion in an electric field- Select by size
    - *Differential Mobility Analyzer*
- Condensation technique
  - Counting (Optical)
    - Make particles "large enough" to count
    - *Condensation Particle Counter*
- Charge detection
  - Measures total charge
    - *Aerosol Electrometer*
- Optical
  - Counting – *Optical Particle counters* (> 300 nm)
  - Mass Concentration - *Laser photometer*
- Other
  - Single Particle Mass Spectrometry
  - Fluorescence

Systems to Characterize

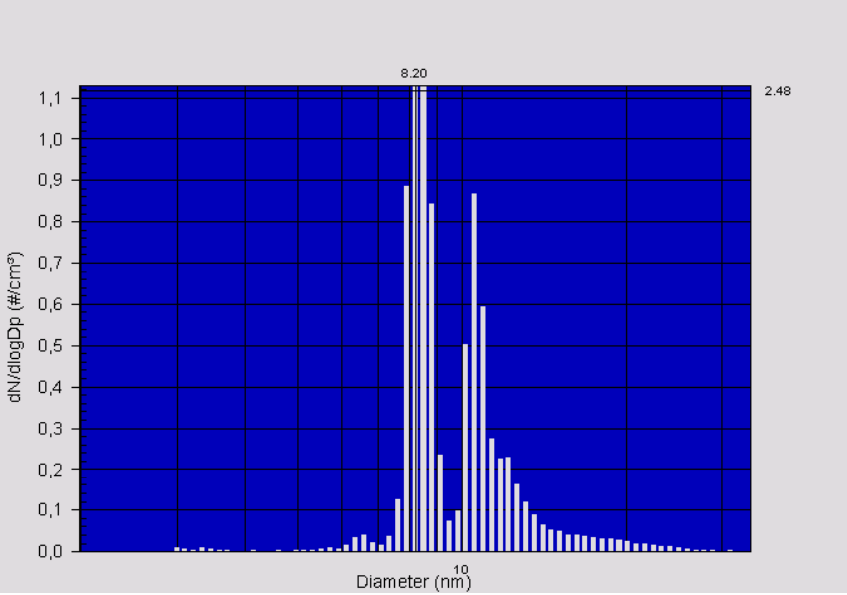
Measurement Techniques combined and optimized

- Particle Size Spectrometers
  - Provides size distribution
    - Fast Scanning used to study - More transient situations - e.g., Engine exhaust
- Total Charge measurement
  - Surface Area Monitoring
  - Simulate the Deposition in different regions
    - Provides lung "deposition" information (Bronchial, Alveolar)
- Classify particles
  - Provides particles in the desired size range
    - From a polydisperse to monodisperse distribution
- Overall
  - Size distribution, number counting, surface area, volume ..
  - Detailed measurements, portable systems, personal monitoring

