Characterization of Exhaust Emission Particulate Matter by Transmission Electron Microscopy

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Motivation:

- Health effects of PM are of intense interest

- TEM characterization well suited to provide information on individual particles
  - Morphology
  - Elemental composition
  - Crystal structure

- Comparisons between spark ignition PM and diesel PM
PM from black smoker pickup
PM due to incomplete combustion of lube oil observed
PM observed with both turbostratic and graphitic crystal structure
Chain morphology with primary carbon spheres 20–60 nm
Typical Spark Ignited Motor Vehicle Exhaust PM
Test Methodology

- Sample exhaust stream in dilution tunnel with MOUDI (micro-orifice uniform deposit impactor)
  - Cold start idle
  - Hot idle
  - High speed cruise

- Temporarily attached 3mm Cu TEM grids coated with holey carbon films to various stages of MOUDI

- Analyze PM for crystal structure, morphology and elemental composition with TEM, STEM and EDS
PM emissions from a pre-control vehicle

- 1967 Chrysler 300 rebuilt with factory parts
- Conduct FTP tests at Automotive Testing Laboratory
  - Unleaded Fuel (UTG96)
  - Leaded Fuel (UTG96 doped to 0.8 g/l with tetraethyl lead)
  - UTG96 32.2% Aromatics
The PM size distribution shows substantial mass at very small particle diameter; MOUDI stages 7, 8, and 9 are very different using leaded fuel.
Initial diesel PM observations

Secondary Electron Image

Transmitted Electron Image
EDS of individual particles from leaded fuel shows Pb, Br, and Cl as well as C, Si, Cu.
EDS of individual particles from unleaded fuel shows only signature from carbon, silicon, and copper (TEM grid).
Micrograph of a typical particle emitted while burning leaded fuel shows lead (dark areas) interspersed with carbon soot.
Micrograph of a typical particle emitted while burning unleaded fuel shows chain agglomerate carbon soot structure.
Some lead was evident in the PM from unleaded fuel operation, but the leaded-fuel test results were 1000x higher.
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