A Drift Tube Ion Mobility Spectrometer (DT-IMS) combined with a Condensation Particle Counter for Analysis of Sub 10 nm Aerosol Particles

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Drift tube-ion mobility spectrometer (DT-IMS) devices allow for determination of the electrical mobilities of charged particles through measurement of the time necessary for a particle to travel a fixed distance through a tube in the presence of an electrostatic gradient. These instruments have traditionally been limited to measurements of ionized molecules and small (~1 nm) cluster ions. Previously developed devices are not able to sample charged aerosol particles from the ambient because of the high electric fields present at the beginning of the drift region. An additional limitation of existing DT-IMS devices is the low sensitivity of the Faraday Cup Electrometers at concentrations found in typical aerosols. Conversely, DT-IMS devices have the advantages of mobility invariant high resolving power (>R~20), low drift gas flow rates compared to differential mobility analyser (DMA) sheath gas flowrates and shorter measurement times as compared to most scanning differential mobility analyses. Therefore, modification of such devices, such that they can be coupled to sensitive condensation particle counters (CPCs) and used for aerosol particle electrical mobility measurement is of interest.

We have made such modifications, developing a DT-IMS applicable for 2-10 nm aerosol particle analysis, which is described in this presentation. The modifications to traditional DT-IMS devices required for application in ambient pressure aerosol measurement include a novel gateless sample introduction scheme, and the ability to couple to an aspirating CPC. The gateless sample introduction, with particle pathlines and electrical field strengths depicted in Figure 1, uses a combination of a controlled flow path and stepped voltage at the start of a measurement to effectively select a 'packet' of aerosol. Additional aerosol is not able to enter the sample region after the start of a measurement due to the presence of an electrostatic field. The coupling to a CPC requires a controlled flow that splits to provide the drift gas and the gas aspirated by the CPC at the drift tube outlet. A prototype device with these inlet and outlet modifications has been constructed and tested. Example results for charge reduction electrospray generated Cytrochrome C aerosol particles are shown in Figure 2. The prototype DT-IMS has a linear relationship between drift time and mobility, a resolving power greater than 10, and can measure 2-10 nm aerosol particle electrical mobility distributions in less than 5 seconds.

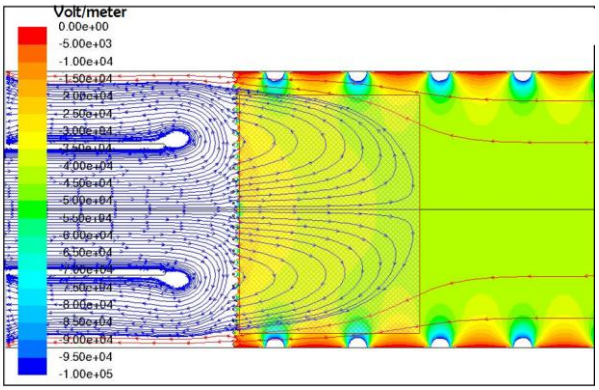

Figure 1. The pathlines (blue) of aerosol particles entering the inlet of the DT-IMS when the electric field is not applied. Color contours reveal the intensity of the electric fields when applied; these fields drive aerosol particles within the sample packet zone down drift tube (to the detector).

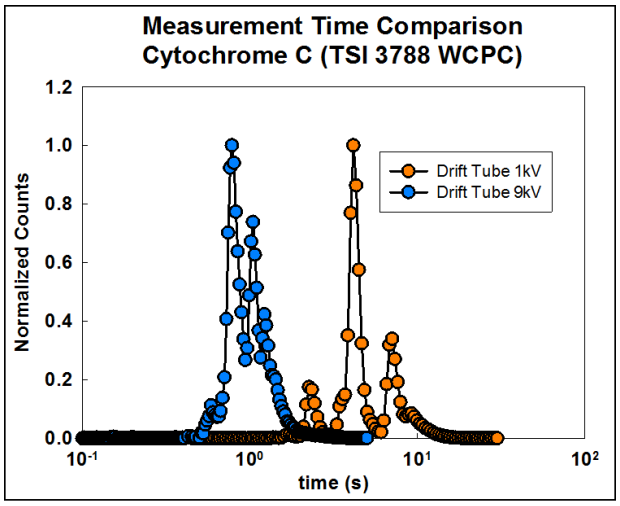

Figure 2. Normalized CPC signal intensity as a function of drift time (inversely proportional to electrical mobility) for electrosprayed Cytochrome C in the DT-IMS. The most prominent peaks in the displayed distributions correspond to the singly charged monomer ion at 3.15 nm mobility diameter, with the peak to the right corresponding to the Cytrochome C dimer (4.35 nm). Longer drift times enable greater peak separation.

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