Development of a particle production method for calibration of a nanoparticle composition analyzer

*Koichi Murakami[1], Hiroki Otake[1], Nobuyuki Takegawa[1]

1.Graduate School of Science and Engineering, Tokyo Metropolitan University

1. Introduction

Atmospheric aerosols play an important role in global climate change and air pollution. Online measurements of chemical composition of ultrafine particles (nanoparticles) is important for better understanding of the formation processes of aerosols. Production of well-defined test aerosol particles is necessary to evaluate the performance of an online instrument (e.g., aerosol mass spectrometry). The purpose of this study is to develop a system for the production of test particles and to understand factors affecting the size distributions of test particles for stable operation and control.

2. Experimental Apparatus

The particle production method is based on homogeneous nucleation and subsequent growth of nuclei using oleic acid as a condensable material. The benefits of using oleic acid include: (1) it has moderately low saturation vapor pressure at room temperature, and evaporative loss can be neglected after particles are formed; (2) oleic acid particles are in liquid-phase and thus bounce of particles upon high velocity impact is negligible; and (3) it is a non-toxic material and easy to use. The equipment consists of three main sections; an evaporator of oleic acid, a condenser tube, and a size distribution analyzer. The evaporator produces oleic acid vapor by heating a liquid reservoir. In the condenser tube, homogeneous nucleation takes place by supersaturation of oleic acid vapor due to large temperature difference between the evaporator and condenser. The size distributions of formed nanoparticles are measured using a scanning mobility particle sizer (SMPS). The dependence of the size distribution on the evaporator temperature and flow rate was measured with and without an activated carbon denuder. The flow rate affects the saturation ratio, residence time in the tube, and flux of oleic acid vapor transported downstream. The activated carbon denuder affects the concentration of condensable vapor in the tube.

3. Results

Key parameters of the particle size distribution (peak diameter, width, and number of modes) showed complex dependence on the evaporator temperature, air flow rate, and presence of the activated carbon denuder. Specifically, the flow-rate dependence of the peak diameter with the activated carbon denuder exhibited a trend opposite to that without the denuder. An optimal size distribution for nanoparticle experiments (peak diameter of 40-50 nm) was obtained at a relatively higher flow rate in the presence of the activated carbon denuder. Possible mechanisms of the change in the size distributions are discussed based on simple theoretical calculations.

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