Building and Fire
Research Laboratory

NIST
National Institute of
Standards and Technology

Measurement of Incidental Nanoparticles in Residential Environments

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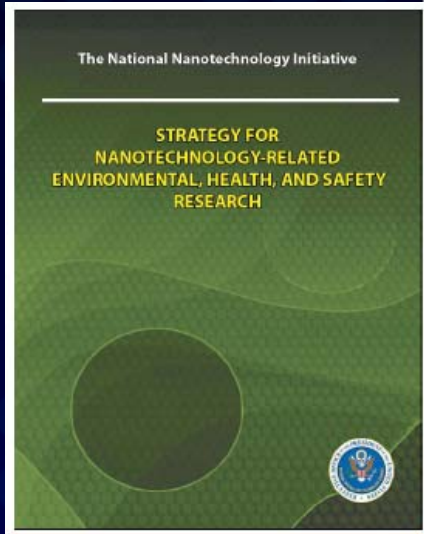
EPA Nanoparticle Air Monitoring Workshop
March 2-3, 2009 RTP, NC

NNI, Nano-EHS and NIST

- **National Nanotechnology Initiative:**
  - multi-agency (26), multi-disciplinary Federal program
  - coordinates nanoscale S&T
  - prioritizes, invests in EHS research
- **NIST charged by NNI**
  - To coordinate government and industry nano-measurement efforts
  - To help develop a unified approach to manage potential nano-EHS risks



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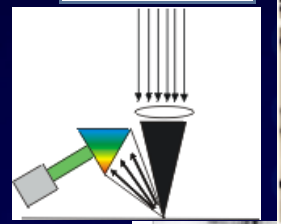
NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

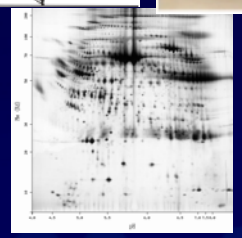
NIST & Nano-EHS

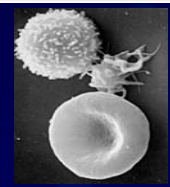
Three Major Areas

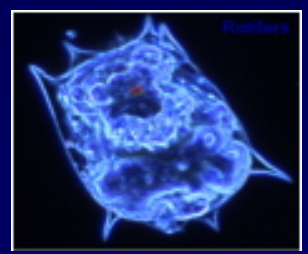
- **Standards**
  - Reference materials
  - Documentary– with SDOs
- **Nanomaterial Characterization**
  - Chemical and physical parameters
  - Type and amount of nanomaterial
- **Health and Environmental Impacts**
  - Methods to support understanding effects
  - Nanomaterials in biological and environmental systems:
    - Wastewater
    - Food-chain

Material Standards for Environmental Health & Safety for Engineered Nanoscale Materials
Report of the NNI Workshop 09/07









IAQ Group Nanoparticle Research Activities

Current Work: Ultrafine Particle Measurements in Test House

- Indoor source generation rates
- Outdoor contribution to indoor concentration
- Ultrafine particle transport properties (e.g., coagulation and deposition)

Future Plans

- Environmental chamber experiments
- Model development of indoor nanoparticle exposure
- Application of fate and transport work to Nano-EHS (e.g., potential exposure control options such as local exhaust and air filtration)

Background

Ultrafine particle (UFP, < 100 nm) features:

(a) UFPs outnumber all other particles

(b) They are mostly surface—attached compounds are more bioavailable

(c) UFP can penetrate human cells and may have direct route to brain

Recent reports of effects on human health:

(a) Oxidative Stress–Induced DNA Damage (Braun et al., 2007)

(b) Cardio-respiratory mortality & Cardiovascular mortality (Stölzel et al., 2007)

Background (cont.)

Major outdoor sources of UFPs:

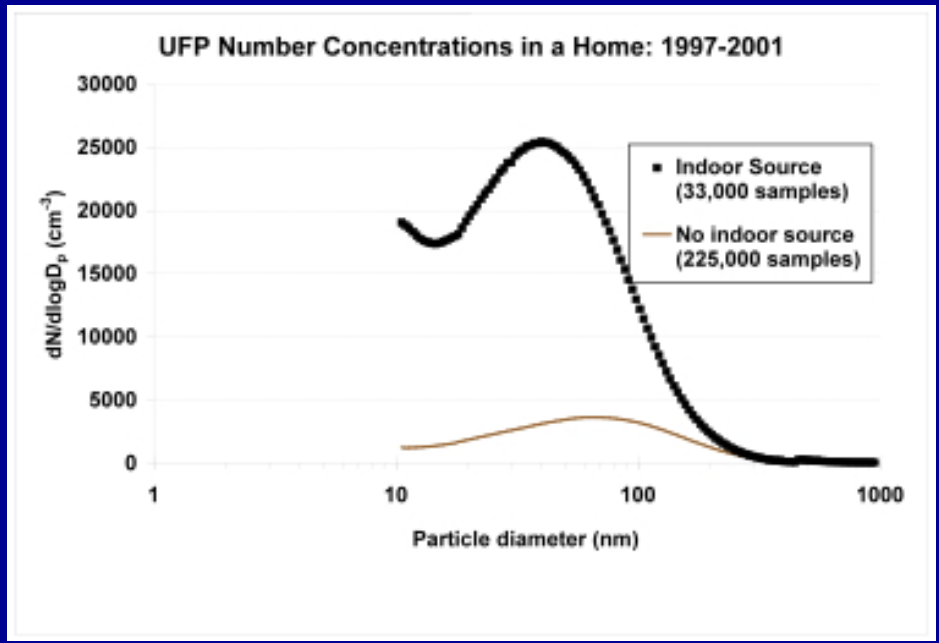
- Emissions from vehicles
- Photochemically produced gas-to-particle conversion
- Regional atmospheric nucleation events

