Separation of Small Particles Using Nanomanipulators in the ESEM

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Introduction

Numerous articles demonstrate that atmospheric aerosols act as major contributors to global climate change and are responsible for adverse health effects on humans. Thus, there is a need to characterize environmental particles in detail. Most established methods are designed to obtain information about chemistry, morphology, structure or surface of single particles. However, to date, no method combines different analytical techniques to obtain information from a specific particle. We present an approach, which allows us to combine ESEM (Environmental Scanning Electron Microscope) and TEM (Transmission Electron Microscope) to enhance information about selected environmental particles.

Problem

Attemps to investigate particles with different analytical techniques, are often faced with the problem, that different analytical techiques require different sample holders. Thus, particles of interest need to be transferred from one sample holder to another. This is rather difficult, when dealing with particles of only a few microns.

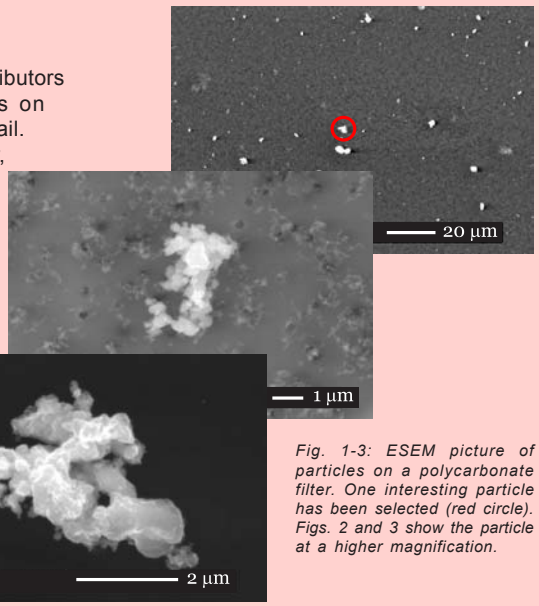


Fig. 1-3: ESEM picture of particles on a polycarbonate filter. One interesting particle has been selected (red circle). Figs. 2 and 3 show the particle at a higher magnification.

Fig. 4: Particle sticking to the glass needle.

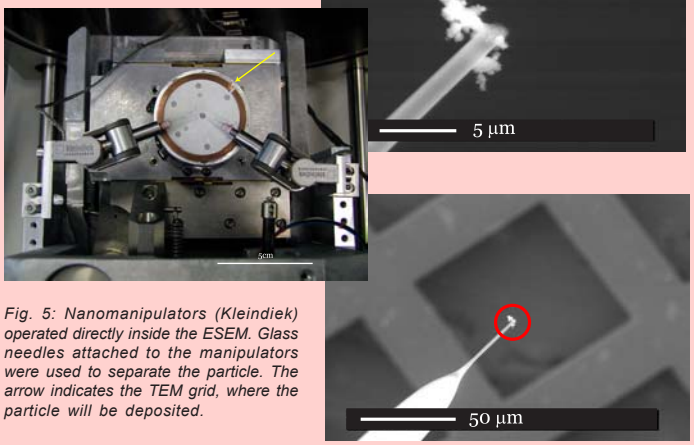


Fig. 5: Nanomanipulators (Kleindiek) operated directly inside the ESEM. Glass needles attached to the manipulators were used to separate the particle. The arrow indicates the TEM grid, where the particle will be deposited.

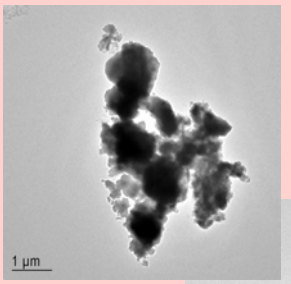
Fig. 6: Particle transported over the TEM grid.

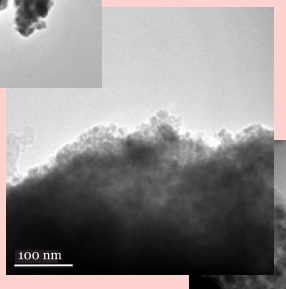
A Possible Solution

Particles were selected for more detailed study based on their morphology in the ESEM. This technique does not require any sample treatment and thus particle can be used for further analysis. Figs. 4-6 show how particles are transferred to TEM grids. A glass needle with a sharp tip attached to the Manipulator (Kleindiek), is operated directly within the ESEM. Directing the needle towards the particle causes the particles to stick to the needle, which then can be transferred to a position above the TEM grid (fig. 6) When the particle touches the TEM grid it bounces off the needle and sticks to the carbon film on the TEM grid.

Example

The morphology of particles sampled next to a busy road in Zurich was investigatd using an XL30 ESEM-FEG (FEI). Using the Manipulators, the particle was placed on a TEM grid. TEM analysis was conducted on a CM30 with an acceleration voltage of 200kV.
While the information gained within the ESEM is limited to morphology, the data from the TEM reveals details about the internal structure of the particle. In this example, it can be seen, that the particle is an agglomeration of small spheres. The spheres have a diameter of roughly 20 - 40nm and could represent primary particles from diesel or gasoline combustion.





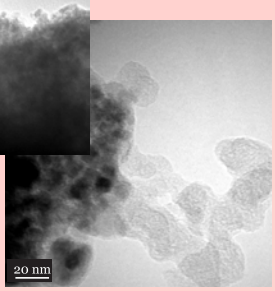


Fig. 6-9: TEM bright field images of the separated particle. The smooth surface of the particle displayed in figs. 2 and 3 (ESEM) actually consists of many small spheres. The spheres have a diameter of 20 - 40 nm as shown in fig. 9.

Summary

We propose a possible solution for the combination of different analytical techniques. In an example, we presente a combination of ESEM and TEM. Only the information from both ESEM (morphology) and TEM (internal structure) allowed us to identify and allocate the selected particle to a specific source.

Particle

ESEM

Nano-Manipulator

TEM