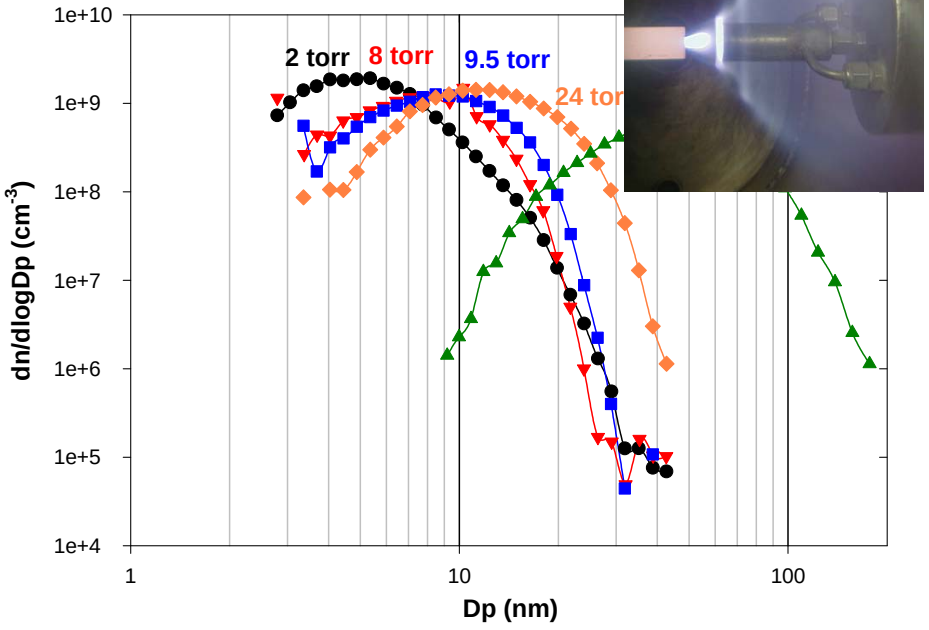
NanoParticle Size Spectrometers

Scanning Mobility Particle Sizer: High Size Resolution

Differential Mobility Analyzer & Condensation Particle counter



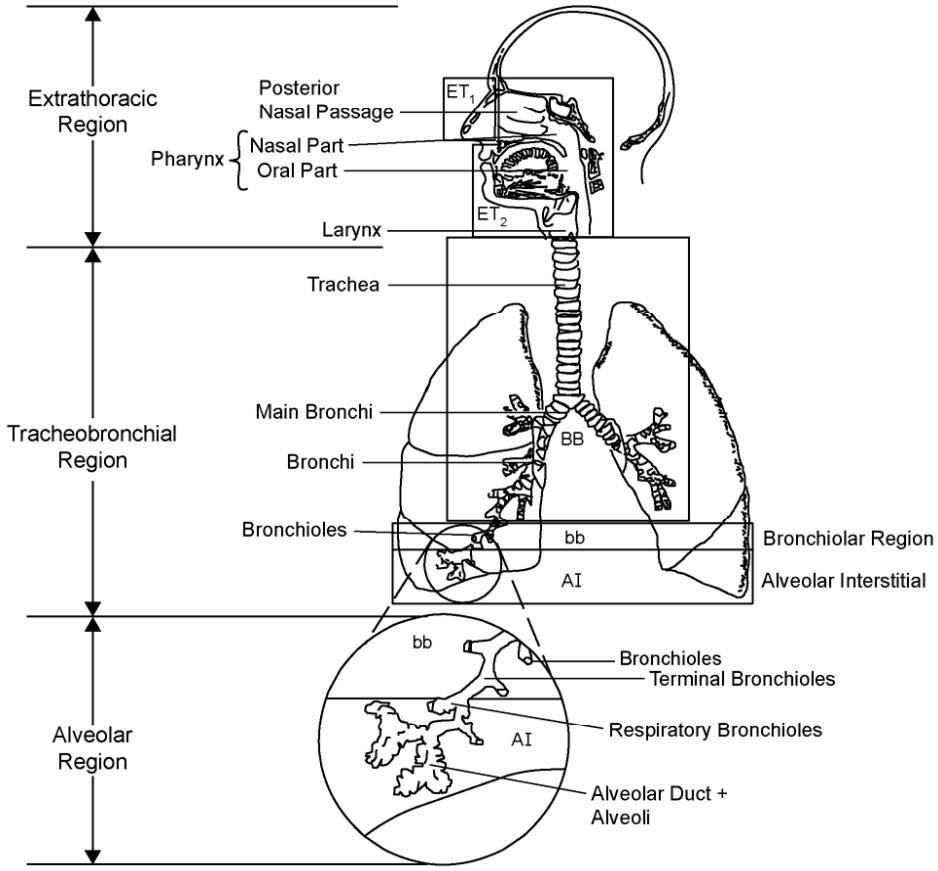
Kaufman, S: In-house data



Nanoparticle Synthesis

Respiratory Deposition

Diagrammatic representation of respiratory tract regions in humans

