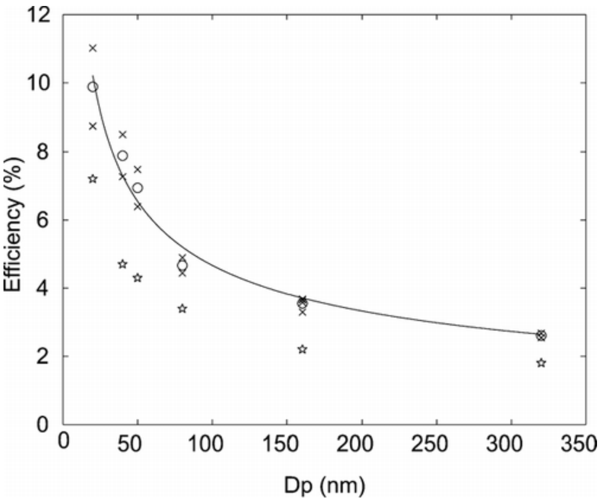
Brief characterization of the naneos miniature TEM sampler

The naneos miniature TEM sampler is loosely based on a previous TEM sampler design of ours that was published in aerosol science and technology. ("Theoretical and Experimental Evaluation of a Portable Electrostatic TEM Sampler", Aerosol Science and Technology 41(5):520-528, 2007; direct link http://www.tandfonline.com/doi/abs/10.1080/02786820701253327). Some things in the miniature TEM sampler are better than the device described in that paper, some are worse. In particular, the miniaturization made some compromises necessary. Nevertheless, the paper is still useful to understand the general concepts behind the electrostatic deposition, since the physics doesn't change. I will compare the current miniature TEM sampler with the original here, and with the original I mean the version described in the AS&T paper quoted above.

We have never studied the performance of our miniTEM samplers as deeply as we did for the original TEM sampler. The results shown below are typically just "anecdotal evidence".

Deposition efficiency

We measured the deposition efficiency of the original sampler at different monodisperse particle sizes; the graph below is from the paper; the stars are the theoretical calculation, the circles are the mean of the experimental data.

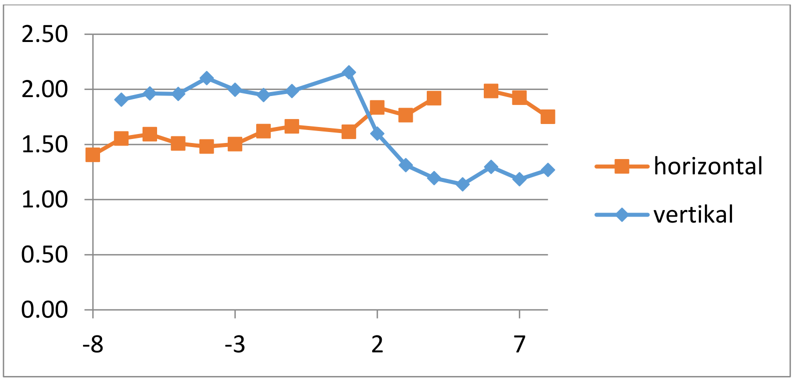


The shape of the deposition efficiency curve is expected to be identical in the new device (i.e. the size dependence should be the same), but we have never measured the deposition efficiency of an individual device at multiple particle diameters; only at single particle diameters, typically at 50nm. Due to the detection principle of the miniature TEM sampler, which requires pulsed charging, the deposition efficiency is lower (since the particles are not always charged); and we also operate at a lower electrical field strength, lowering the deposition efficiency a bit more. In general, the deposition efficiency seems to be **about 2-3% at 50nm diameter** (individual devices show some variation).
Please note that the figure above suggests that sampling efficiency continues to increase for smaller particles. This is not the case, as the very small particles will have a lower charging efficiency, and will be collected less efficiently. It's hard to put a number to this, but I would suspect that 10nm particles will be collected less efficiently than 20nm particles, 5nm particles will hardly be collected at all.

