SAND2010-5251P

Novel Instrumentation for Selective Photo-Ionization and Trapping of Fine Particles

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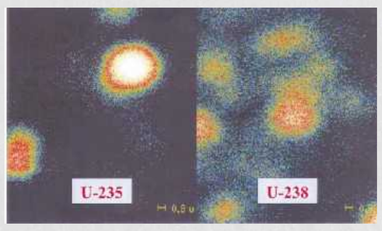
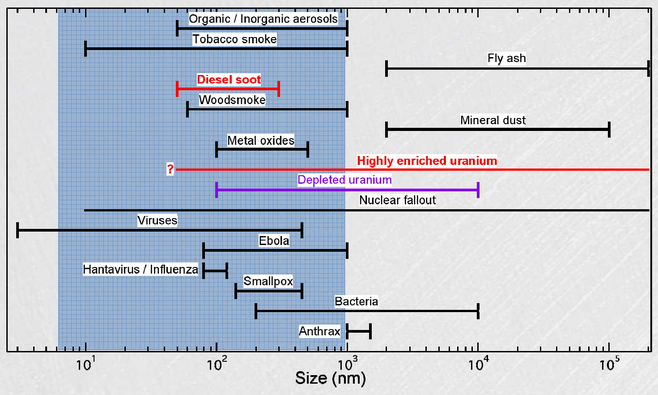
LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Problem

Lack of methods for collection and *in situ* analysis of fine particles for evidence of proliferation activities

Without selective collection, finding trace quantities of uranium is the proverbial "needle-in-a-haystack" problem





Uranium enrichment can produce fine atmospheric particles, providing an indicator of proliferation activities. These particles are difficult to detect because of (1) low ambient concentrations, (2) small size (<1 µm), (3) high concentrations of other particles.* Fine particles are difficult to trap (i.e., follow gas flow and are aerodynamically "slippery") and difficult to sort. Enriched uranium particles will likely be <1 µm, nonspherical, dense uranium oxide or uranyl fluoride.

Our technique is designed to solve the "needle-in-a-haystack" problem.

Approach

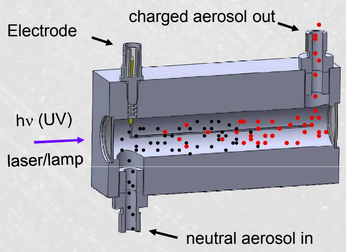
We are using ultraviolet light from lasers and lamps to select between the target and background particles.

Ultraviolet (UV) light can impart a charge to a particle — "photoionization"

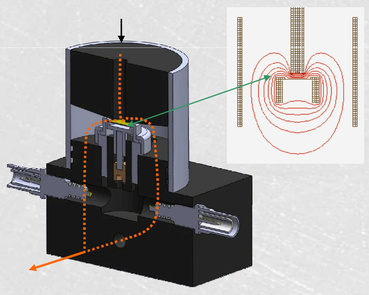
- **By carefully selecting the light source and intensity, different particles in a mixture can be charged to different degrees.**
- **The efficiency of the particle charging depends on the intensity of the light.**
- **Lasers and lamps can be used to produce the desired light.**
- **A brief voltage pulse can help sweep away electrons, preventing recombination with the ions.**

An electric field can be used to move the charged particles to a trap.

- **Smaller charged particles and particles with more charges on them move more easily in an electric field.**
- **Uncharged or insufficiently charged particles are not trapped.**



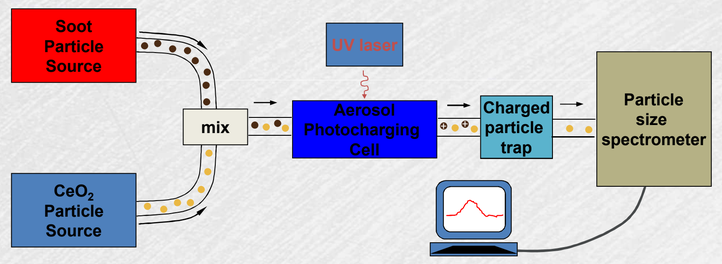
Particles flow into the chamber and are ionized by a UV laser or lamp



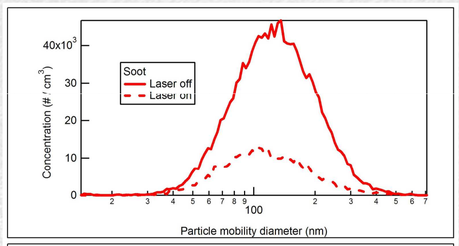
The charged particles are trapped using an electric field

Results

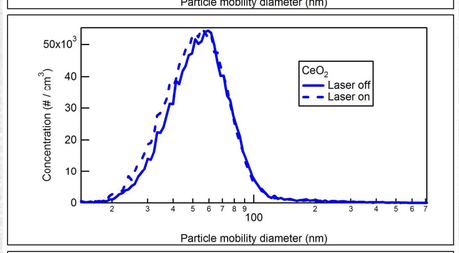
Particle separation experiment schematic drawing



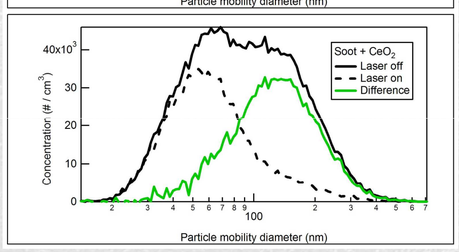
- **Soot source**: ethylene flame followed by particle diffusion-dryer
- **CeO_2 source**: aerosol atomizer using CeO_2 powder suspended in H_2O and dryer
- **UV source**: 243 nm produced by frequency conversion using 1064 nm Nd:YAG laser and 630 nm dye tunable laser
- **Charged particle trap**: parallel plate electrostatic trap
- **Particle size spectrometer**: scanning mobility particle sizer (TSI)



Soot has a size peak at ~140 nm and is significantly ionized and trapped when the 243 nm (UV) light is turned on. High concentrations used for this demonstration reduce trapping efficiency. Greater than 95% trapping has been demonstrated using concentrations closer to ambient.



CeO2 has a size peak at ~60 nm and does not ionize at 243 nm and, therefore, is not trapped. Using shorter wavelengths, CeO2 can be ionized and trapped.



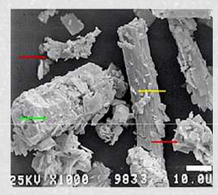
The mixed aerosol of soot and CeO2 shows the expected bimodal distribution with the laser off. With the laser on selective trapping of soot is clearly evident.

Significance

Our technique is versatile and could be used for:

Nuclear nonproliferation and forensics to detect enriched uranium particles

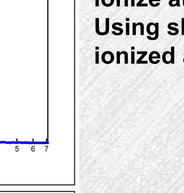
- **Revealing covert activities**
- **Monitoring for treaty verification**



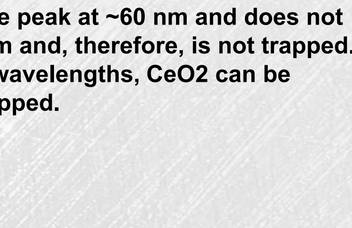
U_3O_8 with platelets of PuO_2*

Explosives detection

Chem / bio warfare detection



Smallpox



Ebola virus

Energy R&D

- **Fossil fuel / biofuel particle sampling for engine development**
- **Coal power plant toxic emissions monitoring**

Diesel soot†

*Tamborini & Betti, *Mikrochimica Acta* 132, 411 (2000).
†Clague et al., *Carbon* 37, 1553 (1999).

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