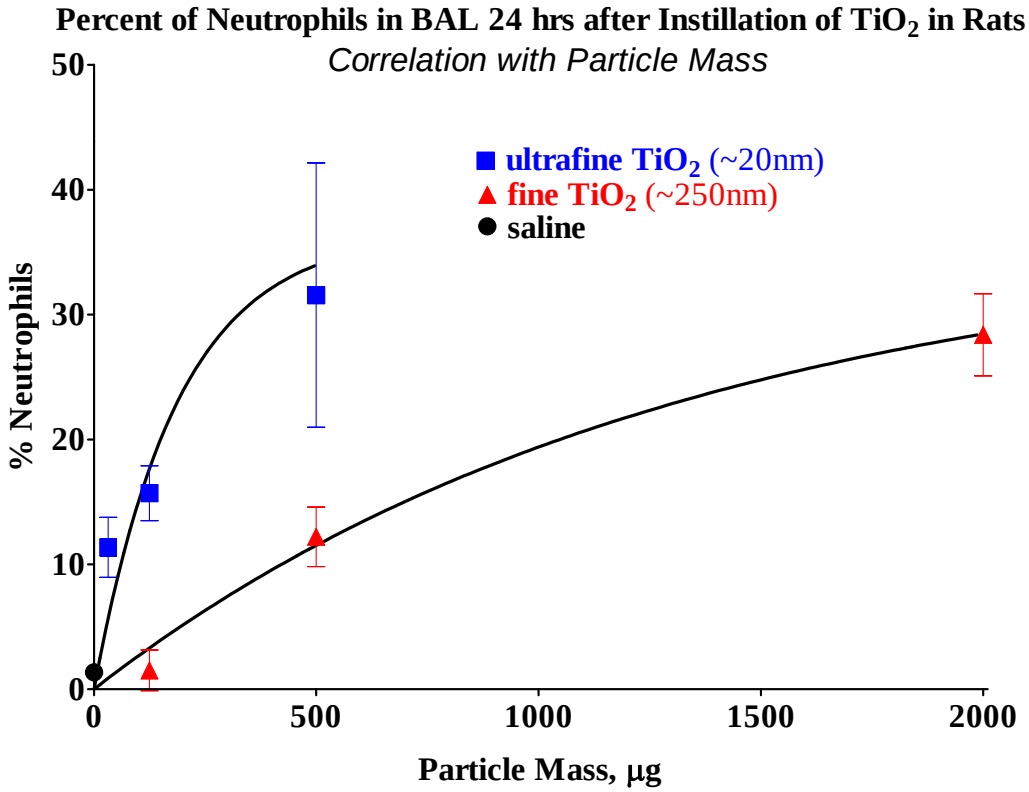


Based on International Commission of Radiological Protection (1994) and U.S. Environmental Protection Agency (1996a). Air Quality Criteria for Particulate matter, 2004, p 6-5.

Health Effects

NanoParticles – "All surface and no volume !"

Ultrafine and nanoparticles appear to be more toxic than the larger sized particles of same composition

