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Visualizing Aerosol Phase Phenomena with Liquid Phase Transmission Electron Microscopy

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With the increasing interest in human impacts on the environment, fundamental understanding of the physics and chemistry of atmospheric processes continues to be an important area of study. Specifically, aerosol nanoparticles impact atmospheric pollution, radiative forcing, and cloud formation dynamics. Aerosol nanoparticles with sizes < 100 nm interact with water vapor in the atmosphere as cloud condensation nuclei (CCN) [1]. Hygroscopic aerosol particles, such as salts, quickly condense water and can seed formation of clouds, while hydrophobic aerosols, such as soot particles, have less impact on cloud formation. However, due to a lack of single particle measurements the nanoscale chemical and transport processes involved in cloud condensation on aerosols are poorly understood. To have deeper understanding of the atmospheric CCN interactions, single particle characterization of the water condensation dynamics on atmospheric CCN is required.

Here we describe a liquid phase transmission electron microscopy (LP-TEM) method to visualize in real time water condensation on single atmospheric aerosols with nanometer scale sizes [2]. Figure 1 shows a schematic of the LP-TEM aerosol experiment, where dry aerosol nanoparticles are deposited onto the silicon nitride membranes. The aerosols were generated by atomizing an aqueous solution of the material into micron sized water drops, which were then dried and impacted on the silicon nitride membranes. The microfluidic cell was assembled under dry conditions, which enables initial imaging the nanoparticles under low-humidity conditions. Water vapor at a controlled relative humidity can be introduced using a syringe pump and vacuum pump to control the flow rate and saturation. An internal heating system within the microfluidic lines enables introducing superheated water vapor and prohibits liquid water condensation inside the microfluidic lines. The system consists of sub-mm sized resistive heating wires fed into the microfluidic lines, which are connected to an external power supply. This system also enables introducing supersaturated water vapor by taking advantage of the temperature gradient between the heating fluid lines and the room temperature sample region. Figure 2 shows TEM images of sucrose (Figure 2a) and cholesterol (Figure 2b) aerosol particles in the microfluidic cell under dry conditions prior to water vapor introduction. Figure 2c shows a TEM image of water droplets formed inside the microfluidic chamber to due to residual water vapor in the microfluidic system. We expect this new method will enable visualizing nanoscale dynamics of water condensation onto atmospheric aerosols under controlled relative humidity [3].

References:

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[2] Wang, M., Leff, A. C., Li, Y., Woehl, T. J. ACS Nano, **15** (2021), p. 2578–2588.
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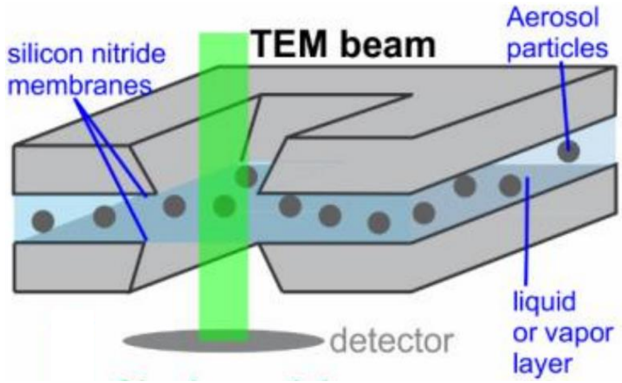

Figure 1. Schematic of LP-TEM imaging of aerosol nanoparticles.

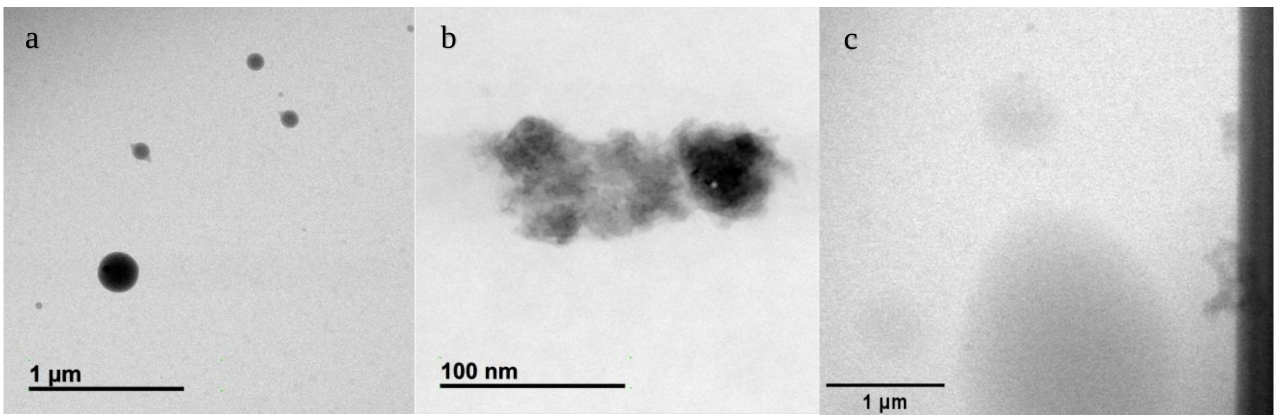

Figure 2. LP-TEM images of a) dry sucrose aerosol particles and b) dry cholesterol aerosol particles. c) LP-TEM image of water droplets formed on sodium chloride aerosol particles.

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