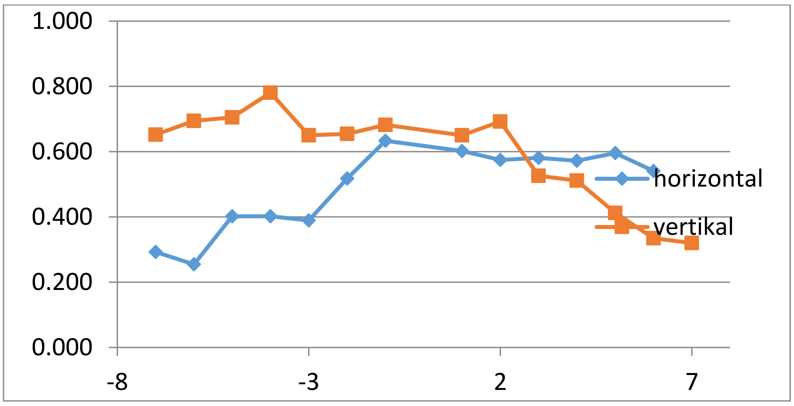
Deposition homogeneity

Due to space constraints, the flow field in the deposition zone is no longer radially symmetric in the miniature TEM sampler (unlike the original). For the original device, we showed that the deposition was uniform over the TEM grid, at least for particles that are not too small (we calculated that e.g.

5nm particles will end up being focused on the center of the grid). This is no longer the case in the miniTEM, **the deposition pattern is nonuniform** because the flow field is nonuniform. It's hard to quantify this nonuniformity, because the orientation of the TEM grid in the sampler is unknown. We tried to quantify something by counting the number of particles per μm^2 of TEM grid area along a "cross" (two straight lines perpendicular to each other through the center of the TEM grid) – but of course, a different orientation of that cross might give a different result. Here's one sample result; the x-axis is the number of fields from the center (basically the entire grid), the y-axis is the number of particles per μm^2 . Particles were 50nm in diameter.



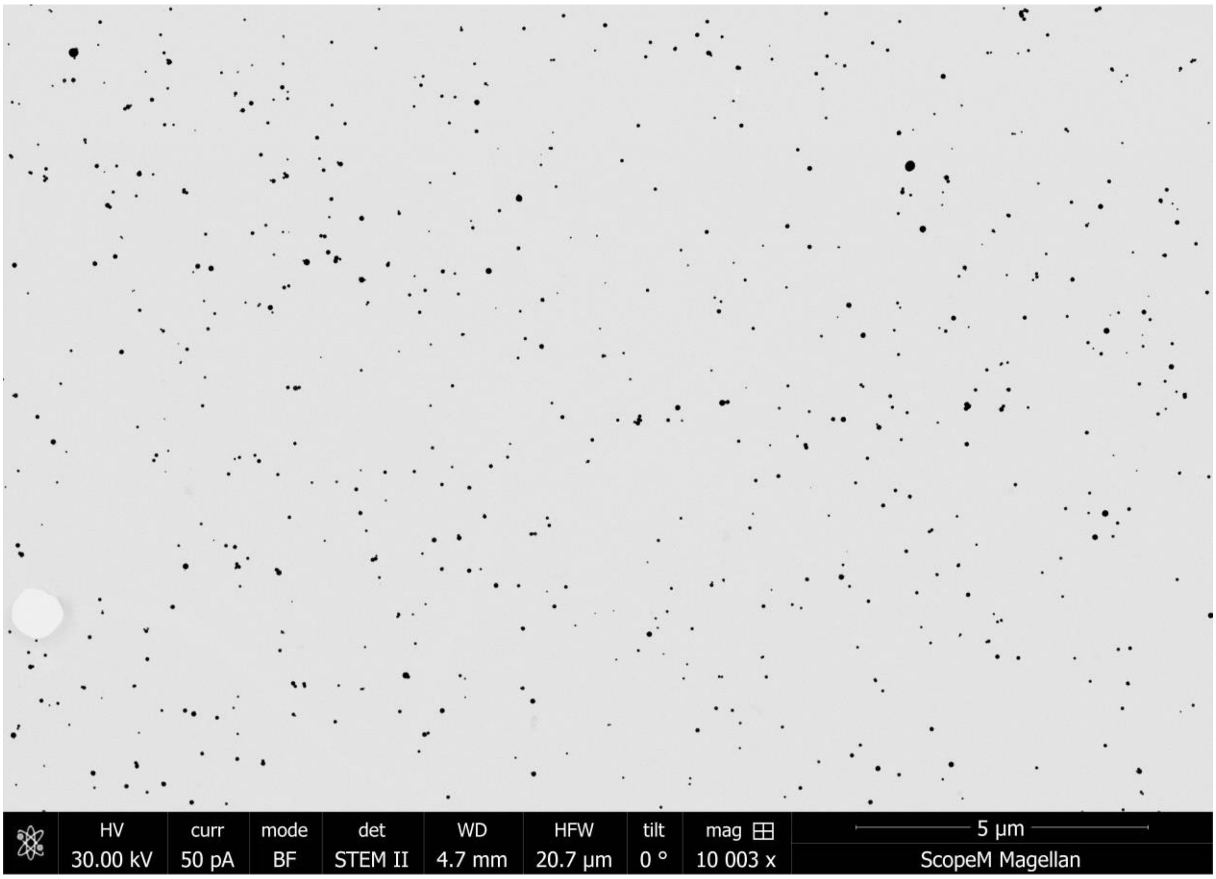
For a different sample, with a different random orientation and 100nm particles we got this:



