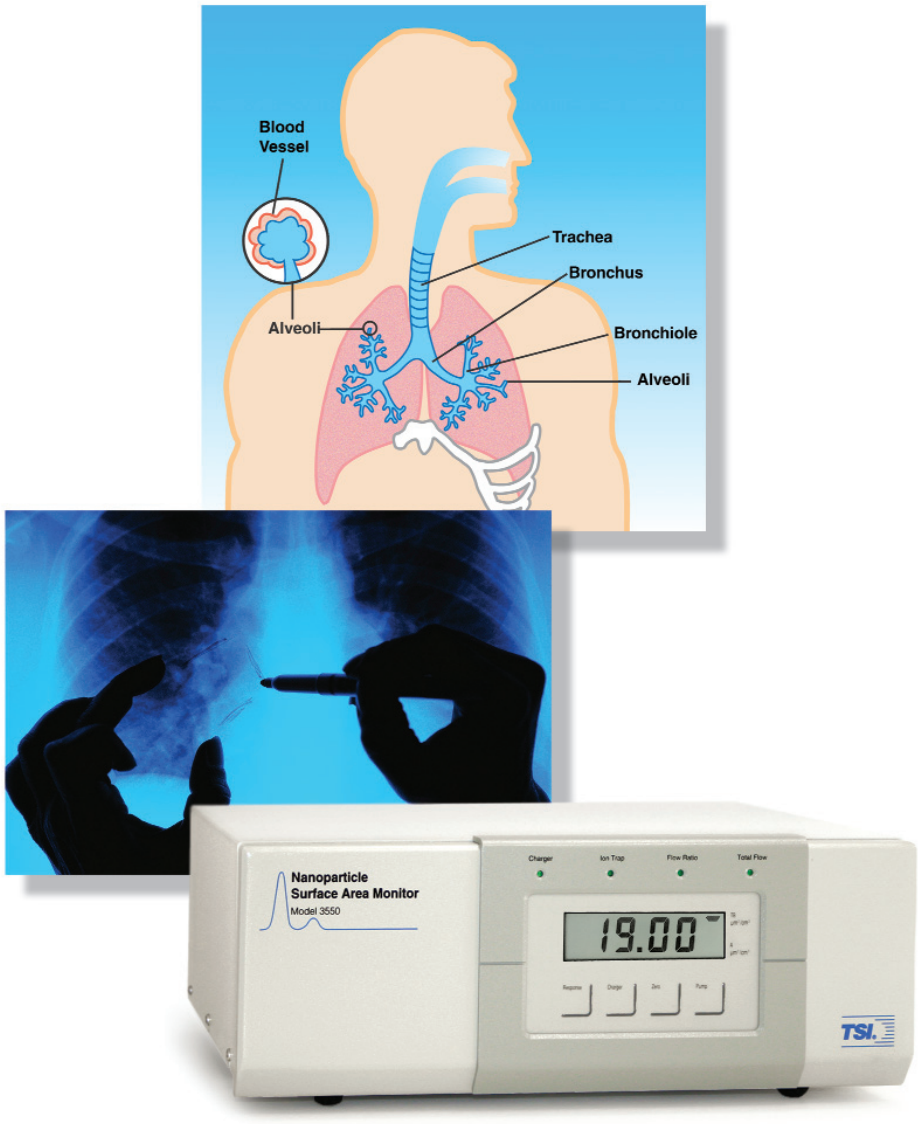
Model 3550
Nanoparticle Surface Area Monitor

Measures lung-deposited surface area of inhaled particles



TSI®

How Do You Measure Nanoparticle Exposure?

There is ever-increasing interest to develop nano-scale materials, structures, and devices on a commercial basis to take full advantage of the unique properties affecting physical, chemical, and biological behaviors that result. However, occupational health risks associated with manufacturing and use of nanoparticles are not clearly understood. Subsequently, workers may be exposed to these nanoparticles through means of inhalation, at levels that greatly exceed ambient concentrations.

