Nanomaterials and the Environment & Instrumentation

Oct 6 , 2009

TRUST. SCIENCE. INNOVATION.

Corporate Overview

- TSI was founded in 1961
- Design, manufacture & market scientific & industrial instrumentation
  - Two major market segments
    - Environmental
    - Industrial
  - Two major customer groups
    - Research and Analytical
    - Test and Measurement
- Corporate headquarters – Shoreview, MN

Are We Asking the Right Questions?

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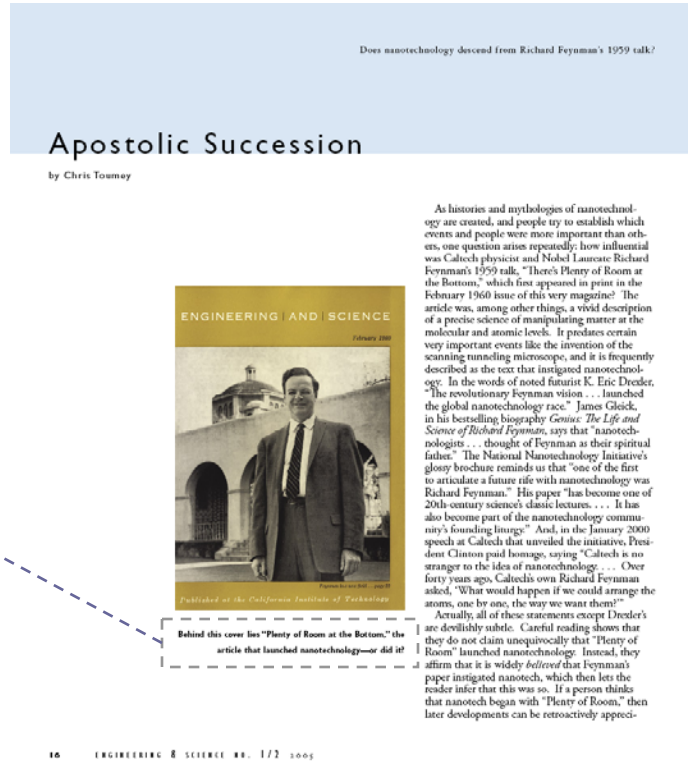
Outline

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

Did it launch Nanotechnology?

- Talk by Feynman Dec 29, 1959 (APS, Caltech)
  - *There's Plenty of room at the bottom*
- Published as an article (page 22) in Feb 1960 in ***Engineering & Science*** (Caltech) with the subtitle
  - *An Invitation to enter a new field of physics*
- 2005 *E&S* article
  - ***Apostolic Succession***
    - by Chris Toumey

" Behind this cover lies 'Plenty of Room at the Bottom,' the article that launched Nanotechnology - or did it? "



Does nanotechnology descend from Richard Feynman's 1959 talk?

Apostolic Succession

by Chris Toumey

As histories and mythologies of nanotechnology are created, and people try to establish which events and people were more important than others, one question arises repeatedly: how influential was Caltech physicist and Nobel Laureate Richard Feynman's 1959 talk, "There's Plenty of Room at the Bottom," which first appeared in print in the February 1960 issue of this very magazine? The article was, among other things, a vivid description of a precise science of manipulating matter at the molecular and atomic levels. It predates certain very important events like the invention of the scanning tunneling microscope, and it is frequently described as the text that instigated nanotechnology. In the words of noted futurist K. Eric Drexler, "The revolutionary Feynman vision . . . launched the global nanotechnology race." James Gleick, in his bestselling biography *Genius: The Life and Science of Richard Feynman*, says that "nanotechnologists . . . thought of Feynman as their spiritual father." The National Nanotechnology Initiative's glossy brochure reminds us that "one of the first to articulate a future rife with nanotechnology was Richard Feynman." His paper "has become one of 20th-century science's classic lectures. . . . It has also become part of the nanotechnology community's founding liturgy." And, in the January 2000 speech at Caltech that unveiled the initiative, President Clinton paid homage, saying "Caltech is no stranger to the idea of nanotechnology. . . . Over forty years ago, Caltech's own Richard Feynman asked, 'What would happen if we could arrange the atoms, one by one, the way we want them?'"

ENGINEERING AND SCIENCE

Behind this cover lies "Plenty of Room at the Bottom," the article that launched nanotechnology—or did it?