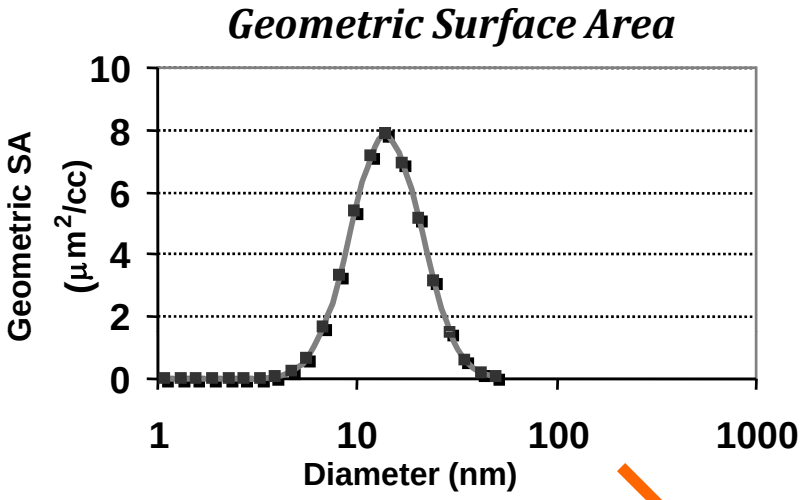


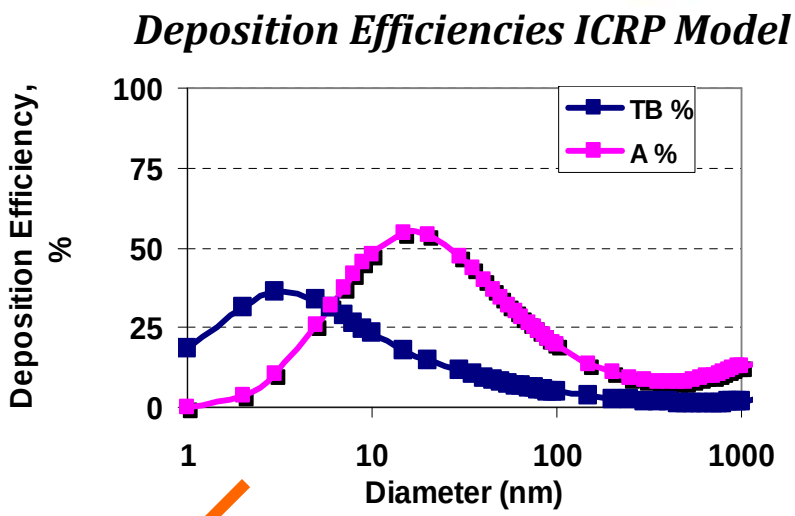
Oberdörster, 2001

Lung-Deposited Surface Area

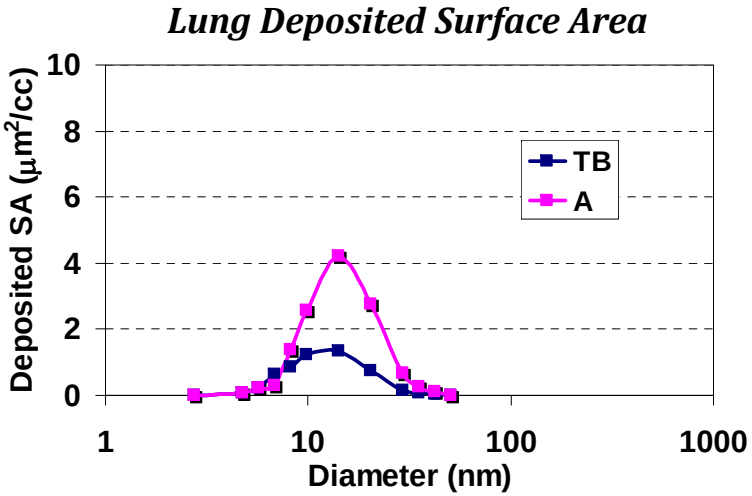
- Workplace Exposure
- Diffusion charger + Electrometer
  - *Nano Surface Area Monitoring System*
- Measures Lung-Deposited Surface Area ($\mu m^2/cm^3$)
  - Tracheobronchial (TB)
  - Alveolar (A)
- Provides a simple, fast solution for measuring surface area dose
  - Function of concentration and exposure period
- Measures workplace exposure to nanoparticles
  - Function of concentration, Toxicity and Time

Lung Deposited Surface Area





TB - Tracheobronchial
A - Alveolar



Workplace Monitoring

- Portable particle counters
  - Portable CPCs
  - Continuous monitoring or NP source tracking

- Surface area Monitoring
  - indicates the surface area of nanoparticle aerosols that deposit in the lung

- Portable Optical Particle Counters
  - Work area monitoring (but only for 'agglomerates')