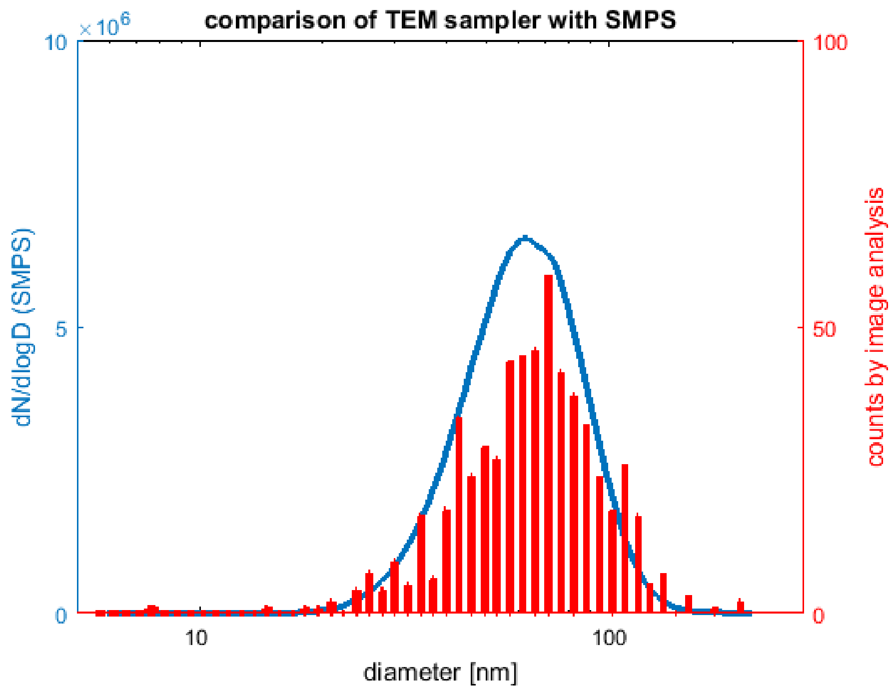
In general, when comparing different samples, we suggest that the central area of the grid should be used, and/or if you want to use images from the side of the grid, that you use images from both sides of the center of the grid, e.g. one from the left of the center and one from the right, as the nonuniformity of the deposition usually will be compensated that way.

Image analysis vs SMPS

We once compared the result of an image analysis performed on a TEM image with the size distribution given by an SMPS. The TEM image was a 10'000x magnification, actually produced on a scanning electron microscope; 605 particles were identified and sized with image analysis software (imageJ). The TEM image used for the image analysis is shown below:



The following graph shows the SMPS size distribution vs the TEM-image-analysis size distribution:



The SMPS gives a geometric mean diameter of 60.6nm, the TEM image analysis gives 63.8nm; the SMPS gives a geometric standard deviation of 1.40, the TEM image analysis gives 1.49. Despite the size dependency of the deposition, the TEM and SMPS size distribution nearly agree. Please note that all results shown here are usually for a single device, and individual devices may vary slightly in performance.