PRODUCT DESCRIPTION

High transmission Tandem DMA for nanoparticle studies

Introduction: The tandem Differential Mobility Analayzer (TDMA) is a powerful combination for particle analysis first introduced by McMurry and colleagues, which has been used to measure accurately electrical mobility changes in aerosol particles associated to evaporation, condensation, chemical reactions, charge reduction (or charge evaporation), nucleation, etc. This system produces particularly rich information when exploited to investigate molecular ions or small clusters, since particle diameter is in this case discrete, and a series of well defined peaks rather than a continuum mobility spectrum is obtained (Figure 1).[1]

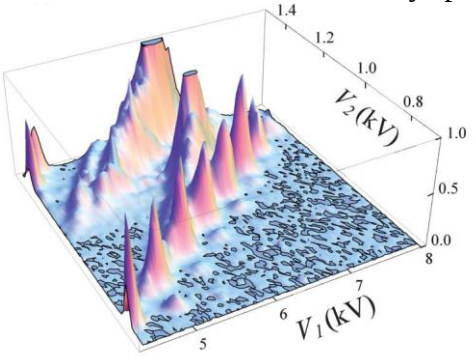

Figure 1: Representation of the charged particle signal detected versus the voltages of the 2 DMAs in a TDMA system, for the complex cluster pattern formed on electrospraying a solution of an ionic liquid with structure $[A^+B^-]$. Each of the sharp peaks seen is associated to a cluster $(AB)_nA^+_z$. The main series of peaks in the diagonal line to the right is associated to ions undergoing no changes between both DMAs. The small peaks to their right result from evaporation of a single salt molecule. Peaks to their left order themselves in various lines associated to various levels of charge loss.

The potential of TDMAs for cluster studies has been traditionally limited by low resolution at nanometer sizes, a difficulty now resolved by use of supercritical DMAs. These devices keep the flow laminar at Reynolds numbers considerably larger than 2,000, offering resolving powers up to 100 at 1 nm. Early TDMA investigations of molecular clusters were facilitated by the development at SEADM of software to perform quasi-continuous scanning of the voltages of both DMAs, producing a single data file that may be represented and analyzed in the form of complete two-dimensional mobility maps such as seen in Figure 1.[2] This early work, however was limited by the slow response time (~1s) of existing detectors (CPCs and electrometers), and by the modest transmission efficiency of intense space-charge dominated ion sources into the analysis region of the first cylindrical DMA. This problem has been overcome by the commercial development at SEADM of supercritical parallel plate DMAs, where the source of nanoparticles may be placed in the close vicinity of the inlet slit (rather than sampled through a tube and then distributed into an annular chamber before being passed to a cylindrical aerosol

[1] M. Attoui, M. Paragano, J. Cuevas, and J. Fernandez de la Mora, Tandem DMA generation of strictly monomobile 1-3.5 nm particle standards, Aerosol Sci. and Tech., **47(**5**).** 499-511**,** 2013
[2] M. Attoui, J. Fernandez-García, J. Cuevas, G. Vidal and J. Fernandez de la Mora, Charge evaporation from nanometer polystyrene aerosols. J. Aerosol Sci. 55 (2013) 149-156

inlet slit).[3] The result is a high transmission of the nanoparticles from the source to the first DMA. Once in the analyzing region of the first DMA, separation of the various ion mobilities decreases drastically the space charge problem, leading to good transmission of mobility-selected nanoparticles into the second DMA and the detector, even when the second DMA is of the more affordable cylindrical type. This physical accessibility advantage of parallel plate DMAs applies equally to problems where high initial concentrations of particles or a high initial temperature leads to rapid particle coagulation or chemical reactions, such as in laser ablation sources, flames, electrical discharge sources, etc. Flat DMAs sample preexisting charged particles into the separation region in times that may be as small as 1 μs. Once there, the sheath air achieves an essentially instantaneous dilution and freezing of reactions, condensation or coagulation processes. Note in particular that this interruption of all kinetic processes is achieved without dilution of the particle sample, so the transmitted signal is orders of magnitude higher than in cylindrical DMAs. This multiplication of the signal then permits much faster electrical measurements yielding rich 2D mobility spectra in minutes rather than tens or hundreds of minutes. While supercritical TDMAs have been used already with electrospray sources, their exploitation in most other particle generation systems producing high nanoparticle concentrations in very short times remains completely unexplored. This instrument therefore offers a high potential for scientific discovery in areas such as combustion, laser ablation, nucleation, sparks and other discharge sources, etc.

