A fast-scanning DMA train for the precision quantification of nanoparticle dynamics

P.M. Winkler[1,2], J. Ortega[1], P.H. McMurry[3], J.N. Smith[1,4]

[1]Atmospheric Chemistry Division, National Center for Atmospheric Research, Boulder, CO, USA
[2]Fakultät für Physik, Universität Wien, 1090 Vienna, Austria
[3]Department of Mechanical Engineering, University of Minnesota, Minneapolis, MN, USA
[4]Department of Applied Physics, University of Eastern Finland, Kuopio, Finland
Keywords: Nanoparticle dynamics, size distribution, time resolution, DMA train.
Presenting author email: paul.winkler@univie.ac.at

Nanoparticle dynamics can be measured reliably by SMPS if the size distribution is changing slowly in the course of a single scan. Once the size distribution changes significantly during one scan, the resulting distortion may heavily impact the correct interpretation of the relevant distribution parameters. The need for instruments reliably analyzing nanoparticle growth at high time resolution has been pointed out recently (Winkler et al., 2012).

In this study we report on a new experimental device dedicated to the precision measurement of freshly formed growing nanoparticles. To this end, we combine a set of five differential mobility analyzers (DMAs) into a so-called DMA train in which each DMA is set to classify a single fixed particle size. The DMA train is specifically designed to resolve growth rates exceeding the time resolution provided by conventional SMPS.

The DMA train presented here utilizes five TSI 3085 nanoDMAs together with four TSI 3025 ultrafine condensation particle counters (UCPC) and one diethylene-glycol (DEG) based CPC (Iida et al., 2009). Thereby, size information can be retrieved from large clusters around 2 nm mobility diameter and upwards. DMAs were usually operated with sheath and excess flow rates of 15 L min^{-1} and a 1.5 L min^{-1} aerosol flow. The DMA in combination with the DEG-CPC, however, was operated at 20 and 2 L min^{-1}, respectively. In order to minimize particle losses in the lines to the DMAs transport flows of 8.7 and 2.3 L min^{-1} were used for particle sizes below and above 5 nm, respectively.

The performance of the DMA train was tested under laboratory conditions using the NCAR biogenic aerosol chamber. The 10 m^3 chamber is continuously flushed with HEPA filtered dry zero air together with the precursor vapor until a steady-state monoterpene (α-pinene) concentration of ~4 ppb is reached. Particle formation is subsequently initiated by increasing ozone to about 40 ppb. Gas-phase products were monitored using a proton transfer reaction time-of-flight mass spectrometer (PTR-TOF-MS). Particle evolution was monitored with the DMA train.

Figure 1 illustrates the time evolution of different particle sizes as measured by the DMA train. The particle sizes shown were obtained from two consecutive chamber runs under identical conditions. The reproducibility of size distribution data clearly indicates stable conditions in the chamber and supports the reliable operation of the DMA train. As can be seen, all particle sizes show a steep increase in concentration from basically zero to full appearance within 7-8 minutes. Obviously, a regular SMPS with a typical 5 minute scan time would not be able to resolve the particle dynamics correctly. Also it is important to note that the results shown here are statistically significant for raw counts as low as 0.1 cm^{-3}. This is a consequence of the averaging that can be performed due to the sampling at fixed sizes.

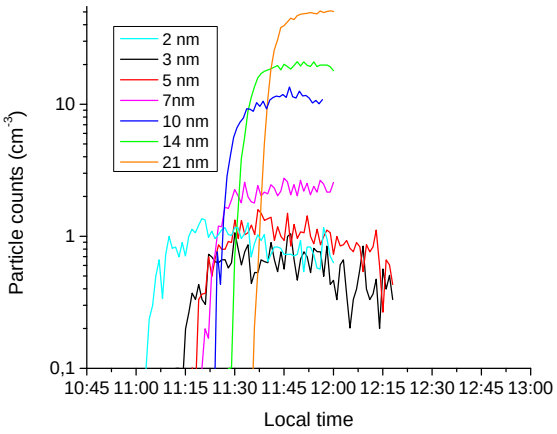

Figure 1. Raw data obtained from two consecutive formation events in the NCAR biogenic aerosol chamber under identical conditions. Chemical reaction was initiated at 10:45.

For the study of early nanoparticle growth we have designed a DMA train operating five DMAs equipped with CPCs in parallel at fixed sizes. Features of the DMA train include size distribution scan times of one second for a size range between 2 and 20 nm. Statistically significant data could be obtained for classified particle concentrations as low as 0.1 cm^{-3}. The performance test in a chamber study of α-pinene ozonolysis under close-to-ambient conditions demonstrates the superiority of this set-up over regular SMPS for the purpose of growth analysis.

This work was supported by the Austrian Science Fund (FWF): J3198-N21. The National Center for Atmospheric Research is supported by NSF.

Winkler, P. M., et al., *Geophys. Res. Lett.* **39**, L20815 (2012).
Iida, K., et al., *Aerosol Sci. Technol.* **43**, 81 (2009).