Nanoparticles Sampling Techniques for an Aerosol- / Particle Mass Spectrometer

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For the measurement of the particle formation kinetics in technical processes, the Research Centre in Karlsruhe developed a particle mass spectrometer (PMS) specifically for the measurement of the size distribution of primary particles in the flames and plasmas with very high concentrations of particle numbers in the range of 108 to 1012 cm-3. Therefore, an intact sampling technique is needed which is suitable for particles in the size range of a few nm.

The particle mass spectrometer uses a classic molecular beam sampling technique with an inlet nozzle and a second nozzle as a skimmer. The system has been tested successfully covering different nanoparticle sources, such as microwave plasma synthesis, a low-pressure flame and a spark generator. These particles sources are characterized by very small primary particles of a size range from 3 to 10 nm and they generate a very high number concentration, which is difficult to measure online with other measurement methods. The molecular beam technique, as a sampling method, offers the following advantage: Due to the supercritical expansion, the incoming gas is frozen very quickly; furthermore, all interactions between the particles or interactions between particles and gas molecules are blocked within the shortest possible time (ms). On the other hand the disadvantages of this sampling technique are bad particle transmission into the measurement chamber and a very high pumping capacity, which has to be provided for supercritical expansion into the molecular range.

For sampling purpose other Aerosol- / Particle Mass Spectrometers use almost exclusively an aerodynamic lens. The first generation of these lenses was designed for a minimum particle size of 300 nm and a second generation of commercially designed lenses are now available down to 30 nm, which are used in the AMS (Aerodyne) and the ATOFMS (TSI). McMurry has designed and tested an aerodynamic lens for particles smaller then 10 nm. An optimized aerodynamic lens system arisen from CFD-Simulations combines the advantage of a supercritical expansion through a critical nozzle and forms a well-defined beam through a multilevel aerodynamic lens, especially for nanoparticles.

The measurement principle of PMS is based on the deflection of a charged nanoparticle beam by a homogeneous field of a capacitor. The deflection capacitor separates the incoming particles according to their polarity in a negative and a positive charged fraction. The deflection voltage is proportional to the ratio of the kinetic particle energy to its charge ($U \sim ½\ m\ v^2\ /\ z$). By varying the deflection voltage, particles of different energy-to-charge ratio are collected at the faraday cups, which are located symmetrically to the left and right of the centre line at the end of the detection chamber. The current generated at the faraday cup is proportional to the incoming number of particles times their total charge and it is measured with a highly sensitive amplifier. The amplification is 10^{10} V/A with an ultra-low-noise 3-dB bandwidth of 7 kHz. The results can be translated to retrieve the ratio of the kinetic particle energy to the number of charges ($½\ m\ v^2\ /\ z$). To convert this energy spectrum into the particle size distribution, the number of charges (z), the particle velocity and the material density must be known. For an accurate measurement, detailed knowledge of the molecular beam and of the particles included is necessary. Furthermore, the particle speed in the molecular beam, the charge number per particle and the ratio of charged to uncharged particles is also needed.

The quality and the particles transfer of the molecular beam sampling technique were measured with SiO2 - nanoparticles from the microwave plasma synthesis; and the absolute particle mass was detected with a quartz crystal microbalance (QCM) installed in the molecular beam.