➢ Typical outdoor concentrations may range from 5,000 - 30,000 particles/cm^3 occasional spikes to 50,000 - 100,000 particles/cm^3 caused by nucleation bursts

Background (cont.)

Major indoor sources of UFPs:

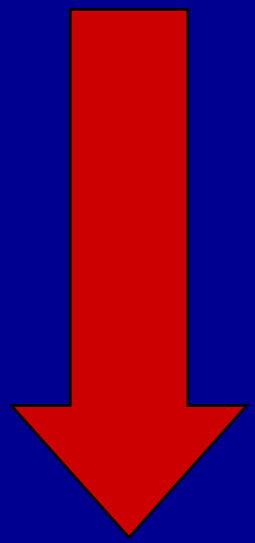
- Combustion
- Electric heating elements
- Electric motors



Comparison of indoor source with the contribution of outdoor sources to indoor personal exposure (Wallace et al., 2002)

Focus of NIST Monitoring Effort

Most previous work on indoor sources has investigated UFPs from 10 nm - 100 nm



New technology allows measurements down to 2.5 nm

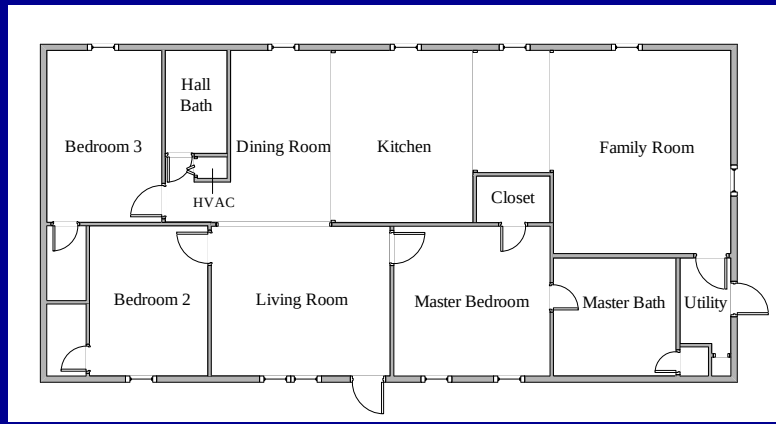
To extend our knowledge of the 2.5 nm - 10 nm region

Objectives

- Measure UFPs from Major Indoor Sources
  - Combustion (Gas Stove)
  - Electric Heating Elements (Electric Stove & Toaster Oven)
- Calculate Decay Dynamics
  - Coagulation
  - Deposition
- Calculate Source Strength (Emission rates)

Experimental Methods

Photograph of NIST test house



Floor plan of NIST test house

GC-ECD (Gas Chromatography with Electron Capture Detector) to estimate the air change rates continuously

Experimental Methods

SMPS system

Scanning Mobility Particle Sizer (SMPS)

- Electrostatic Classifier
- Nano-Differential Mobility Analyzer (DMA) (2 nm to 64 nm)
- Water-based Condensation Particle Counter (CPC)
- Vacuum Pump
- Automatic switcher for indoor-outdoor sampling

Nano-DMA

Experimental Methods

Modifications of SMPS to measure down to 2.5 nm:

- A stronger neutralizer (Krypton-85) is used to fully neutralize the aerosol at high concentrations
- A vacuum pump and a critical orifice are used to increase the inlet aerosol flow rate from 0.6 L/m to 1.5 L/m to decrease diffusion loss of smaller particles
- No impactor to reduce diffusion losses