Actually, all of these statements except Drexler's are devilishly subtle. Careful reading shows that they do not claim unequivocally that "Plenty of Room" launched nanotechnology. Instead, they affirm that it is widely *believed* that Feynman's paper instigated nanotech, which then lets the reader infer that this was so. If a person thinks that nanotech began with "Plenty of Room," then later developments can be retroactively appreci-

16 ENGINEERING & SCIENCE NO. 1/2 2005

Technologies for NanoParticle Characterization

- 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*

Systems to Characterize

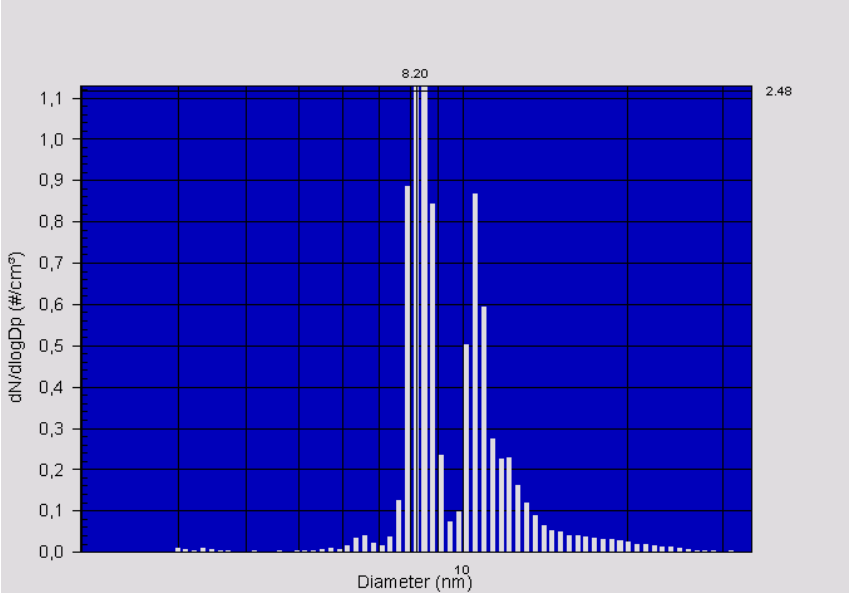
Measurement Techniques combined and optimized