Current workplace exposure limits are based on particle mass. However, a growing number of experts contend that surface area, rather than mass, should be measured. Nanoparticles have far more surface area for the same amount of mass of larger particles, which increases the chance they may react with the body (Shanbhag *et al.*, 1994; Oberdörster, 1996; Donaldson *et al.*, 1998). As a result, the need has arisen to assess workplace conditions and personal exposure to engineered nanoparticles based on the measurement of particle surface area.

The Model 3550 Nanoparticle Surface Area Monitor measures the human lung-deposited surface area of particles (reported as $\mu m^2/cm^3$) corresponding to tracheobronchial (TB) and alveolar (A) regions of the lung. The Model 3550 provides a simple and fast solution for measuring the surface area equivalent dose of particles in the size range from 10 to 1000 nm.

Features and Benefits

The Model 3550 offers features and benefits that are important to basic and applied research in the field of occupational health and exposure:

- **Unique measurement.** Obtain surface area equivalent dose of inhaled particles.
- **User-selectable measurement modes.** Configure measurement for TB or A deposition response. Correlate particle dosing in different regions of lung with health end points of interest.
- **Easy to use.** Begin taking measurements within minutes of set up. The 3550 can be operated continuously for unattended, long-term exposure monitoring.
- **Comprehensive data-collection software.** Collect, store, and display data as running average, time-weighted average (8-hour), or cumulative-total deposited surface area.
- **Excellent sensitivity.** Detect nanoparticles down to 10 nm.
- **Wide dynamic range.** Measure concentrations in the range of 0 to 10,000 $\mu m^2/cm^3$, spanning a wide range of exposure dosages.
- **High time resolution.** Data rate of one measurement per second detects short periods of high intensity exposures.

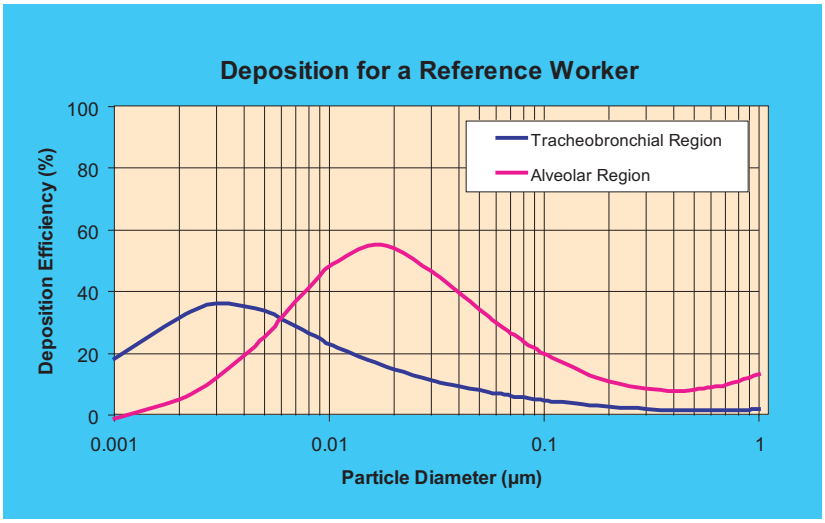


Figure 1. *Fractional deposition of inhaled particles in respiratory tract of a reference worker (source: ICRP-1995).*

Applications

The Model 3550 Nanoparticle Surface Area Monitor is well-suited for measuring and monitoring workplace exposure to nanoparticles and for inhalation toxicology and epidemiology studies of nanoparticles. Recent research (Oberdörster 2001) has shown that lung-deposited surface area plays an important role in toxicity of nanoparticles and is the measurement metric that relates best with particle-induced adverse health effects.