Experimental Methods

Gas Stove

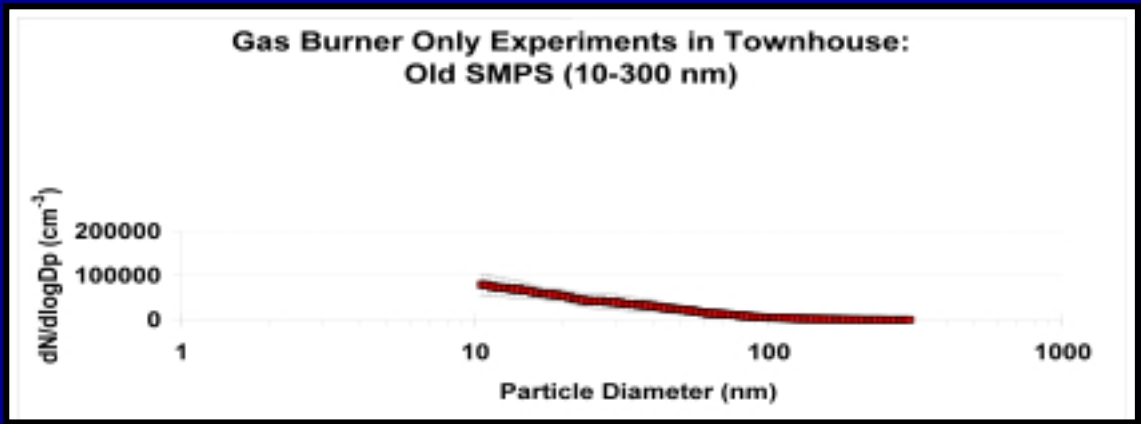
Electric Toaster Oven

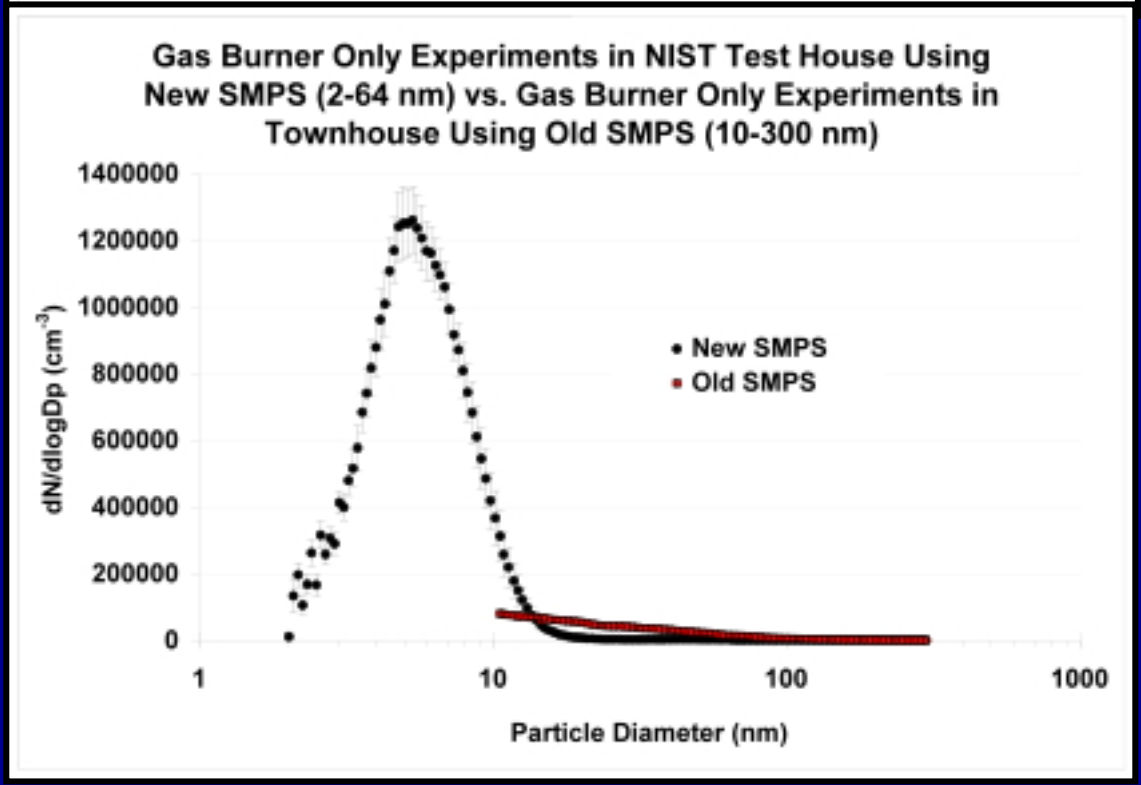
Test Conditions:

Gas & electric stoves: stovetop burners/coils , oven, broiler with/without food

Electric toaster oven: set to “BROIL” “TOAST” or “BAKE” (at 450 ^{o}F)

