Development of a Miniature Electrical Ultrafine Particle Sizer (mini-eUPS)

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Multiple particle sensors with the built-in networking feature are in high demand for continuous monitoring of near-surface fine and ultrafine particle (UFP) size distributions in cities where heavy traffic is often encountered and/or in residential communities in close proximity to freeways. The monitoring of near-surface fine and ultrafine particles stems from the recent epidemiologic studies evidencing UFPs are particularly relevant to human health, like pulmonary diseases (Hoek et al, 2002; Stewart et al, 2010). The increased asthma prevalence has also been found to often occur in the area with high UFP levels in ambient air (Samet et al, 2008). However, the near-surface variation of fine and ultrafine particles is often significant because of random near-surface wind variation and high diffusivity of UFPs. Multiple sizers are thus required to measure the near-surface variation of UFPs. Under the consideration of budget limit, it is very desirable to have cost-effective particle sizers in compact package and having the capability of networking together. Future applications such as the traffic control in smart cities, early fire detection in buildings and hospitals, indoor air quality monitoring and control, worker protection in the facility producing and processing UFPs and vertical profiling of UFPs will be feasible if the above-stated sizers were attainable. In this work we have developed a new miniature UFP sizer (i.e., mini-eUPS) based on particle electrical mobility technique for the above applications.

The prototype mini-eUPS consists of three major components, i.e., mini-plate aerosol unipolar charger, mini-plate DMA and mini Faraday cage with a sensitive pre-amp. The temperature (T) and relative humidity (RH) of sampled aerosol flow are also measured at the sizer inlet. The aerosol inlet is integrated with a mini-plate aerosol charger. In the charger, unipolar ions are generated via the corona discharging of a 50-µm-in-diameter tungsten wire and passed sampled aerosol through a designed flow channel next to the ion-generation chamber. An iphone-sized DMA in the parallel-plate configuration (i.e. mini-plate DMA) is applied to classify particles according to their electrical mobilities. Aerosol and sheath flowrates are monitored and controlled to ensure the proper operation of the mini-plate DMA. A mini-Faraday cage with a sensitive electrometer is applied at the downstream of mini-plate DMA to measure number concentration of classified particles. With all the filter, pumps, flowmeters, high voltage power supplies, driving circuits and an embedded micro-processor, the developed mini-eUPS has the overall package of 6" (L) × 5" (W) × 6" (H) and the weight of slightly less than 3 lb. Additional to measure the temperature, relative humidity and size distribution of fine and ultrafine particles, the developed mini-eUPS also records the timing as well as the global position and altitude of the measurement. More, the self-diagnosis and wireless communication functions (i.e., data reporting, hopping, downloading and storage) are all included in the prototype. The mini-eUPS can thus work either as a single-alone unit or a node in a wireless sensor network.

The data reduction scheme based on the constrained least square method is included in the embedded micro-processor to quickly retrieve the particle size distributions from measured raw data during the measurement. Fig. 1 shows the size distributions of particles measured by developed mini-eUPS and TSI SMPS. Polydisperse test particles were generated by atomizing salt solutions using a Collison atomizer and dried via a diffusion dryer. The good agreement between the measurements of mini e-UPS and SMPS was obtained. Field testing of the developed mini-eUPS is now in progress. The detail evaluation of mini-eUPS will be given in this presentation.

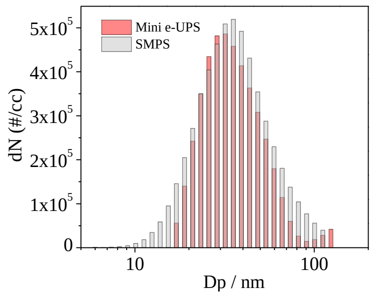

Figure 2 Comparison of particle size distribution measured by mini-eUPS and TSI SMPS

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