# Direct observation of the internal and external morphology of size-segregated single particles and their interactions with alveolar epithelial cells

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Aerosol morphology depends on aerosol formation processes and atmospheric transformation and is a crucial factor relevant to aerosols' ensuing interactions with surrounding gases, vapors, and other environments [1]. Although single-particle techniques have improved significantly [2], considerably less is known concerning the three-dimensional (3D) external and internal morphology at the single-particle level. Particle-particle variability is a source of uncertainty in human and environmental impact assessments. Building on our earlier work [3], this study explores the 3D internal chemical mixing states and external shapes of single urban aerosols and expands the synchrotron-based techniques to single aerosol particles containing low-density (e.g., carbonaceous or biological) elements.

Urban aerosols were size-fractionated and collected on transmission electron microscopy (TEM) grids using a cascade impactor. On the other hand, standard reference particles (e.g., carbon back [CB] and diesel engine particles) were directly added to alveolar epithelial cell samples. The transmission (hard) X-ray microscopy (TXM) at the 01B1 beamline of Taiwan Light Source and the soft X-ray tomography (SXT) at the 24A beamline of Taiwan Photon Source were used to acquire 2D radiographic and 3D tomographic images of aerosol samples at a spatial resolution of 30–60 nm. Subsequently, the 3D morphology of single aerosol particles was reconstructed using sequential projections with the azimuth angle rotating from –90° to +90°. The synchrotron-based data were supplemented with TEM and energy-dispersive X-ray spectrometer (EDS) analysis for 2D images and elemental composition.

The TXM 3D tomographic images show that single urban aerosol particles exhibit complex, as well as transient, internal mixing states and structures, e.g., homogeneously-, heterogeneously-mixed, multiple inclusions, fibrous, porous, and core-shell configurations. After exposing the alveolar epithelial cells to standard reference CB particles, the SXT results show that the cell membrane and organelles (e.g., lipid bodies, mitochondria, etc.) and the CB particles can be clearly imaged and visualized in 3D. Interestingly, some CB particles were observed inside the cells. The potential biological or pathological responses in terms of cell morphology, the size and number of lipid bodies, and mitochondria are still under study. Updated results will be presented at the time of presentation at the conference.

[1] C. Marcolli, U.K. Krieger, *Trends Chem.*, **2020**, *2*, 1–3.
[2] W. Li, L. Shao, D. Zhang, C.-U. Ro, M. Hu, X. Bi H. Geng, A. Matsuki, H. Niu, J. Chen, *J. Clean Prod.*, **2016**, *112*, 1330–1349.
[3] L.-H. Young, W.-Y. Chen, C.-C. Wang, M.-T. Tang, S.-C. Tseng, B.-H. Lin, C.-W. Lai, Y.-H. Chen, T.-T. Yang, Y.-T. Lin, *Chemosphere*, **2022**, *307*, 135799.