Results – Gas Burner

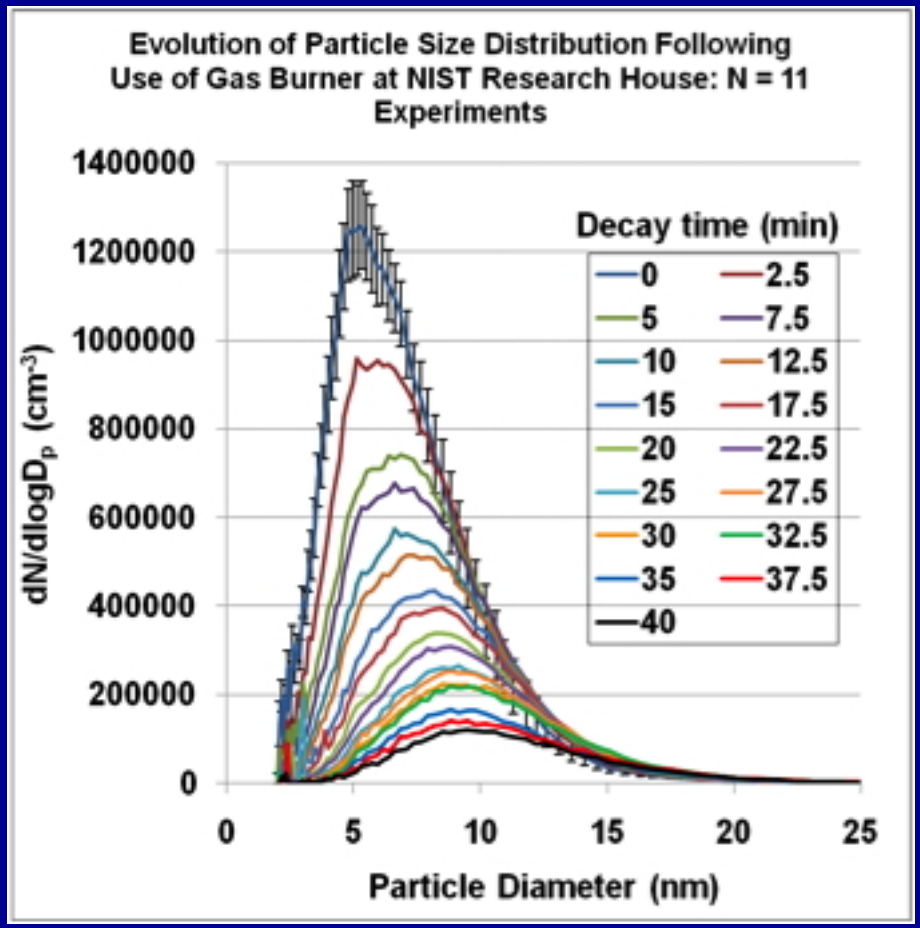




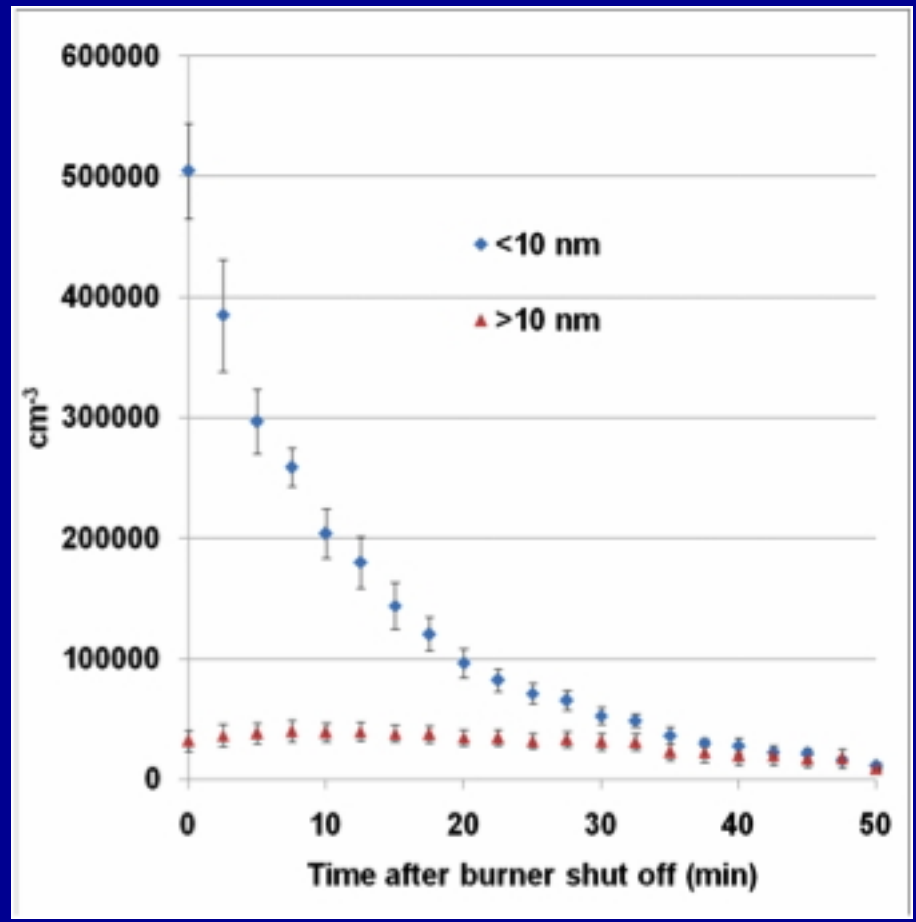
Old SMPS: > 10 nm

New SMPS: > 2 nm

Results – Gas Burner