- 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

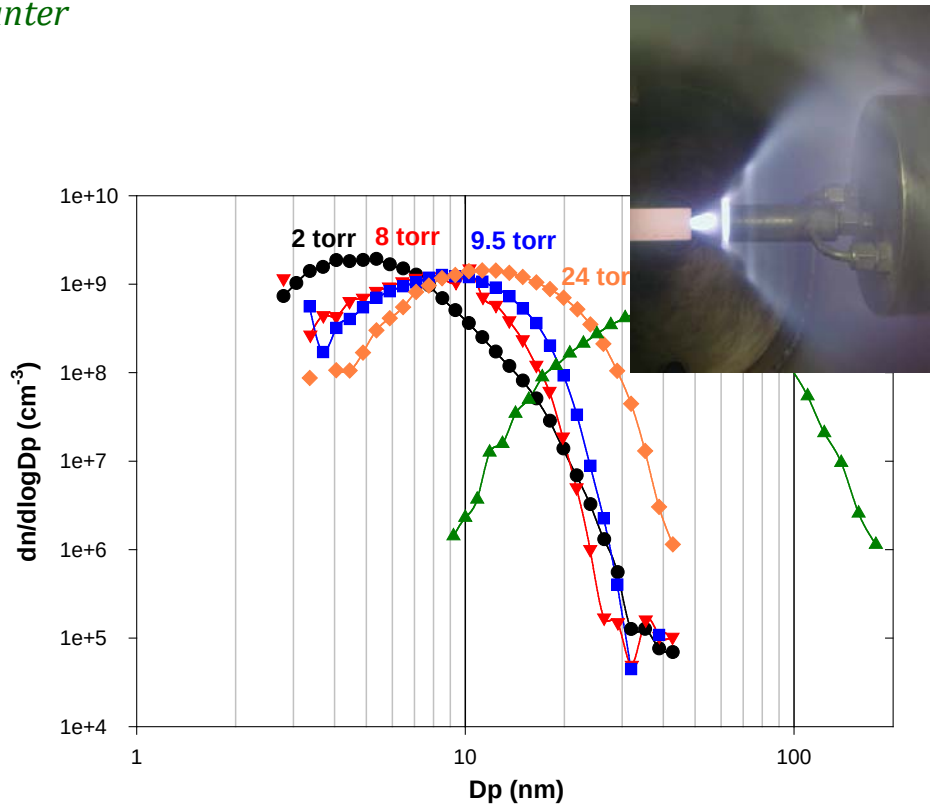
NanoParticle Size Spectrometers

Scanning Mobility Particle Sizer: High Size Resolution

Differential Mobility Analyzer & Condensation Particle counter



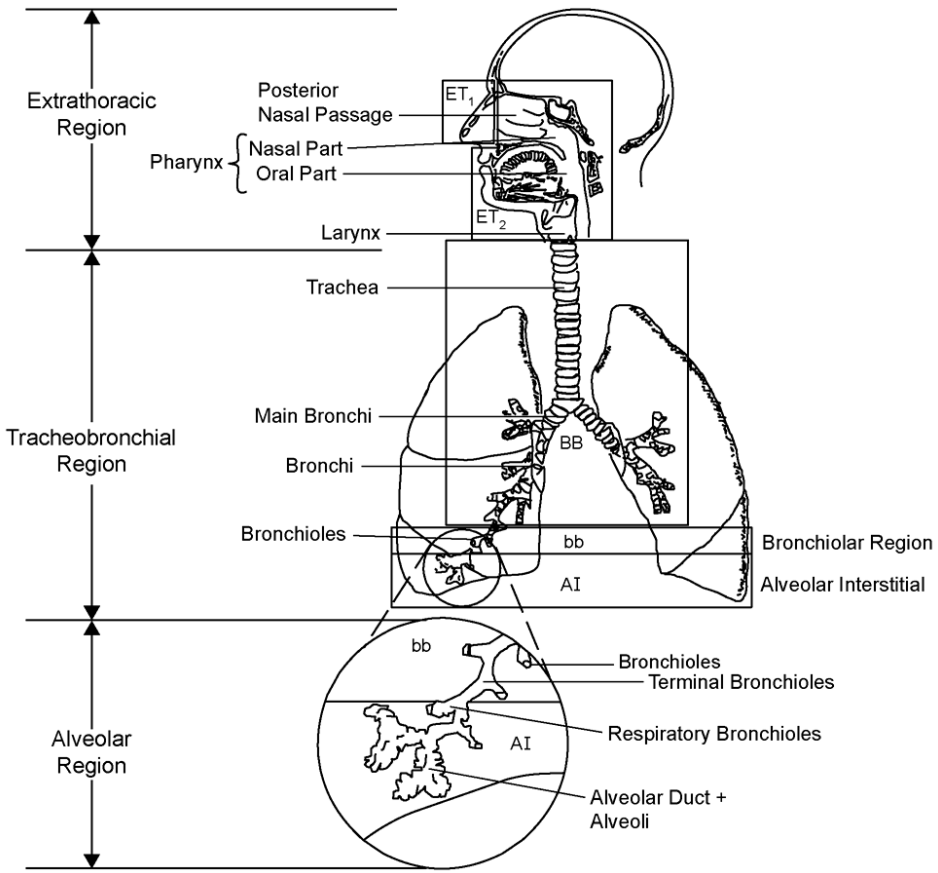
Kaufman, S: In-house data



Nanoparticle Synthesis

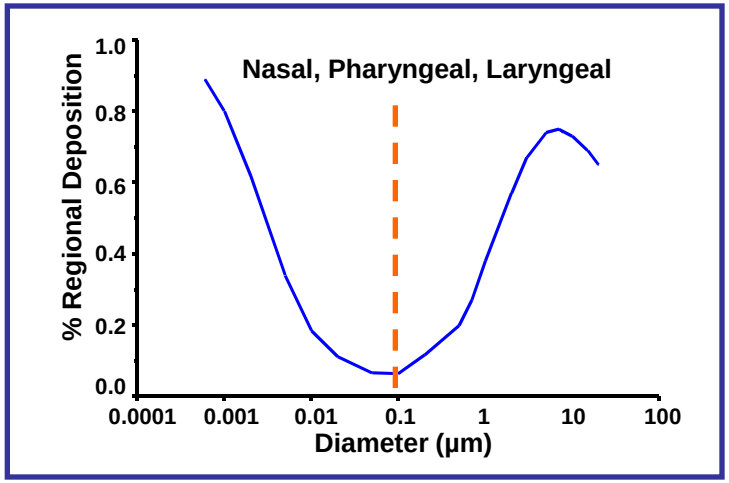
Respiratory Deposition

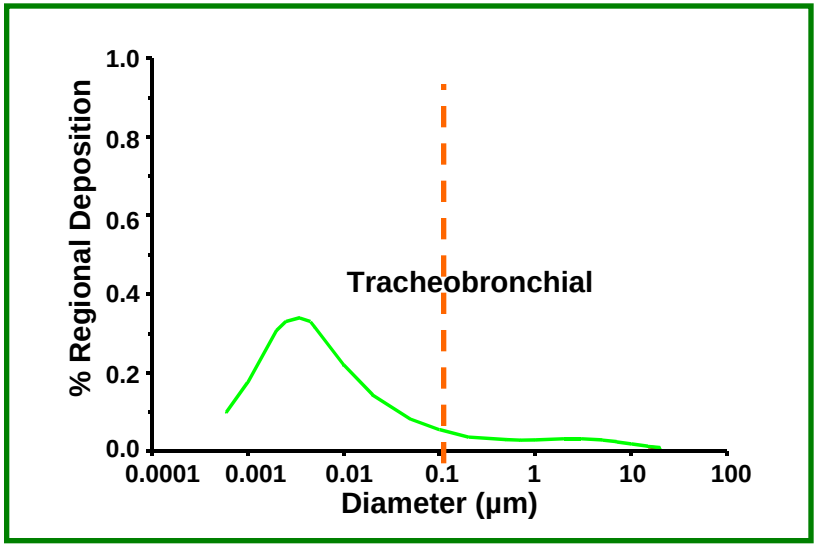
Diagrammatic representation of respiratory tract regions in humans