Personal Sampling & Personal Protection

- Sampling of particles
  - Continuous flow recording
    - Exposure monitoring

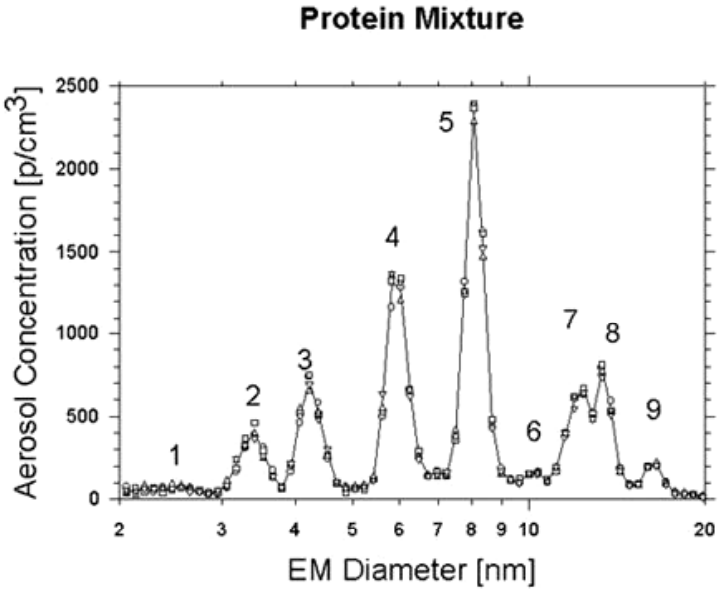
- Fit test any tight fitting respirator
  - Including those used for protection against nanoparticles
    - PortaCount® universal fit test system
    - OSHA compliant

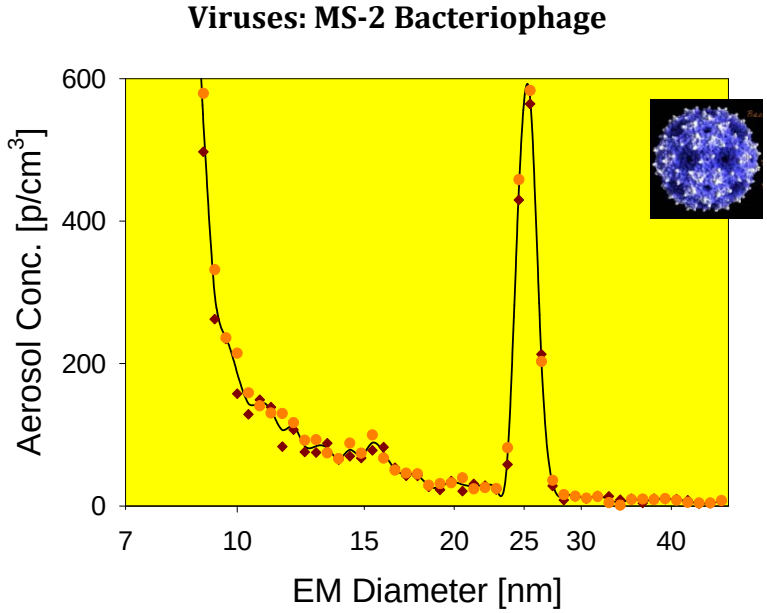
Particles in water

- Electrospray the sample
  - Ultra fine droplets
    - One particle/droplet
- Charge the particle
  - Particle carry charge
- Use a Differential Mobility Analyzer
  - Size discrimination using electrical mobility
- Use a Condensation Particle Counter (CPC)
  - Number of particles for the selected size
    - Selected by the mobility

Particles in water

Electro sprayed & used Differential Mobility Analyzer and Condensation Particle Counter

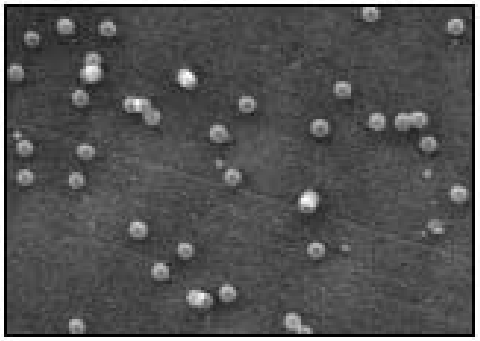




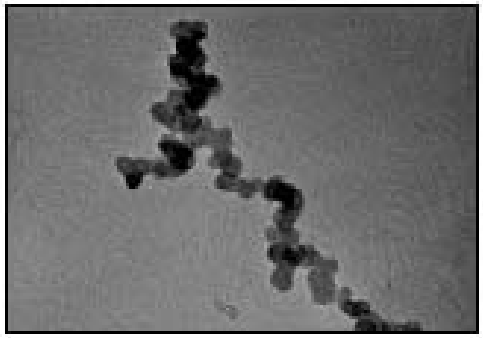
Kaufman, S. In-house data of electrosprayed protein mixture in ***2 to 20 nm range***