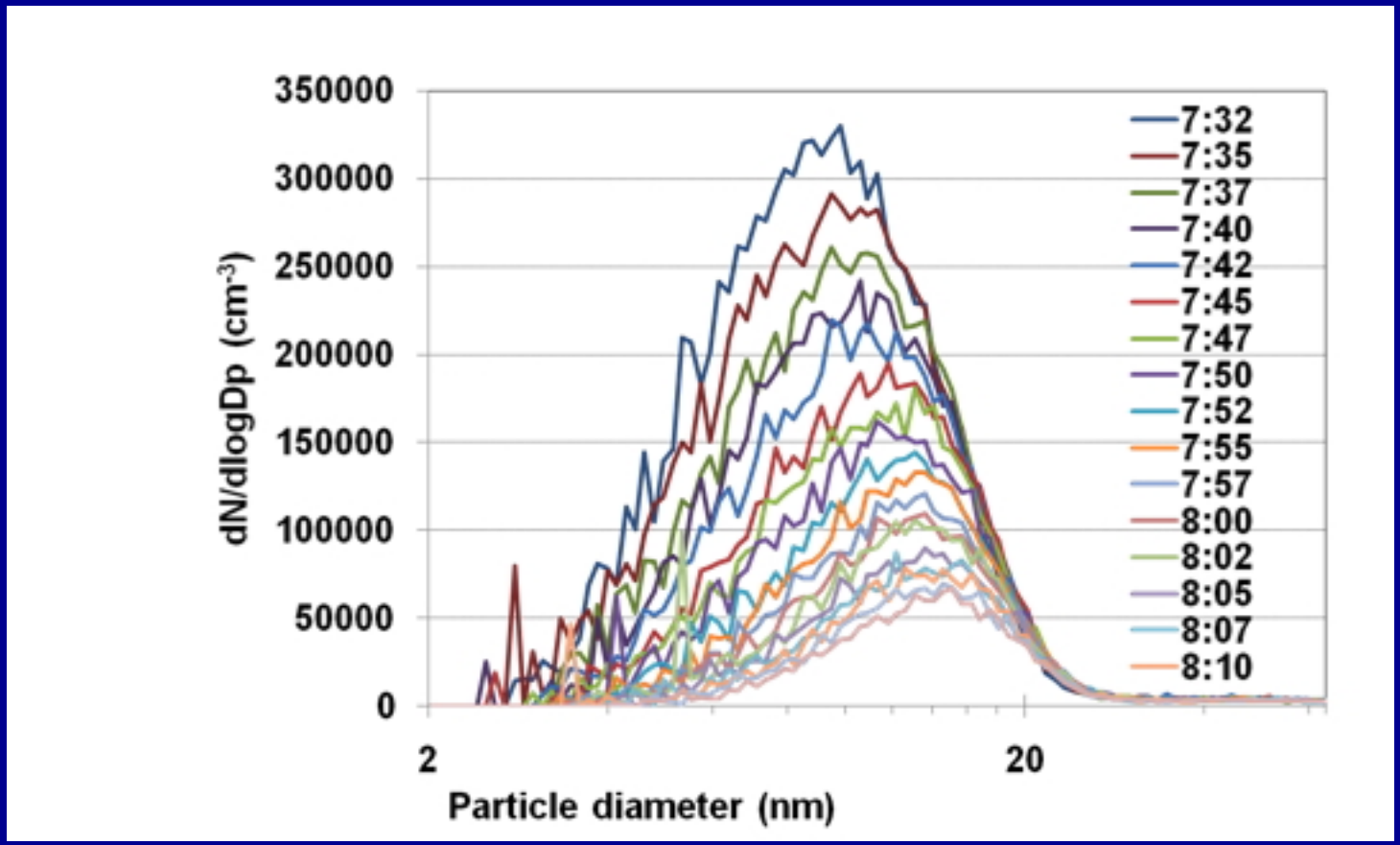


Average size distribution of particles produced by a single gas burner on High setting (N = 11 experiments)

