A new simple instrument for real-time monitoring of airborne nanoparticles

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Introduction

During the handling of nanomaterials there is the risk that nanoparticles are released in airborne state, and these nanoparticles might be harmful to health when inhaled by the employees. Thus, there is a growing need for monitoring of nanoparticle concentrations at workplaces and in the environment.

The Scanning Mobility Particle Sizers (SMPS) constitutes the standard instrument for measuring size and concentration of nanoparticles. While such instruments provide a complete size distribution even for very low number concentrations, they offer however a limited time resolution and they are rather large and elaborate to operate.

To evercome these disadvantages of traditional instruments, we have developed the simple portable instrument “Nanocheck” (GRIMM model 1320), which is intended for fast and easy assessment of nanoparticle exposure risks.

Principle of the Nanocheck

The main elements are (1) a Diffusion charger, (2) a condenser, and (3) a Faraday Cup Electrometer.

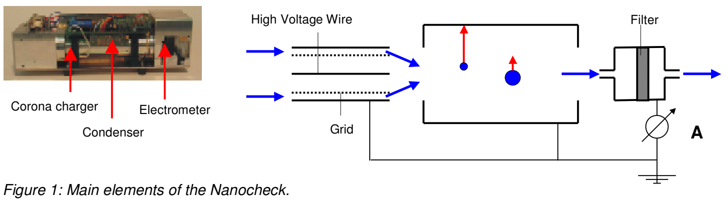

Figure 1: Main elements of the Nanocheck.

Downstream the diffusion charger, particles of diameter d have a mean charge Q: $Q \sim d^{\alpha}$. Measurements are done in two steps. In the first step, the condensor is operated just as an ion trap to measure the total current I_{tot}. In the second step, the condensor is operated at 60 V and the current I_{oE} is measured. The difference between the two currents is denoted as ΔI, $\Delta I = I_{tot} - I_{oE}$.

The mean diameter of the nanoparticles d_{mean} is infered from the ratio $I_{tot} / \Delta I$, this ratio increases with increasing d_{mean} since the fraction of the number of particles that is removed by the condensor decreases with increasing particle size. The difference is mainly attributable to the particle size dependent slip correction factor.

The total number concentration N can then be infered from I_{tot} , which is roughly a measure for the product N x d_{mean}.

Each individual instrument is calibrated with a set of monodisperse NaCl particles. The mobility diameters set with a differential mobility analyser (DMA) serve as a reference for particle diameters, and concentration measurements by condensation particle counter (CPC) as a reference for total number concentrations.

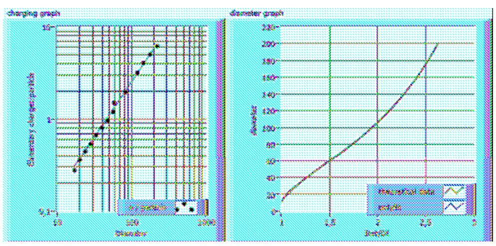

Figure 2: Example data from the calibration. Left: Charge on the particles as a function of particle size, right: Particle size as a fuction of the ratio $I_{tot} / \Delta I$.

Specifications

Measured parameters:	Total number concentration and mean particle diameter
Particle size range:	25 – 400 nm
Detection limit:	~ 500 1/ccm (dependent on particle size)
Zero calibration:	Automatic, before measurements
Sample Flow Rate:	1.2 lpm
Time resolution:	Selectable, 10 s – 1 h
Maintenance:	Filter change after 6 months (at normal use), annual calibration recommended
Communication:	RS232 and analog (0 – 5 V)
Operating conditions:	0 – 35°C, 0 - 95% RH (intergrated dryer)
Power:	10 – 24 VDC
Dimension:	7 x 7 x 24 cm
Weight:	1.4 kg

Measurements with the Nanocheck

The Nanocheck can be operated with any GRIMM optical aerosol spectrometer that cover the size range of larger particles (250 nm – 32000 nm). For indoor measurements, aerosol spectrometer and Nanocheck form a battery powered portable system, and the monitoring of Nanoparticles is accomplished along with the standard measurents for occupational health (inhalable, thoracic and alveolic mass concentrations according to EN 481). The Nanocheck can as well be used for outdoor environmental measurements, in this case the monitoring of nanoparticles is accomplished together with the determination PM10 or PM 2.5 mass concentrations. Alternatively, number size distribution or mass size distribution of larger particles can be measured in 31 size channels simultaneously with the monitoring of Nanoparticles, both for indoor and outdoor systems.

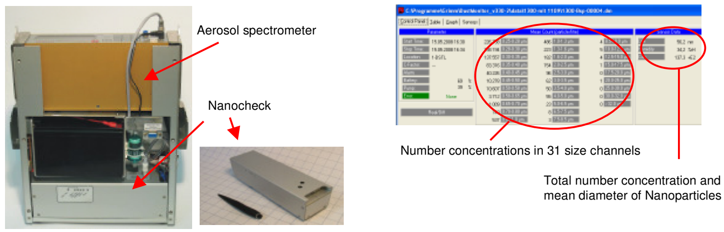

Figure 3: Left: The portable combination of Nanocheck and aerosol spectrometer for indoor workplace monitoring , right: output of the instrument .

Applications

(A) Monitoring of workplace concentrations

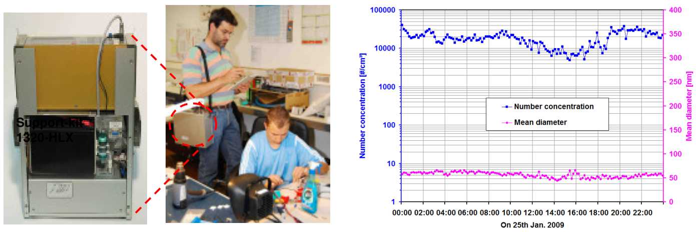

Figure 4: Left: Monitoring of nanoparticle concentration during soldering. Right: measured number concentrations and mean diameter.

(B) Monitoring of ambient nanoparticles

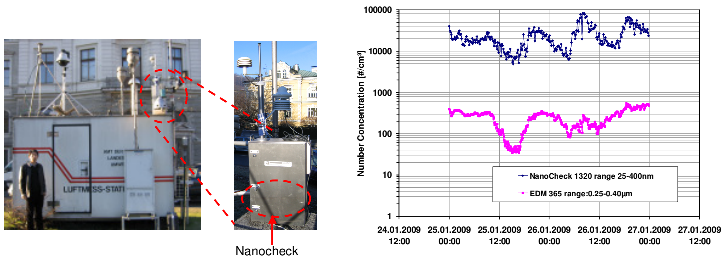

Figure 5: Left: Monitoring of ambient nanoparticles in Salzburg, Austria. Right: Total number concentrations measured with the Nanocheck and optical aerosol spectrometer.

These measurements served as a test of the Nanocheck at rugged conditions with low temperatures and high humidities. A remarkably good correlation of number concentrations in the size range 25 – 400 nm (measured by the Nanocheck) and the concentrations in the size range 250 – 400 nm (measured by the optical spectrometer) was observed at this site.

Summary

The Nanocheck is a small mobile instrument to measure total number concentrations and mean diameter of nanoparticles with a time resolution of 10 s.
The Nanocheck is used together with an optical aerosol spectrometer, which serves for the measurement of larger particles. Thus the monitoring of nanoparticles can be accomplished simultaneously with the well established measurement of mass concentrations. The instrument can be used both for indoor measurements of workplace concentrations, and for outdoor measurements of ambient nanoparticles.