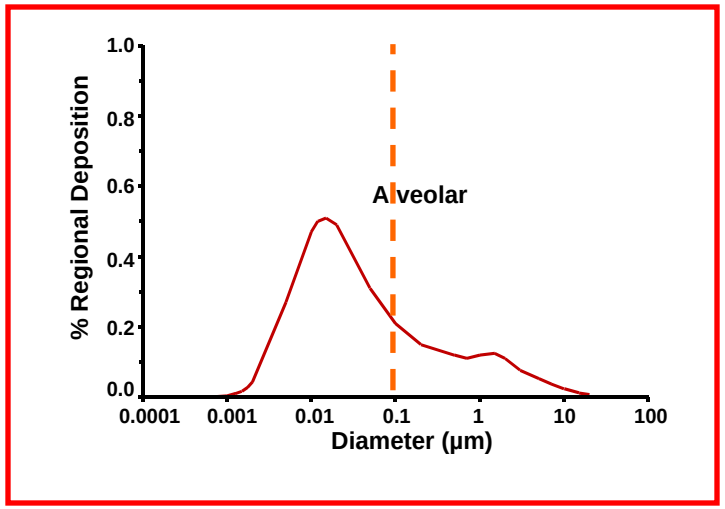


Based on International Commission of Radiological Protection (1994) and U.S. Environmental Protection Agency (1996a). Air Quality Criteria for Particulate matter, 2004, p 6-5.

Fractional Deposition of Inhaled Particles in the Human Respiratory Tract



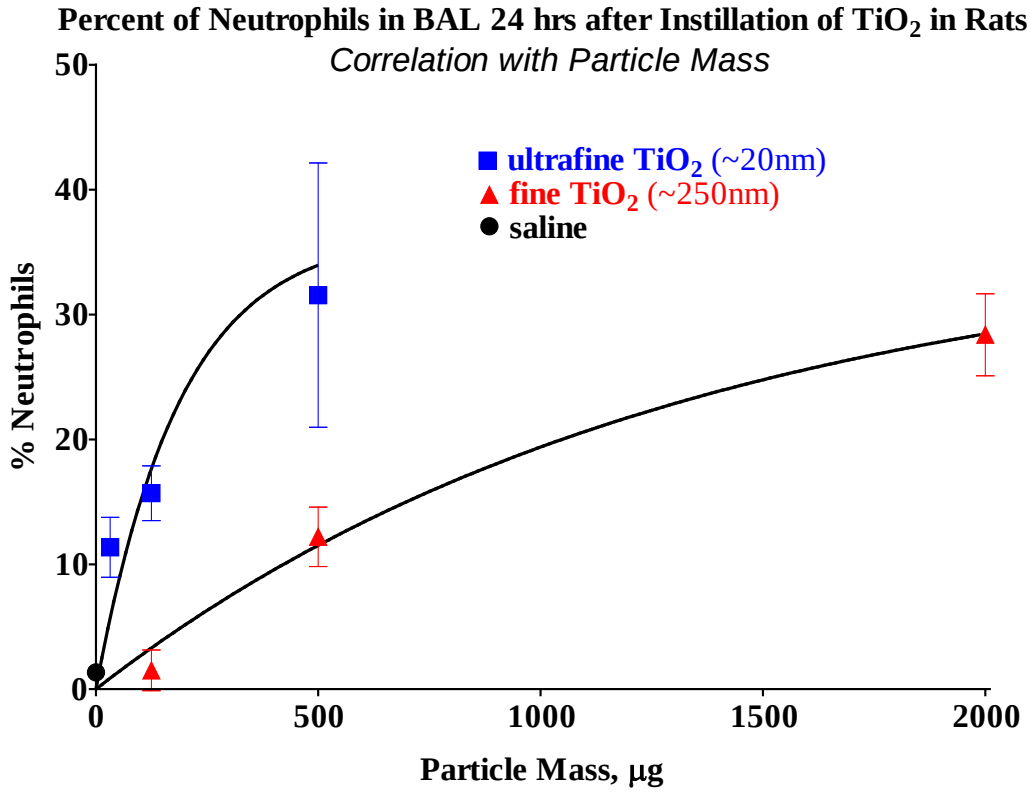




Health Effects

NanoParticles – "All surface and no volume !"