The 3550's measurement (when set to measure either TB or A) matches the corresponding lung deposition of particles for a reference worker as predicted by human-lung deposition model published by the International Commission on Radiological Protection (ICRP, 1995; Figure 1). The deposition is calculated for a reference worker as defined in a publication by the American Conference for Governmental Industrial Hygienists (ACGIH, *ed.* Vincent J.H., 1999). Model 3550 does not measure total surface area of particles suspended in air. Rather, it measures surface area of the fraction of these particles that deposit in the TB or A region of the human respiratory tract.

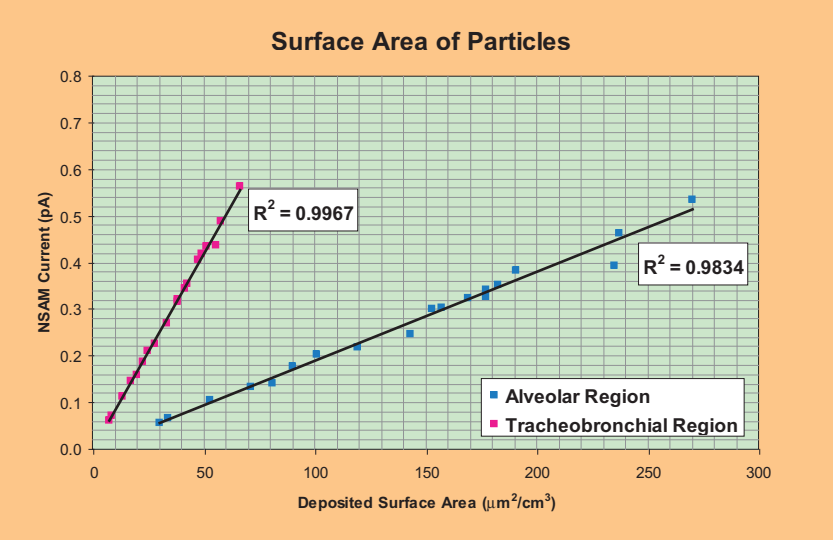


Figure 3. *Surface area of particles deposited in the tracheobronchial and alveolar regions of the lung for a reference worker vs. NSAM current.*