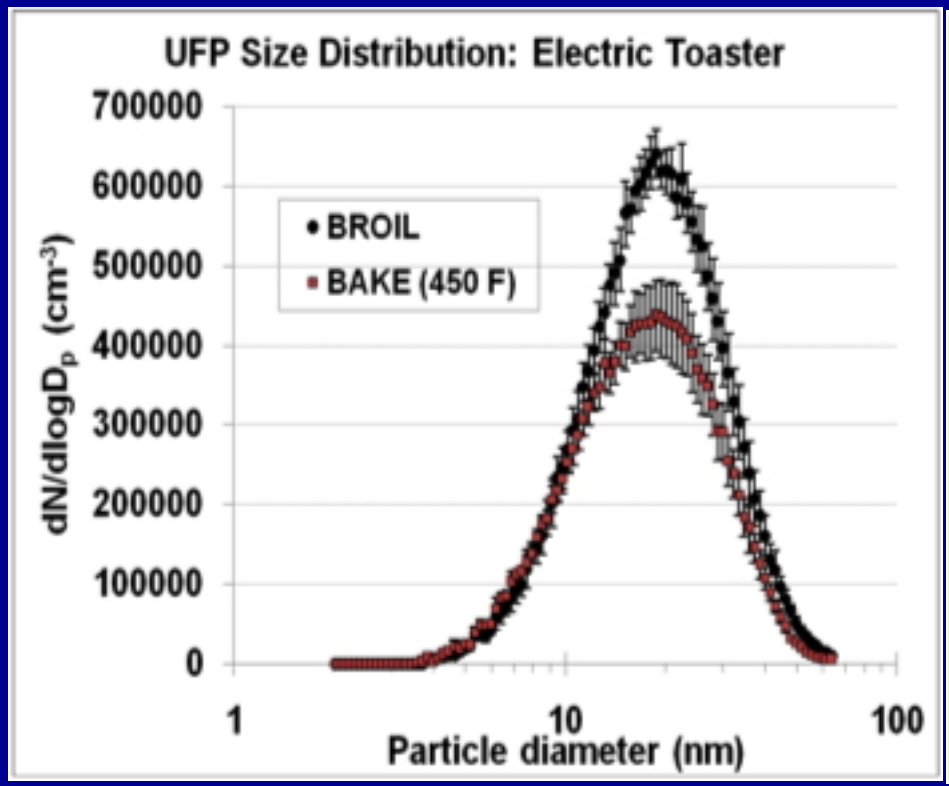


Particle concentrations during the decay period for particles > & < 10 nm

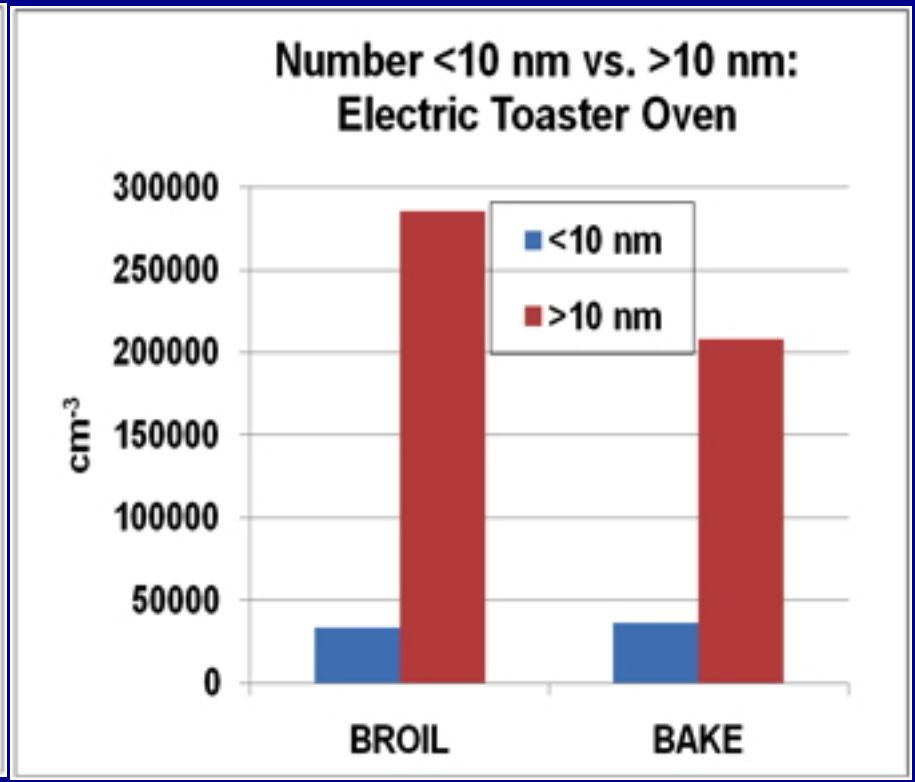
Results – Electric Stove