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



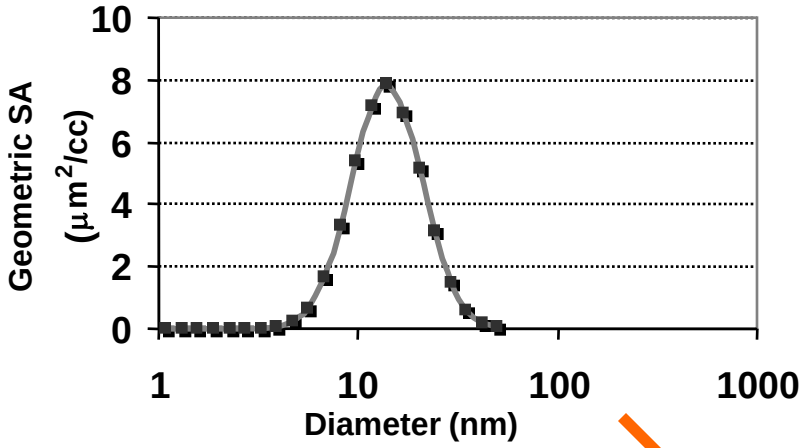
Oberdörster, 2001

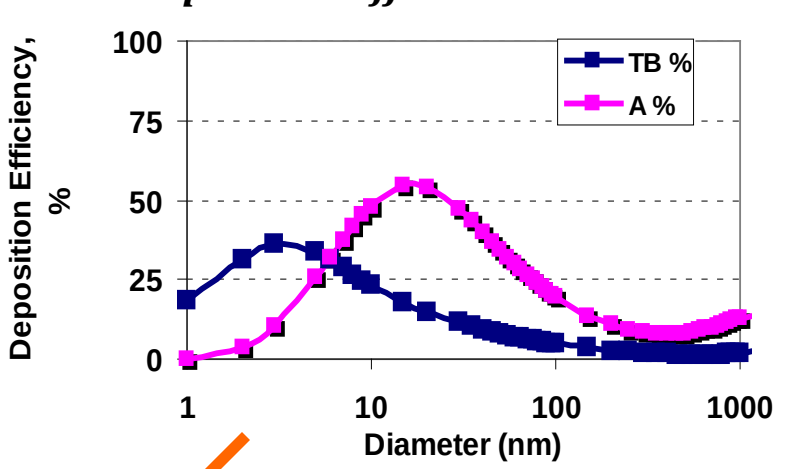
Lung-Deposited Surface Area

- Diffusion charger + Electrometer
  - *Nano Surface Area Monitoring System*
- Measures Lung-Deposited Surface Area ($\mu m^2/cm^3$)
  - Tracheobronchial (TB)
  - Alveolar (A)

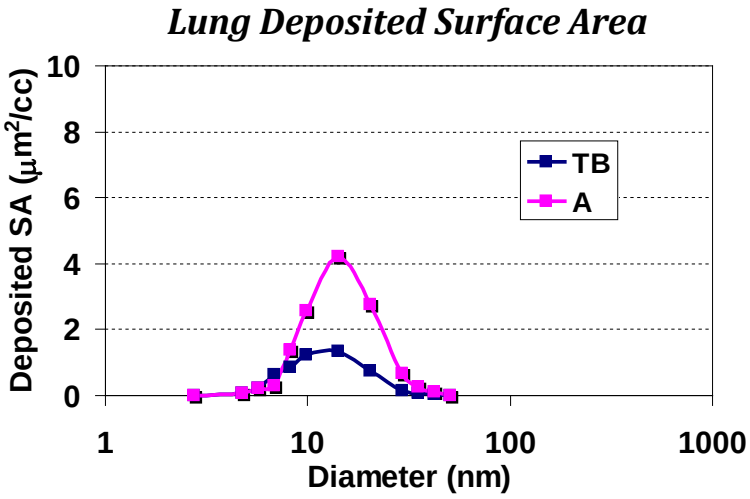
- Provides a simple, fast solution for measuring surface area dose
  - Function of concentration and exposure period
- Measures workplace exposure to nanoparticles
  - Function of concentration, Toxicity and Time

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

Personal Sampling & Personal Protection

- Sampling of particles
  - Continuous flow recording
    - Exposure monitoring

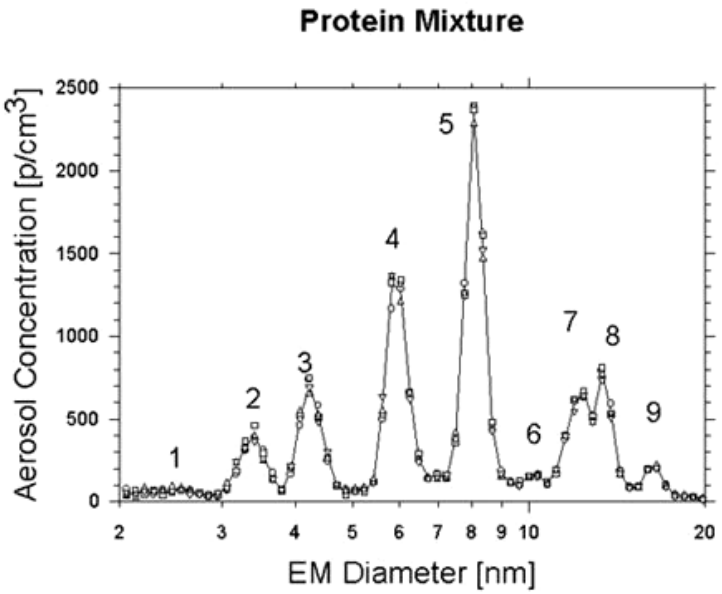
- Fit test any tight fitting respirator
  - Including those used for protection against nanoparticles
    - PortaCount® universal fit test system