Nanoparticles & Agglomeration

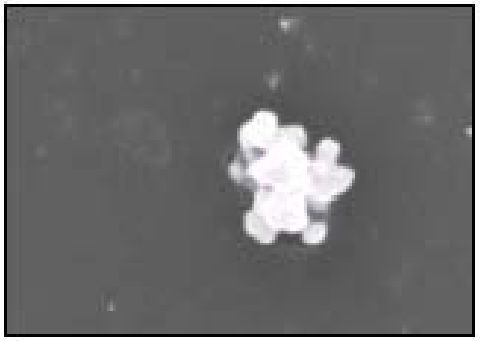
- Nanoparticles
  - Generation, movement, transport…
- Formation of
  - Agglomerates and Aggregates



Spheres



Agglomerates - loose



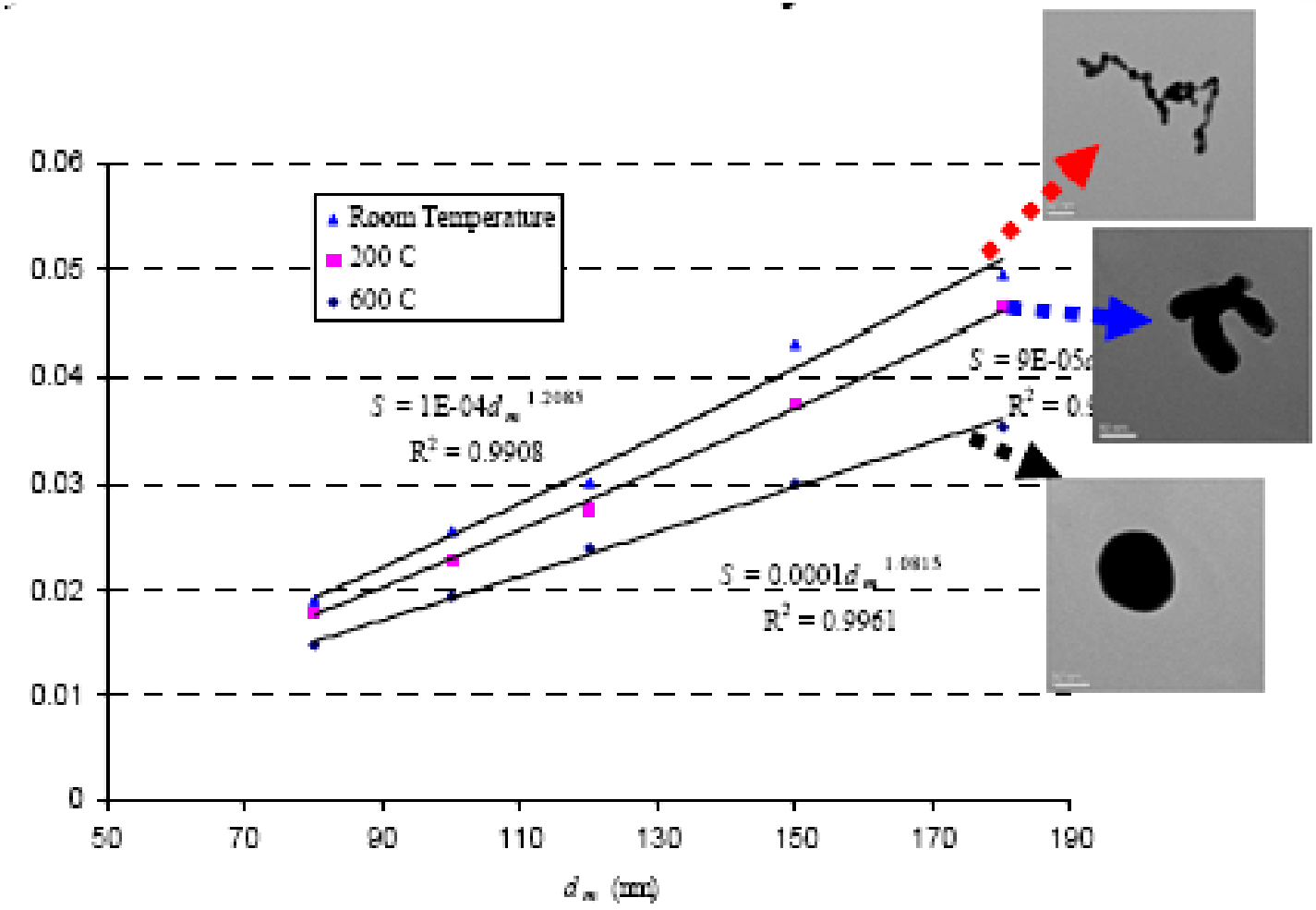
Sintered

- What properties can we quantify?
  - And how?

Nanoparticle Analysis - Approach

- Characterizes
  - Airborne nanoparticle morphology
  - Measures
    - number, surface area and volume distributions of airborne nanoparticle agglomerates
- Sensitivity
  - Electrical charge divided by Number Concentration (#/cm^3)
  - Sensitivity S
    - depends on the particle morphology
- Uses
  - Capacitance of a non-spherical particle (Chang)
  - Mobility of a loose agglomerate (Lall & Friedlander)
  - Capacitance of a loose agglomerate (Brown & Hemingway)

Sensitivity Curve



Courtesy: Pui, Fissan,Wang, Shin, Mertler and Sachweh (2009)

NanoParticles

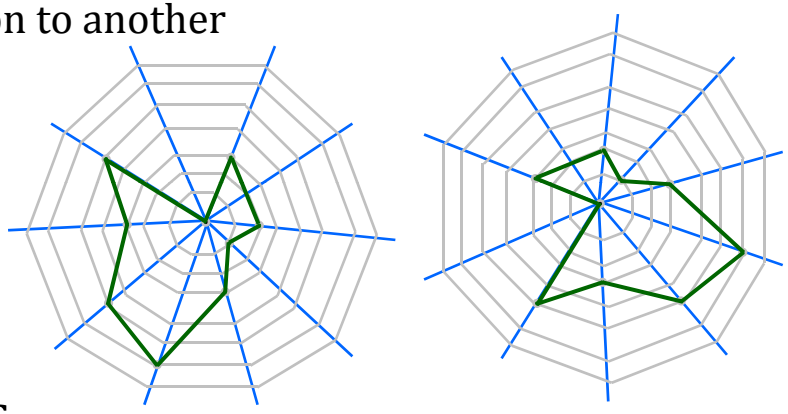
Agglomerates, Aggregates

- Technique provides (for loose agglomerates)
  - Primary particle size, Number
  - Surface area, volume
  - Shape factor

- Future possibilities
  - Characterize Aggregates
  - Fractal dimension
  - Shape factor

Going Forward

- Map the domain
  - Importance of different particle characteristics
    - Can be different from one situation to another



- Chart the course
  - Outline the path with priorities
- Quantify the best processes
  - ❖ e.g., nanoparticle production
- Better communication with the outside world

Going Forwrad

- To separate the “benign” from “toxic”, how would we remove variability?
  - Process – manufacturing, “Impurities”, Sample preparation
- Background (noise) vs Information (signal)
  - Naturally present – small amount
- Develop valid models to examine the critical aspects of transport
  - Can we simulate the conditions (based on a wide range of parameters) and identify critical ones?
  - How would we test all the critical ones?
- Mass “may” to be the “dominant” measure of toxicity?
  - Is a legacy parameter – need large samples
  - Arrive at this through multiple measurable parameters(dia, number, surface area)
- Collect info (“creatively adapt”) from other disciplines
  - Interfacial chemistry, Porous media
- Time line with action items
  - Continuous feedback
  - Update tolls, measurement approaches, standards

Summary

- Challenging field
  - Wide range of work to be completed
  - Dividing up the tasks
    - Funding the key projects
- Exciting opportunities
- Responsible actions