NANOPARTICLE SURFACE AREA MONITOR MODEL 3550*

MEASURES LUNG-DEPOSITED SURFACE AREA OF INHALED PARTICLES

Recent research has shown that the surface area of nanoparticles is highly correlated to exposure related adverse health effects. The Model 3550 indicates the surface area of nanoparticle aerosols that deposit in the lung. The reported measurements correspond to the ICRP lung deposition curves for the tracheobronchial (TB) and alveolar (A) regions of the human respiratory tract. The Model 3550 measures particles in the size range of 10 to 1000 nm. This is an important instrument for research in the fields of inhalation toxicology, health effects, and epidemiology, and for measuring and monitoring workplace exposure. Model 3550 offers user-selectable measurement modes, comprehensive software, continuous operation, a wide dynamic range, and high time resolution.

*US Patents 6,544,484 and 7,812,306.

Applications

+ Basic aerosol research
+ Inhalation toxicology
+ Industrial hygiene research
+ Health effects studies
+ Epidemiology studies
+ Occupational exposure monitoring

Features and Benefits

+ Selectable measurement modes for tracheobronchial (TB) or alveolar (A) deposition response
+ Comprehensive software for collection, storage, and display of running-average, time-weighted-average (8-hour), or total deposited surface area
+ Simple operation, fast set up, and the ability to run continuously for unattended, long-term exposure monitoring
+ Sensitivity down to 10 nm
+ Over five decades of concentration, from 0 to 10,000 $\mu m^2/cm^3$ spanning a wide range of exposure dosages
+ Data rate of one measurement per second detects short periods of high-intensity exposures

UNDERSTANDING, ACCELERATED

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.

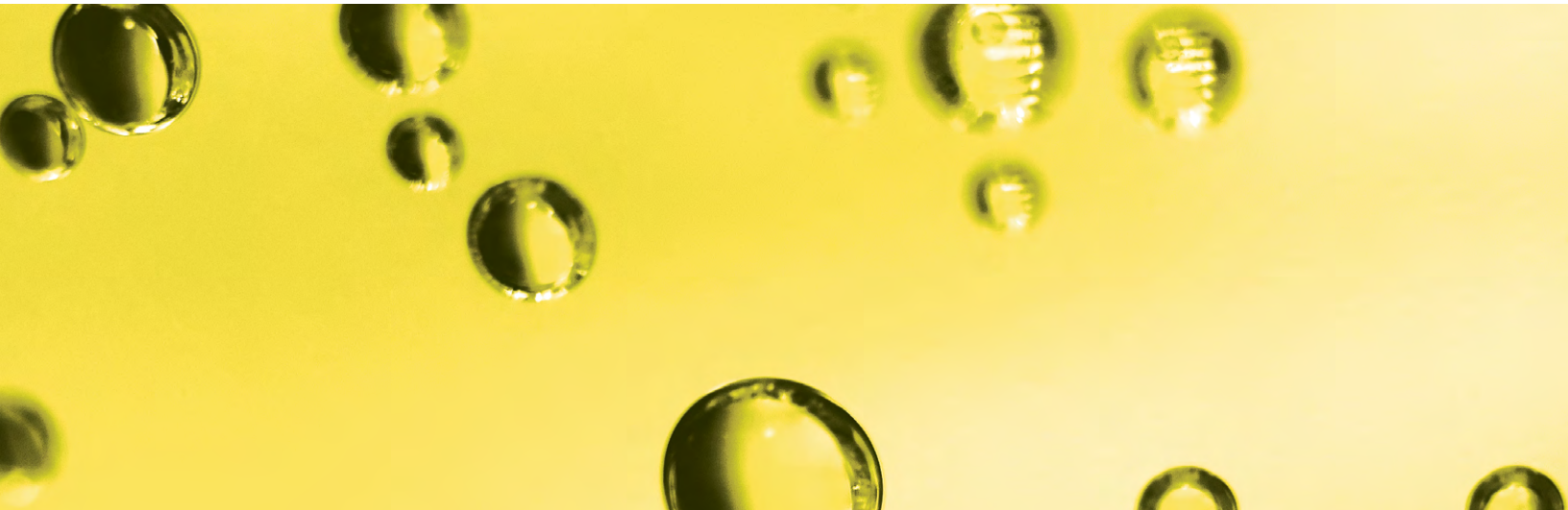
Current workplace exposure limits are based on particle mass. However, a growing number of experts contend that surface area, rather than mass, should be measured. Nanoparticles have far more surface area for the same amount of mass of larger particles, which increases the chance they may react with 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, timeweighted 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.