Particles in water

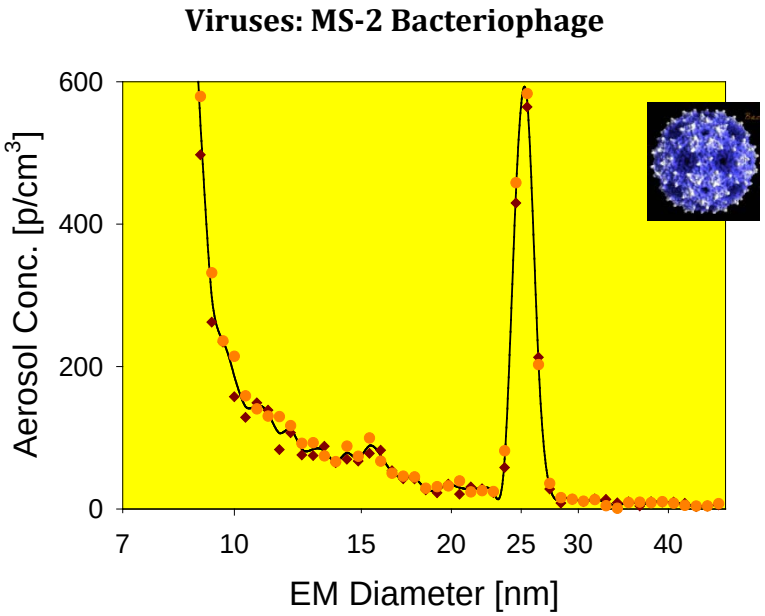
- Electrospray the sample
  - Ultra fine droplets
    - One particle/droplet
- Charge the particle
  - Particle carry charge
- Use a Differential Mobility Analyzer
  - Size discrimination using electrical mobility
- Use a Condensation Particle Counter (CPC)
  - Number of particles for the selected size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

Particles in water

Electro sprayed & used Differential Mobility Analyzer and Condensation Particle Counter

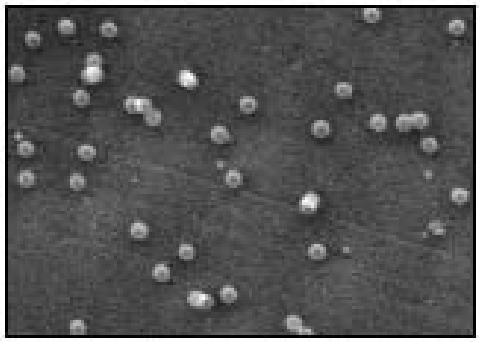


*Kaufman, S. In-house data of electrosprayed protein mixture in **2 to 20 nm range***

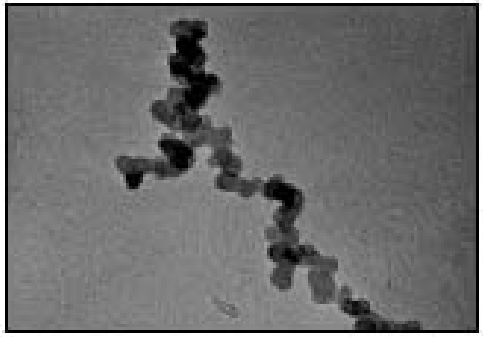


Nanoparticles

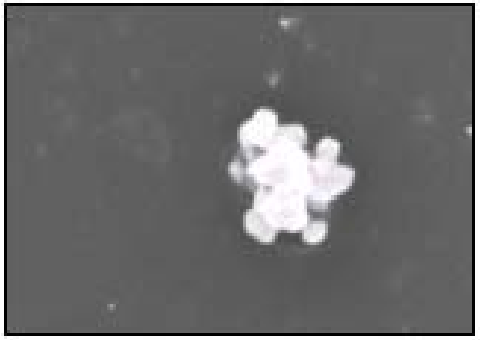
- Nanoparticles
  - Generation, movement, transport…
- Formation of
  - Agglomerates and Aggregates



