Improving the Detection Efficiency of Condensation Particle Counters for sub-2nm Particles: The Temperature Window Effect

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Since its first introduction, the condensation particle counter (CPC; Agarwal and Sem,1980) has been subject to may design improvements and nowadays is considered one of the most important basic instruments for measuring the concentration of aerosol nanoparticles. The performance of a CPC is best described by its detection efficiency (DE). Commercial CPCs suffer from very low DE for particle sizes below 3 nm, mainly due to limitations in the highest supersaturation that can be achieved, without occurrence of homogeneous nucleation.

Previous work (Kuang et al.,2012) has shown that the DE of a CPC for sub 5-nm particles can be improved by increasing the temperature difference (ΔT) between the saturator and condenser tube. This increase lowers the activation barrier, thereby increasing the activation probability of smaller particles.

Here, we introduce a new controlling parameter for improving the DE of continuous flow CPCs. We call this parameter *Temperature Window* (*TW*), defined by the absolute value of the condenser temperature (*Tc*). For example, the same ΔT=30°C is achieved at a T_c=5°C and T_s=35°C, as well as at a T_c =10°C and T_s=40°C. As will be shown, the DE is not the same for these two different TWs. We achieved a significant increase of the DE by maintaining a constant ΔT and shifting to lower TW values (i.e. lower T_c values).

The experimental setup consisted of an electrospray ionization source (ES), a high resolution DMA (half-mini DMA, SEADM), a home-made Faraday cup connected to a Keithley electrometer, and an ultrafine CPC (TSI Model 3025). Tetrabutylammonium bromide ions (TBABr, Sigma-Aldrich) were produced with the ES source in N_2. The first three positively charged n-mers of TBABr had well-resolved single peaks, corresponding to ions with electrical mobility diameters of 1.24 nm (monomer), 1.55 nm (dimer) and 1.73 nm (trimer). The bromide ion produced, when a negative potential was applied to the ES, had an electrical mobility diameter of 0.94 nm.

The DE of the CPC was measured for all of the above-mentioned ions at five different TWs, by keeping ΔT constant at 32°C. The measured DE increased by a factor, ranging from 2 to 8 for the positive ions (fig.1) and by a factor of 35 for the negative ion (data not shown here).

Particle and vapor transport through the condenser tube was modeled using a finite element solver that calculates the mass and heat balance equations simultaneously. It was found that the experimental DE agreed well with predictions. The value of maximum supersaturation along the centerline increases at lower TWs. Most importantly, the activation contour for a given particle size, occupies a larger volume inside the condenser (fig.2) at lower TWs.

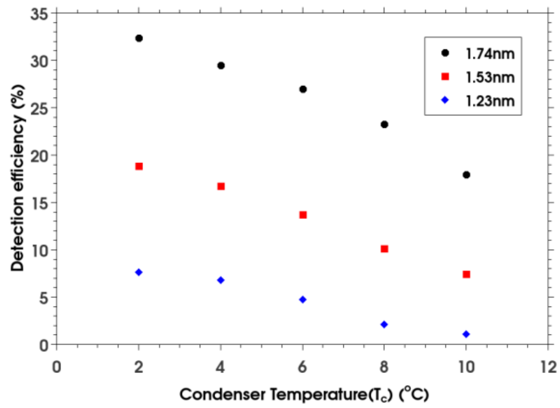

Figure 1. Measured DE for the 3 first n-mers of TBABr as a function of the condenser temperature (ΔT=32°C).

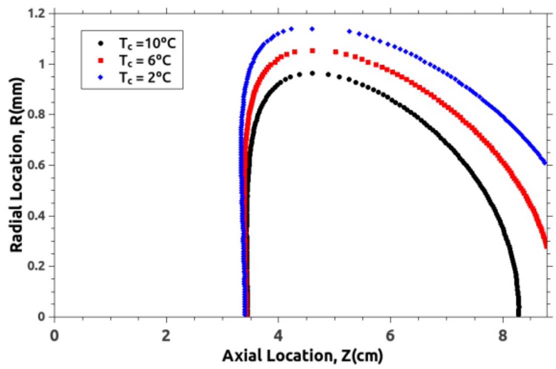

Figure 2. Particle activation contour plot for the TBABr trimer, at 3 different TWs (ΔT=32°C).

In summary, we introduce a new controlling parameter for improving the DE of continuous flow CPCs, namely the temperature window. We report increasing DE for sub-2nm particles and provide a theoretical explanation of this effect.

References

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