Fragmentation of Nanoparticle Agglomerates by Collisions in Supersonic Flows

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A major difficulty in making and handling nanoparticles is their tendency to agglomerate due to van der Waal forces and to form large fractal structures. In the present study, we investigated the deagglomeration of nanoparticles caused by collisions of nanoparticle agglomerates with a vibrating metal plate as well as a fixed metal plate, and the counter-collision of two supersonic flows containing agglomerated particles. Our deagglomeration experiments were carried out under several different conditions using silica nanoparticle agglomerates.

Silica particles (sicastar®, avg. dia. 80 nm; Micromod Partikeltechnologie, Germany) dispersed in methanol were used as the test particles. The liquid sample was atomized by a nebulizer with a N_2 gas expansion flow. The aerosol gas, after passing on a ^{241}Am plate for ionization of the particles, was introduced into a differential mobility analyzer (DMA). The agglomerated silica particles (approx. 150 nm in dia.) which were classified by the DMA were introduced into the collision system at 99.7 kPa. We used two kinds of collision systems: (a) the collision of agglomerates in a flow with a metal plate (as shown in Fig. 1a) and (b) the counter-collision of two supersonic flows containing agglomerates (as shown in Fig. 1b).The resulting degree of deagglomeration of nanoparticles was evaluated by a TEM analysis of the particles after the collision.

Figure 2a shows the distribution of the number of primary silica particles composing the respective agglomerates after the collision of the agglomerates in a sonic flow with a vibrating plate in the collision system shown in Fig. 1a. Compared with the distribution observed in the case of the collision with the fixed plate, we found that the deagglomeration with the vibrating plate was much more successful than that with the fixed plate. We believe that the vibration of the plate is very effective for the deagglomeration of nanoparticles because the vibration of the collision plate enhances the bounce of the fragments formed by the collision. The collision fragments bounced off of the vibrating plate and were deposited on the TEM grid, while the fragments stuck to the fixed collision plate.

Figure 2b shows the distribution of the number of primary silica particles composing the respective agglomerates after the collision of the agglomerates in the two opposed supersonic flows (Fig. 1b). The data shown in Fig. 2b indicate that the proportion of the non-agglomerated particles was as high as approximately 73% and the deagglomeration was achieved without any fusion of agglomerates. The results of the experiments revealed that the collision of agglomerates with a plate generates the problem of particles remaining on the metal plate even under low-collision velocity, and the counter-collision of two supersonic flows containing agglomerated particles induces a highly efficient fragmentation of agglomerates.

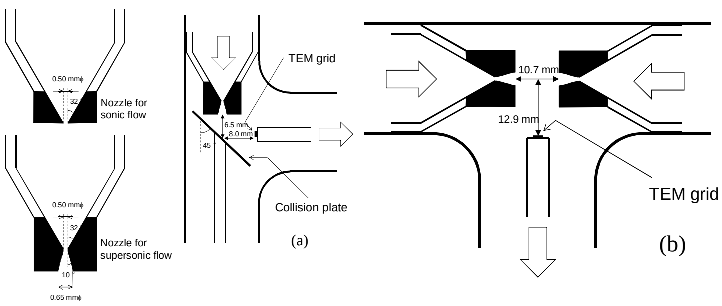

Fig. 1 Schematic diagram of the collision systems

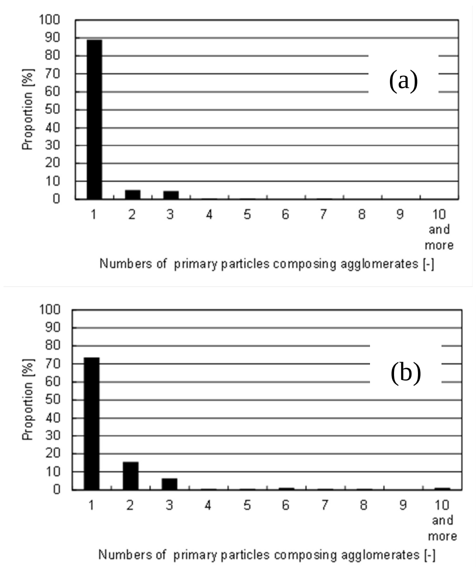

Fig. 2 Distributions of the number of primary silica particles composing the respective agglomerates after the collisions