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.

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 Figure 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.

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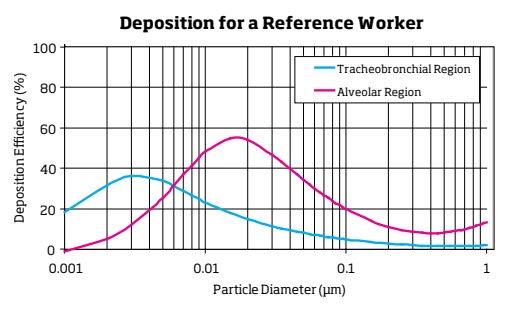

Figure 1. Fractional deposition of inhaled particles in respiratory tract of a reference worker (source: ICRP-1995).

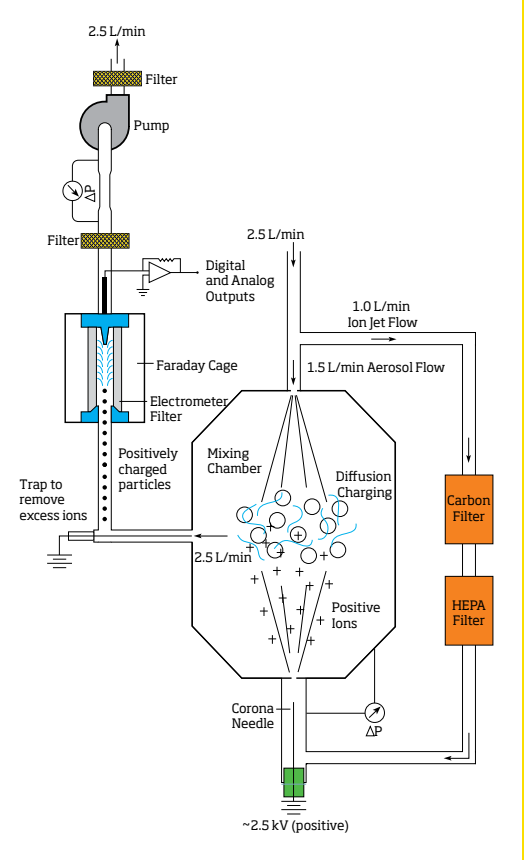

Figure 2. Model 3550 flow schematic.

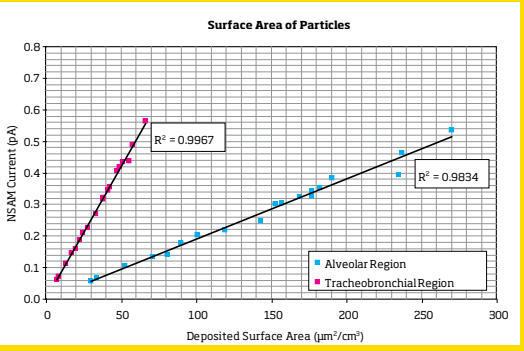

Figure 3. Surface area of particles deposited in the tracheobronchial and alveolar regions of the lung for a reference worker vs. NSAM current.

SPECIFICATIONS

NANOPARTICLE SURFACE AREA MONITOR
MODEL 3550

Particle Size Range
10 to 1000 nm (with 1-µm cyclone)

Measurement Accuracy (20 to 200 nm)†

TB	±20% or 0.1 µm²/cm³
A	±20% or 0.5 µm²/cm³

Concentration Range

TB	0 to 2,500 µm²/cm³
A	0 to 10,000 µm²/cm³

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 (H×W×D)
13.3 cm × 38 cm × 28 cm (5.3 in. × 15 in. × 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
DSUB 9-pin RS-232

Ports

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

Power Requirements
100 to 240 VAC, 50/60 Hz, 200 W maximum

TO ORDER
Nanoparticle Surface Area Monitor

Specify	Description
3550	Nanoparticle Surface Area Monitor and Software

Bibliography

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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.

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