Commercially available tandem DMA system from SEADM. A complete tandem DMA system for nanoparticle research is available from SEADM, including the following components:

1) **Parallel plate DMA P5**, with hardware (leak tight pump with precision velocity control, closed loop connections, cooler) and control software (Figure 2). This DMA is also available coupled to several commercial mass spectrometers, and may be coupled to an existing mass spectrometer with an atmospheric pressure source. Complete DMA-MS systems are also available.

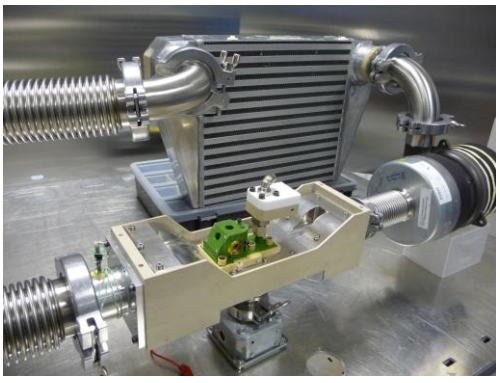

Figure 2: Parallel plate DMA with it's complete recirculation circuit (blower, right; cooler, top; closing circuit partly seen on left), electrospray source (green, above DMA) and electrometer amplifier (below DMA). Its main advantage over conventional cylindrical DMAs is its high transmission, even of ions and particles 1 nm in diameter, particularly from high space charge or high concentration sources of nanoparticles, such as electrospray, laser ablation, flames, etc. The instrument is ideal for combining in tandem with a second device, such as a mass spectrometer or another DMA.

2) **Electrometer detector** (see item below Cylindrical DMA in Figure 3). This instrument has a response time of 1 s with a noise level below 1 fA and a conversion factor of 10^{12} V/Amp. A 10x

[3] J. Rus; D. Moro; J.A. Sillero; J. Royuela, A. Casado, J. Fernández de la Mora, IMS-MS studies based on coupling a Differential Mobility Analyzer (DMA) to commercial API-MS systems, Int. J. Mass Spectrom, **298**, 30-40 (2010)

amplification scale is included. A configuration better suited for TDMA work with 0.1 s response time and conversion factor of 10^{11} V/Amp is also available.

3) **Software** to control both DMAs yielding a two-dimensional representation of results (Fig.1).[4]

4) **Cylindrical DMA Halfmini-3/20 model** (Figure 3)[5]

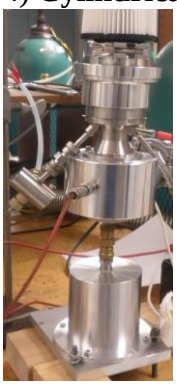

Figure 3: Image of the handheld cylindrical DMA Halfmini-3/20 model plate DMA. This instrument is ideal as a second device in a tandem DMA system, given its considerably lower cost than parallel plate DMAs. It is less appropriate as first element due to its much smaller transmission (much higher sampling time) for charged nanoparticle sources with high concentration or high space charge. A tandem DMA system based on two cylindrical DMAs is recommended only for work with particles with low space charge or concentrations low enough for coagulation through a 1 ms sampling period not to be of concern. The DMA in the figure rests above an electrical detector bolted to the table.

Ordering and enquiries

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[4] Provided free of charge, but requiring availability of commercial Matlab and Labview software, not included.
[5] J. Fernández de la Mora and J. Kozlowski, Hand-held differential mobility analyzers of high resolution for 1-30 nm particles: Design and fabrication considerations. J. Aerosol Sci. (57) March, 45-53, 2013.