Spheres



Agglomerates - loose



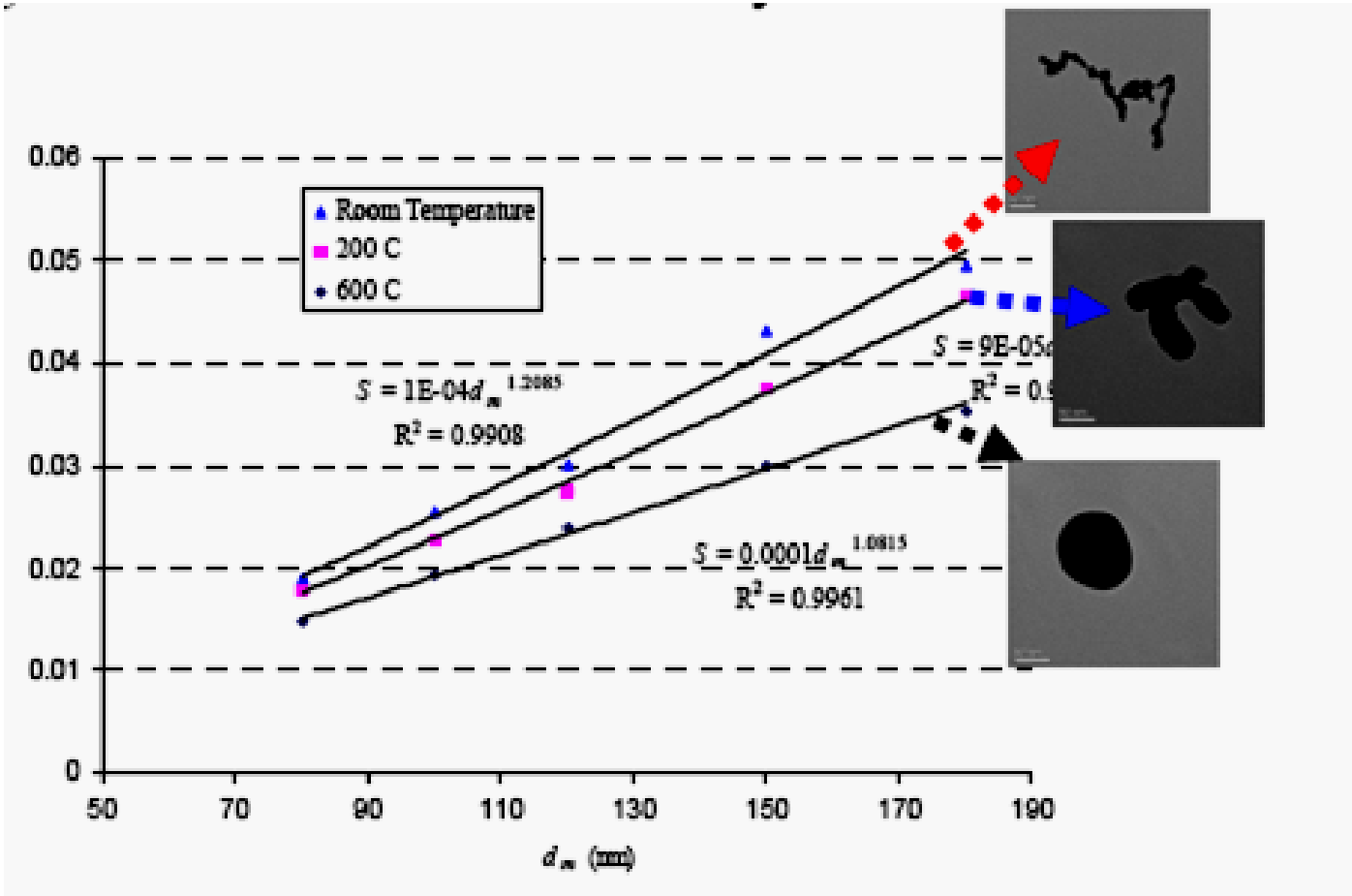
Sintered

- 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.

Sensitivity Curve



Courtesy: Pui, Fissan,Wang, Shin, Mertler and Sachweh :***Measurement of Nanoparticle Agglomerates by Combined Measurement of Electrical Mobility and Charging Properties,*** European Aerosol Conference 2009, Karlsruhe

