Detection near 1-nm with a Laminar-Flow, Water-Based Condensation Particle Counter

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The study of particle nucleation in the atmosphere, as well as in laboratory settings, has driven interest in detection of particles at the onset of their formation. Recently developed condensation particle counters such as the diethylene glycol instrument of Iida et al. (2009) , the mixing instrument of Vanhanen et al. (2011) and butanol instruments of Kuang et al.(2011) and Kangasluoma et al. (2015) have particle size detection limits near 1 nm.

Reported here is a new, water-based condensation particle counter also capable of detection near 1 nm. This "nano-WCPC" employs a three-stage, laminar-flow growth tube that moderates the temperature and water content of the output flow without reducing the peak supersaturation (Hering et al, 2014), and makes feasible operation at the large temperature differences necessary for high supersaturations.

Instrument Description and Methods

As shown in Figure 1, flow enters the nano-WCPC inlet at ~2 L/min, from which a sample flow of 0.3 L/min is extracted. The sample flow passes through a wet-walled growth tube, the first portion of which is cooled to 1-10°C, the second portion is heated to 90°C, and the third is cooled to ~22°C. The optics are held at 40°C. The warmed section, referred to as the "initiator" is 20% of the overall length, and creates the super-saturation for particle activation. The final "moderator" section reduces both water vapor content and temperature, while maintaining the supersaturation. Total length is 180 mm. Liquid water is introduced into the initiator stage at a rate of 1 µL/s using a syringe pump, and the excess accumulates at the bottom of the wick where it is exhausted with the transport flow. The system is implemented using the optics and motherboard from a TSI model 3783.

The nano-WCPC was calibrated using a "half Mini" Herrmann-type high resolution differential mobility analyzer, with confirmation of sizing using tetraheptyl ammonium bromide (THABr, Ude and Fernandez de la Mora 2005). Characterization was extended to 25 nm using the TSI nano-DMA.

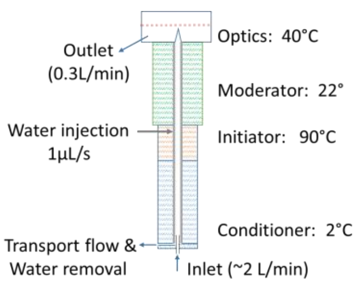

Figure 1. The nano water condensation particle counter.

Results

Figure 2 shows the nano-WCPC response to particles generated by a heated nichrome wire. For an 88°C temperature difference between the conditioner and initiator, the 50% cut-point for this aerosol is 1.5 nm mobility diameter for both positive and negative particle polarities. At these temperatures the nano-WCPC also detects 10%-20% of the ions from either a ^{210}Po or soft X-ray bipolar ion source. Operation at a temperature difference of 80°C essentially eliminates the detection of charger ions, and increases the 50% cut-point for the heated nichrome wire particles to 1.8 nm mobility diameter, as shown in Figure 2.

Initial tests with ammonium sulfate at a 95°C temperature differential indicate 50% detection near 1.0 nm. We also find higher detection for the more water soluble ions of tetrabutylammonium chloride (TBACl) and bromide (TBABr) than for THABr.

Light scatter pulse heights are observed to be very uniform, even though there is no sheath flow, likely due to Stefan flow driving particles towards the centerline.

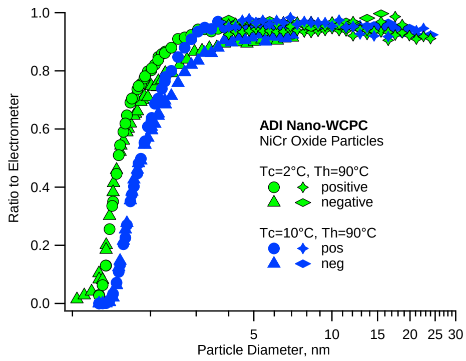

Figure 2. Response of the nano-WCPC to particles from a heated nichrome wire for two sets of conditioner (Tc) and initiator (Th) operating temperatures.

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