Results – Electric Toaster Oven

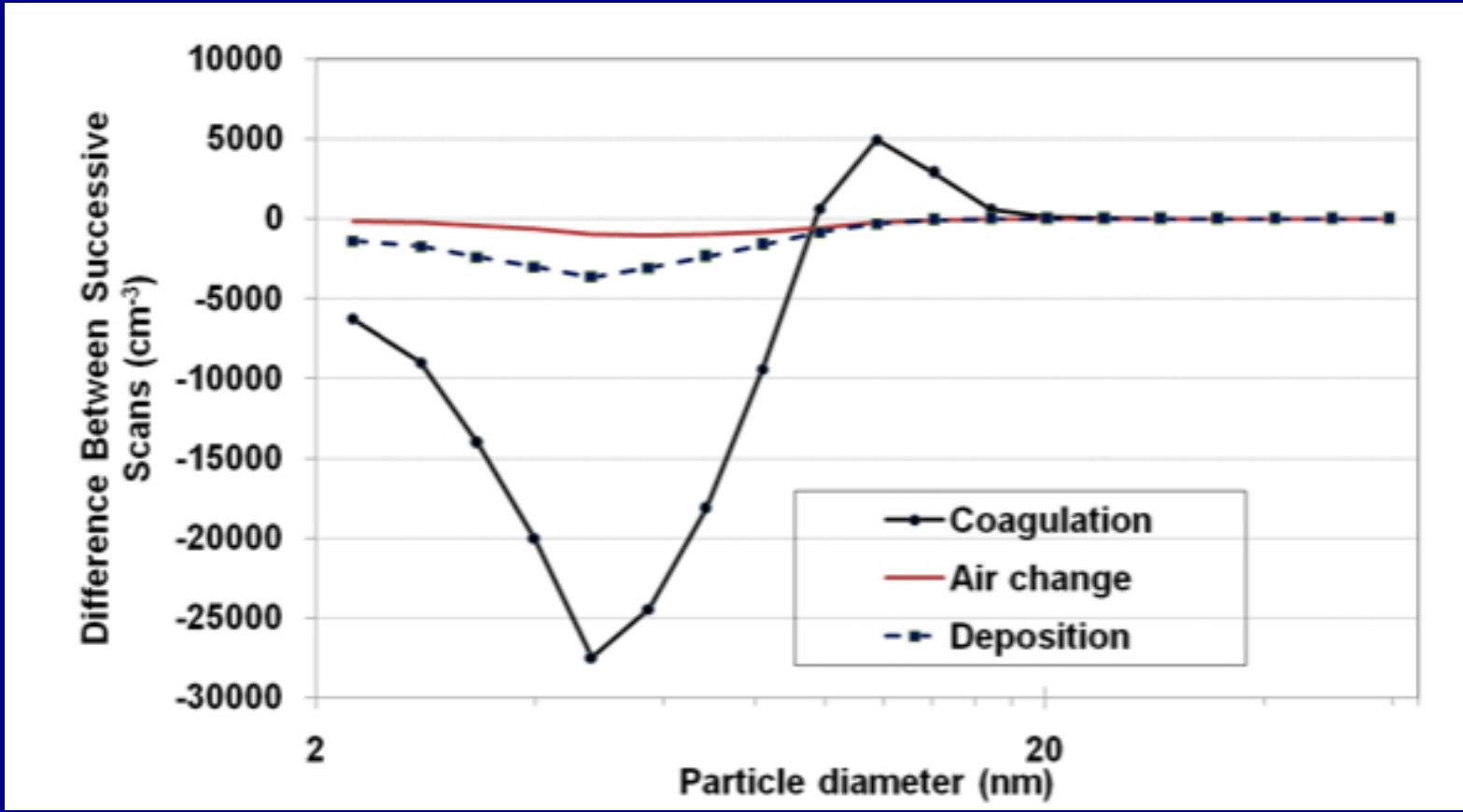


Average size distribution of particles produced by electric toaster oven (N = 6 experiments)



