Clusters of Ag and Cu from a Through-Flow Spark Generator

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In addition to much potential for metal clusters within materials science (Maisser, 2015), there is a need in the aerosol community for reliable and convenient cluster sources for calibration purposes. In particular, there is a need for systems spanning the range from below 1 nm to several nm (Kangasluoma, 2013).

Spark ablation is a versatile technique for the production of very small particles, ranging from single atoms (Maisser, 2015), to about 10 nm (Schmidt-Ott, 1988). Short electric discharges (sparks) ablate the surface of two target electrodes, and the resulting metal vapor condenses in a flow of gas. Changing spark energy, spark repetition rate and gas flow allows control over particle size. Geometry also plays a role. Maisser (2015) found that a wire-to-rod configuration improved performance for cluster generation, compared to a rod-to-rod configurations. Here, we describe the use of a through-flow configuration with two coaxial hollow electrodes.

The VSParticle Generator 1 (VSP-G1) is a compact, benchtop version of the system developed by Schmidt-Ott (1988), with additional flow ports and automated gap control (Figure 1). The additional flow ports allow convenient customization of the flow conditions in the spark zone. In through flow, the carrier gas enters and exits through the electrodes (paths marked with asterisk), reducing the residence time to ~10ms.

Hollow electrodes of Ag and Cu were used in a flow of 13 slm N_2 of 5.0 purity. Capacitance was 20 nF, the mean voltage was 900 V, and the power was less than 4 W. Clusters were characterized by high resolution (resolving power 37) mobility measurements (Half-mini DMA (by SEADM) with an Airmodus A11 CNC), and an aerosol electrometer as detectors), and by mass spectrometry (API-TOF (Junninen et al. 2010)).

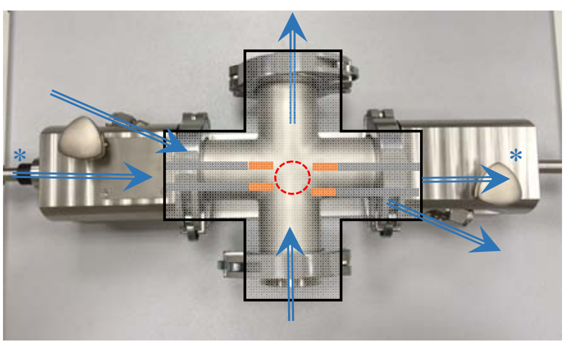

Figure 1. Top view of VSP-G1. Reactor, hollow electrodes and possible flow paths are schematically superimposed.

Size distributions for Ag and Cu in both polarities consist of a peak with a mode round 1.3-1.6 nm, followed by a rather flat band in the 2-5nm range. Stability measurements at fixed mobility show negligible variation in number concentration. Mass spectrometry was used to identify the composition of the clusters. Figure 2 shows mass defect plotted against m/z for positive Ag clusters. The mass defect, Δ, allows convenient distinction between metal and organic species (Kangasluoma, 2013). The bands with positive slope correspond to one or more Ag atoms clustered with several organic ions.
Ag is also present as a single ion (isotopes $_{107}Ag^+$ and $_{109}Ag^+$ at m/z=106.91/108.90, Δ=-0.09/-0.10).

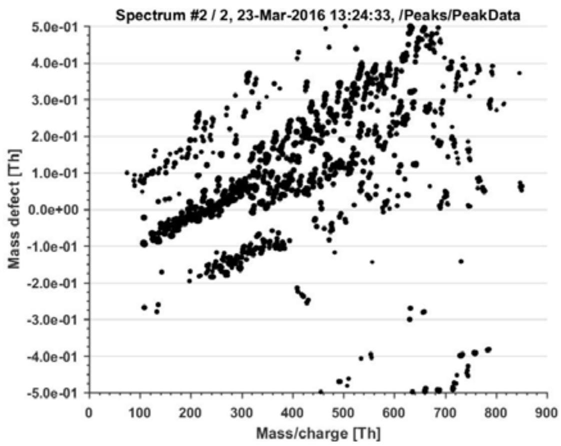

Figure 2. Mass defect vs Mass/charge ratio.

Because of the localized heating in the spark, spark ablation is generally considered a good source of 'uncontaminated' particles (Maisser, 2015). However, the observed abundance of organic species complexed with the metals confirms that gas purity plays a critical role in spark ablation. One explanation is that the spark plasma leads to the formation of reactive species from otherwise inert molecules in the gas.

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