Quantitative TEM sampling

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Introduction

TEM images are ubiquitous in journal articles and talks on aerosols. However, most aerosol samplers perform in an undefined way, and the sampled particles are not representative for the particles present in the gas.

TEM samplers have the potential to introduce two types of sampling biases (and will typically do both):

1) Sampling efficiency may depend on particle diameter
2) Sampling efficiency may be nonuniform on the TEM grid

An ideal sampler would show neither of these effects.

Construction of the sampler

Figure 1 shows the schematic setup of our instrument. Gas is drawn at a flow rate of 0.5lpm through the instrument. Particles are charged in a unipolar diffusion charger, and then brought into a rotationally symmetric deposition zone, where they are deposited onto the TEM grid in an electric field. Particles that are not deposited are detected in an electrometer downstream of the deposition zone. The electrometer is useful to estimate the necessary sampling time for a sensible coverage of the grid.

The rotational symmetry of the sampling zone ensures that the deposition pattern is (at least) rotationally symmetric on the grid.

The entire instrument is 35x25x15 cm in size, and weighs 7.5kg. It is battery-powered for field use.

Finite element modeling

The sampler was modeled with the help of a commercial finite element package (Comsol multiphysics 3.3). Figure 2 shows the calculated deposition of 50nm particles on the grid; the depositon is uniform on the grid. This is important, because uniform deposition means that a single location on the grid is representative for the sample.

Results

Deposition uniformity was verified by counting the number of particles deposited per area over an entire profile of the TEM grid (Figure 3). The modeled deposition efficiency was compared to experimentally determined size-resolved deposition efficiency in the size range of 20…320nm (Figure 4). The model predicts the form of the curve very well, but underestimates the deposition efficiency.

From these measurements, we could derive a calibration curve for the sampler, which can be used to retrieve size distributions from TEM images. Figure 5 shows a comparison of a size distribution measured with an SMPS to the size distribution retrieved from the TEM image.

Conclusions

We have constructed and calibrated a portable TEM sampler. With this sampler it is possible to obtain size distributions directly from a TEM image, and thus to make quantitative statements about an aerosol from a TEM image alone.

The sampler could be miniaturized considerably (by about a factor of 2-3) with little effort.

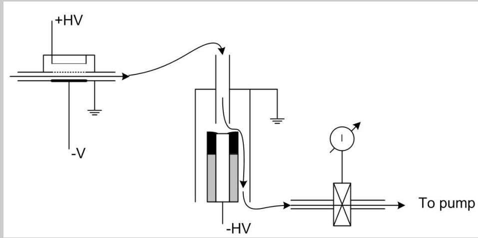

Fig 1: Instrument Setup

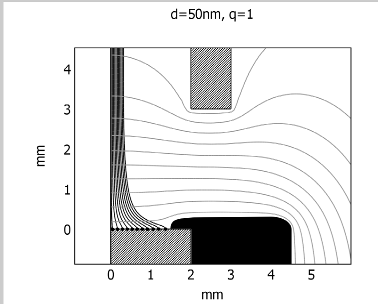

Fig 2: Modeled deposition

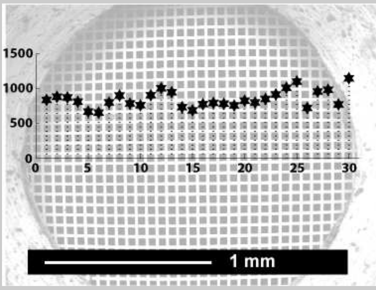

Fig 3: Deposition uniformity

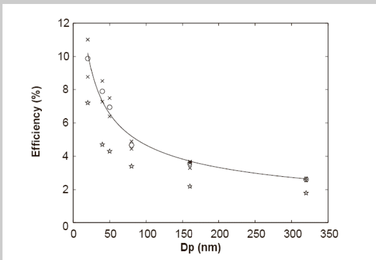

Fig 4: Calculated and measured deposition efficiency

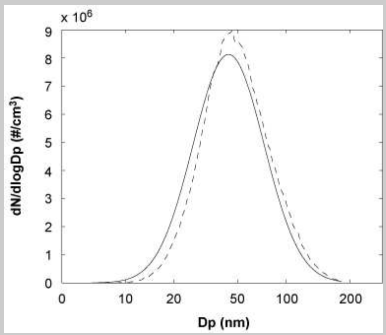

Fig 5: Size distribution measured with SMPS (dashed line) and TEM sampler (solid line)