New developments for fast, high resolution and transmission DMA measurements

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This work reviews new developments for a fast, high resolution and transmission mobility measurements using differential mobility analysis, DMA, including: (i) a low response time, low noise electrometer; (ii) a Static Dissipative Polyurethane tube for high sample outlet transmission and (iii) a HEPA filter to avoid the survival of any charged neutral particles in the recirculating sheath gas, all tested separately with the supercritical, high resolution Halfmini DMA available from SEADM (Fernandez de la Mora, 2013)

Existing supercritical differential mobility analyzers (DMAs) designed for high resolution classification of nanoparticles are short and operate at relatively high gas velocities, resulting in particle residence times typically below 1 ms. Some existing operational amplifier-based electrometers with amplifications of 10^{12} or 10^{11} V/A have response times of ~ 100 and 10 ms (SEADM, 2016), with excellent noise levels providing sensitivities down to less than one or a few fA. Combination of these two elements should accordingly enable the measurement of high resolution spectra in the 1-10 nm size range in times on the order of 1 s. Based on an amplifier circuit developed by Prof. H. Burtscher, two such fast electrometers have been installed in a Faraday cage of small residence time (volume), and used as detectors for a Halfmini DMA (Perez-Lorenzo et al. 2016). Selecting a monomobile ion by setting the DMA voltage at a certain value V_{DMA}, and grounding it periodically, we challenge the detector with a pulsed aerosol current. Both electrometers take 20 ms to provide any response, apparently as a result of dead volumes between the DMA and the charge-collection electrode. The current then rises to half the maximum signal within approximately expected times of about 5 and 25 ms, respectively at 10^{11} and 10^{12} Volt/A. Occasional spikes in the electromenter signal are readily distinguished from the ordinary noise, and do not interfere with identification of mobility peaks. Discounting these spikes, the rms noise level of the 10^{12} V/A device is 0.12 fA when acquiring data at 1 Hz. No ion mobility peak distortion is seen when dwelling for 100 ms at each of the discrete DMA voltages included in a mobility spectrum. The maximal speed of spectral acquisition is investigated in detail with the 10^{11} V/A electrometer by taking mobility spectra of the ions from electrosprayed tetraheptylammonium bromide clusters. We sweep V_{DMA} continuously up and down over 600 V in a saw tooth wave, at a rate of up to 1200 V/s. Very little peak shape distortion is observed, but a clear shift in mean voltage V_{DMA} is apparent, which is symmetric with respect to up or down sweep. The magnitude of this peak translation is linear with sweep frequency, corresponding almost exactly to a pure delay t= 25 ms in the electrometer response. Accordingly, the displacement may be simply offset by adding the correction ΔV_{DMA}= t (dV_{DMA}/dt) to the measured peak voltage. Undistorted high resolution mobility spectra may accordingly be taken in times certainly shorter than 0.5 s, probably even in less than 0.1 s. These tests spanned only a factor of 2 in mobility. Spanning with an exponential voltage sweep at the same resolution the size range from 1 to 10 nm would take (ln100)/ln4=6.64 times longer.

We also address the problem of electrophoretic losses at the outlet of DMAs, which commonly results in a drastic reduction of transmission. The sample transmission efficiency of the Halfmini DMA for mobility-selected ions brought to ground through a Static Dissipative Polyurethane tube is examined (Attoui et al. 2016). The response is reasonably close to ideal, but slight geometrical non-idealities are apparent from small decreases in transmission under accelerating bias voltages.

Finally, the performance of a compact HEPA filter capturing charged or neutral particles surviving in the recirculating sheath gas (operation in close loop) is briefly discussed.

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SEADM (2016), *High performance Electrometer;* http://www.seadm.com/products/technological-modules/electrometer/