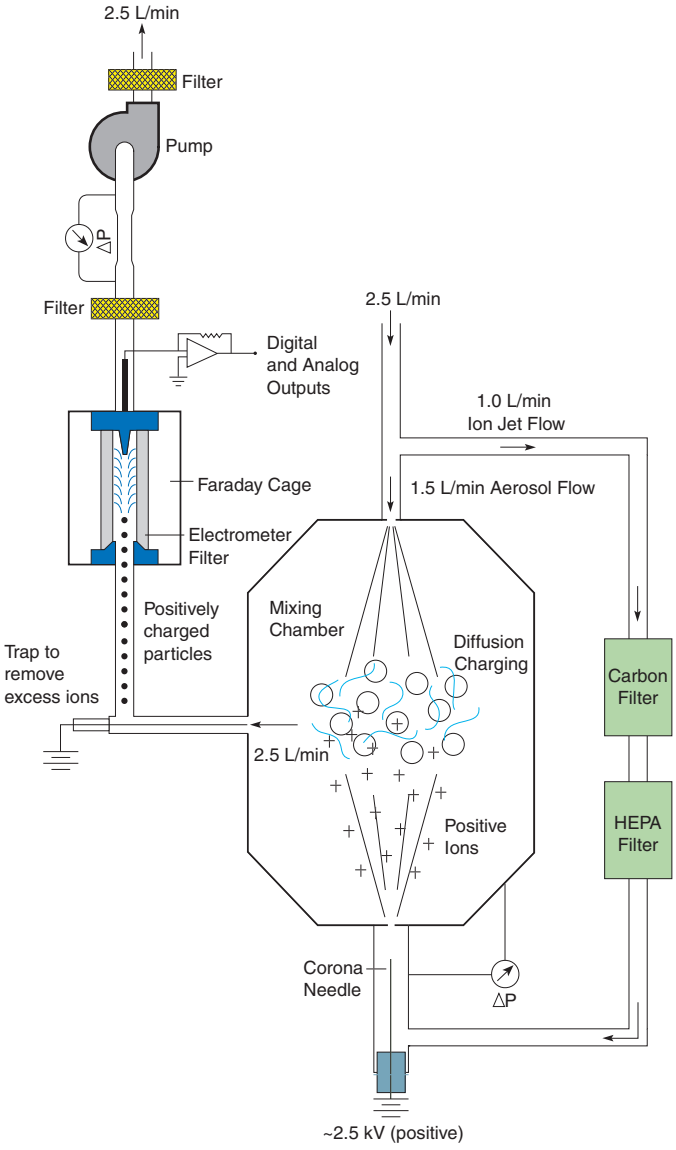


Figure 2. *Model 3550 flow schematic*

Operation

The operating principle of the Model 3550 Nanoparticle Surface Area Monitor is based on diffusion charging of sampled particles, followed by detection of the charged aerosol using an electrometer. As shown in Figure 2, an aerosol sample is drawn into the instrument continuously at the rate of 2.5 L/min. The flow is split with 1 L/min passing through a filter and an ionizer, and 1.5 L/min measured as aerosol flow.

The flows are reunited in a mixing chamber where particles in the aerosol flow mix with the ions carried by the filtered clean air. This patented "counter-flow diffusion charging"* brings the aerosol particles into a defined, charged state. The separation of particles from direct interaction with the corona needle and/or the strong field near it reduces particle losses and makes the charging process more efficient and reproducible. The charged aerosol then passes through a trap to remove excess ions. The aerosol then moves on to an aerosol electrometer for charge measurement. In the electrometer, current is passed from the particles to a conductive filter and measured by a very sensitive amplifier. A microprocessor controls the instrument flows and measures various operational parameters.

As shown in Figures 3, the current signal of the Model 3550 (set to either TB or A response) correlates well with the calculated amount of deposited surface area of particles in respective regions of the lung.

*U.S. Patent No. 6,544,484; additional patents pending

Specifications

Model 3550 Nanoparticle Surface Area Monitor

Particle Size Range	10 to 1000 nm (with 1-µm cyclone)
Measurement Accuracy (20 to 200 nm)†	
TB	±20% or 0.1 $\mu m^2/cm^3$
A	±20% or 0.5 $\mu m^2/cm^3$
Concentration Range	
TB	0 to 2,500 $\mu m^2/cm^3$
A	0 to 10,000 $\mu m^2/cm^3$
Maximum Data Rate	1 reading/sec (1Hz)
Temperature Range	10 to 35°C
Pressure Range	70 to 120 kPa (0.7 to 1.2 atm)
Relative Humidity Range‡	0 to 80%
Front-panel Display	4-digit segmented LCD
Dimensions (HWD)	13.3 × 38 × 28 cm (5.3 × 15 × 11 in.)
Weight	6.8 kg (15 lb)
Computer Requirements	Pentium® 4 processor with 2-GHz speed or better, at least 512 MB RAM
Operating System	Windows® 2000 or Windows® XP operating system or better
Communications Ports	DSUB 9-pin RS-232
Aerosol Inlet	¼-in. OD aluminum tube
Pump Exhaust	¼-in. OD Swagelok® connection
Power Requirements	100 to 240 VAC, 50/60 Hz, 1A maximum

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†Tested for NaCl particles.

‡The instrument will operate optimally under the specified relative humidity conditions. The ICRP-based lung deposition model used to derive TB and A deposition curves in a reference worker (and hence, the instrument's measurement for TB and A regions), does not consider the effect of humidity on particle size.

U.S. Patents 6,544,484 and 7,812,306

To Order

Nanoparticle Surface Area Monitor

Specify	*Description*
3550	Nanoparticle Surface Area Monitor and software

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