Particle concentrations during the peak period for particles > & < 10 nm

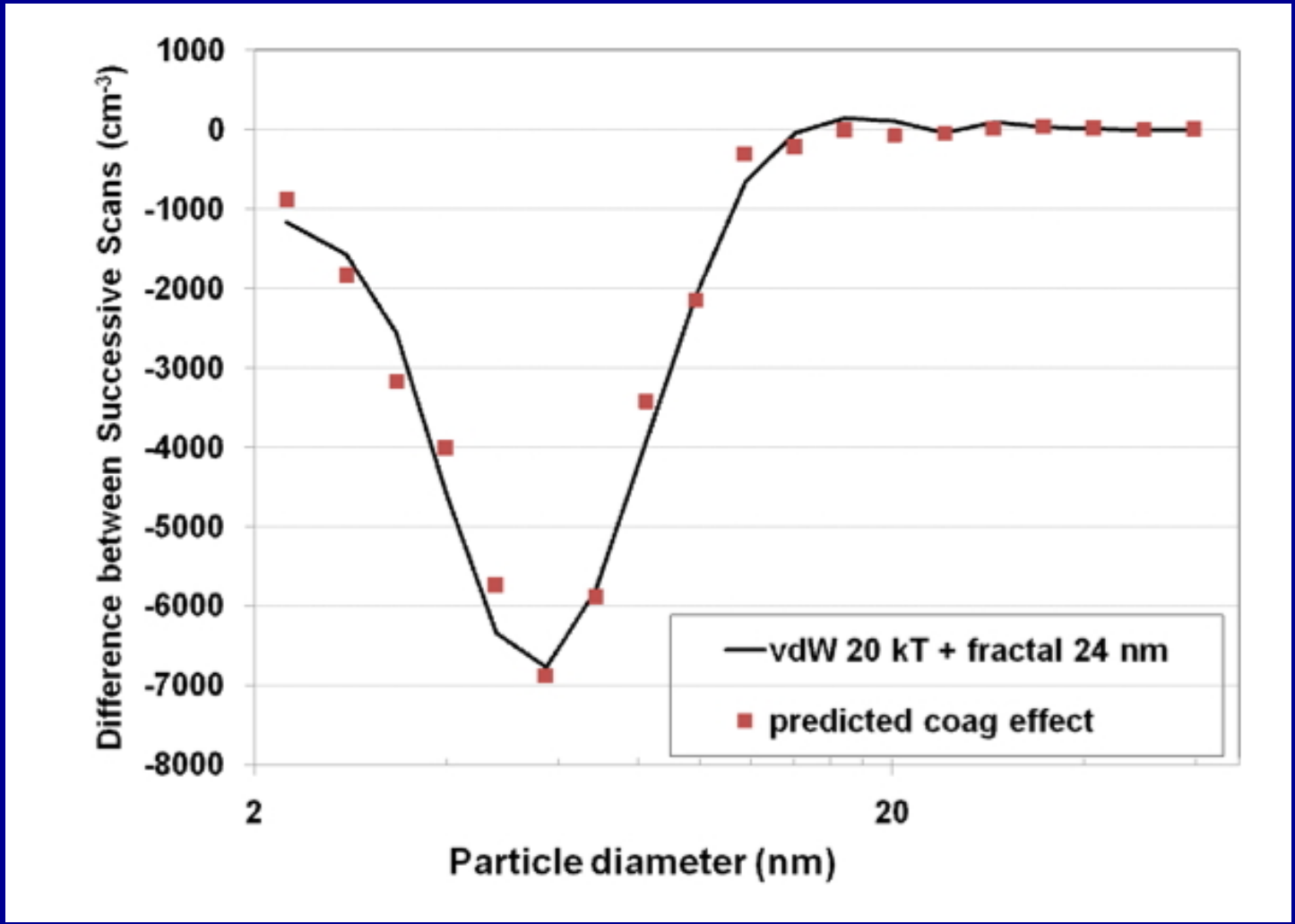
Relative Importance of Coagulation



Coagulation Corrections

- Van der Waals forces: attractive due to induced dipoles
- Viscosity: Resistance between approaching particles
- Fractal shape: “Bead-on-a-string” aggregates of primary nanoparticles cause higher rate of collisions

Coagulation calculation results



Conclusions

- New/modified SMPS/DMA can monitor down to 2.5 nm
- Must account for ventilation, deposition and coagulation to characterize sources and exposure
- Low penetration of ultrafines from outdoors; indoor sources key to exposure
- Gas & electric stovetop burners/coils emit large quantities of nanoparticles < 10 nm
- Gas & electric ovens and electric toaster ovens mostly emit nanoparticles > 10 nm
- Must address incidental nanoparticle “background” to understand nanoparticle exposure

Future Work

- Characterize emissions and fate of other indoor sources: combustion appliances, heating elements, motors
- Develop more complete understanding of importance of indoor sources vs. outdoor sources in human exposure.
- Composition and morphology of ultrafines < 10 nm; some evidence of difference from larger ultrafines.
- Model development of nanoparticle transport and fate for exposure analysis
- Control measures to reduce exposure to incidental nanoparticles

CNST Center for Nanoscale Science & Technology

CNST Nanofab

- **Mission**
  - Provide measurement methods, standards and technology to support all phases of nanotechnology development, from discovery to production
- **Research Program**
  - Collaborative opportunities to develop nanoscale measurement capabilities, focusing on electronics, nanofabrication, nanomanufacturing, and energy
- **Nanofab**
  - National, state-of-the-art, shared use facility open to all users
  - Measurement and fabrication of nanostructures
  - 19,000 sq ft cleanroom (8,000 sq ft at class 100)
  - Experienced, professional staff to train users or operate the tools

http://cnst.nist.gov