NanoParticles

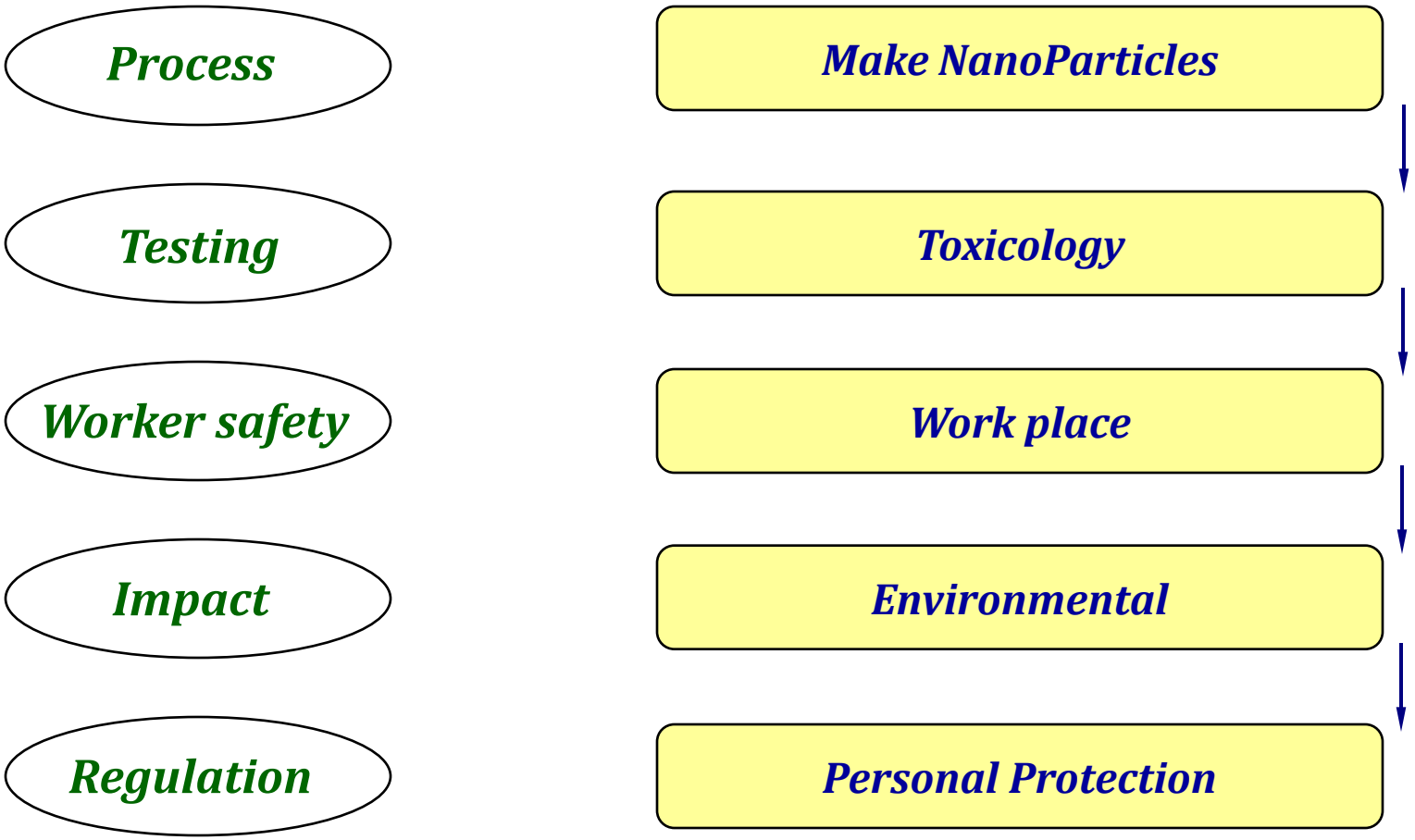
Agglomerates, Aggregates

- Loose Agglomerates
  - Primary particle size, Number
  - Surface area, volume
  - Shape factor
- Future possibilities
  - Characterize Aggregates
  - Fractal dimension
  - Shape factor

How should we proceed ?

- Room for everyone
  - There is so much *(Plenty of)* work to be done - there is *"room for every one"*
- Cut-in to "5-step" approach 
  - 5 steps - from nanoparticle production to personal protection
- Map the domain
  - Importance of different particle characteristics
    - Can be different from one situation to another
- Chart the course
  - Outline the path with priorities
- Go from Recipe to process
  - Quantify the best process – e.g., nanoparticle production
- Deliver the facts
  - Better communication with the outside world

Are these sequential steps?



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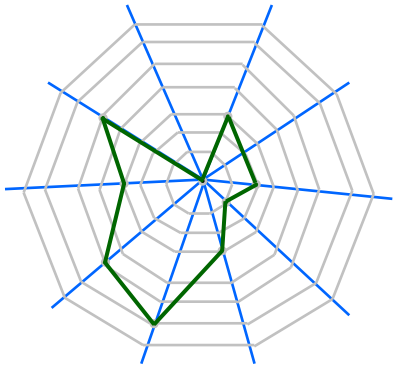

Scenario - Case Study

- To separate the "benign" from "toxic", how would we remove variability?
  - Process – manufacturing, "Impurities", Sample preparation
- What are the different ways we can do accelerated tests?
  - e. g., zebra fish, Do we know how to scale the results?
- Background (noise) vs Information (signal)
- How can we develop valid models to examine the critical aspects of particles/materials?
  - Can we simulate the conditions (based on a wide range of parameters) and identify critical ones?
  - How would we test all the critical ones?
- Is Mass going to be the "dominant" measure of toxicity?
  - Can we arrive at this (in multiple ways) through multiple measurable parameters? (dia, number, surface area)
- Is the science for soil and related contamination well developed?
  - How are they (e.g., porous media) in the nano domain ?
  - What about site remediation?
- Time line with action items
  - Continuous feedback and update - essential