West Virginia University

Investigation of Morphology and Volatility of Ultrafine Diesel PM Using Atomic Force Microscopy (AFM)

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Objective

- Global Objective
  - To characterize toxicity as a function of volatility of ultrafine diesel particulate matter.
- Specific Objectives
  - To image and study the physical characteristics of volatile diesel nanoparticles under atmospheric conditions.
  - To develop a suitable metric for volatility of diesel PM.

Background

- SEM/TEM have been the preferred methodologies for investigating morphology of diesel PM.
- SEM analysis of volatile diesel PM is constrained by the following two factors:
  - Observed size range of volatile diesel particles (5-50nm)
  - The presence of vacuum inside the SEM chamber
- Studies have documented different evaporation behaviors of volatile nanoparticles during SEM/TEM analysis. These behaviors have been attributed to the composite nature of volatile diesel PM [1].

[1] Mathis, U., Kaegi, R., Mohr, M., Zenobi, R.,2004. TEM analysis of volatile nanoparticles from particle trap equipped diesel and direct-injection spark-ignition vehicles. Atmospheric Environment, 38, 4347-4355.

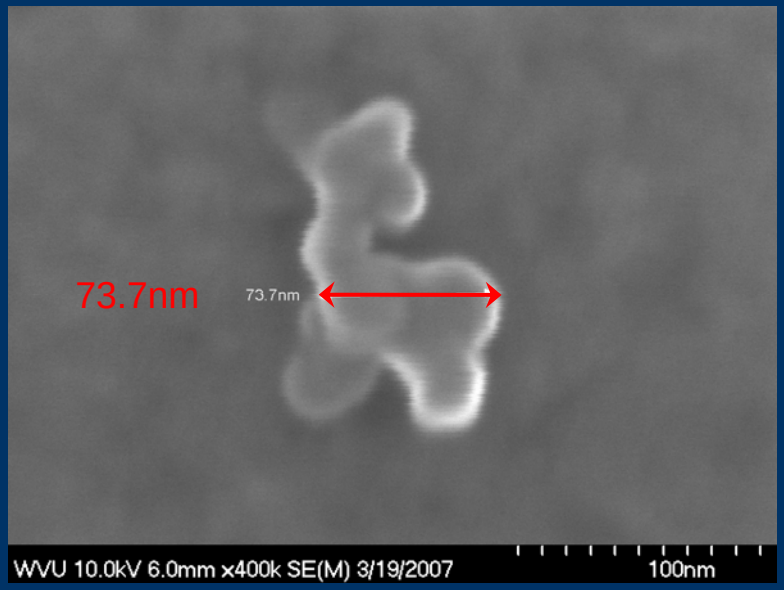


Figure 1

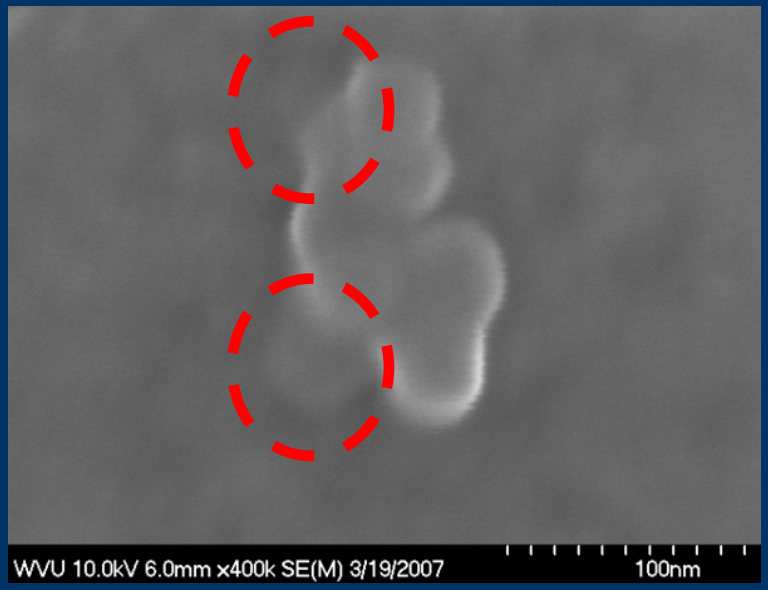


Figure 2

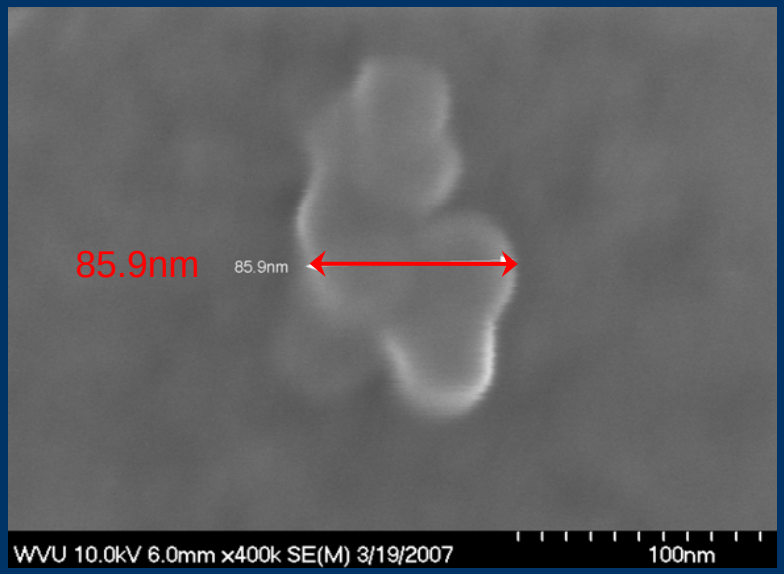


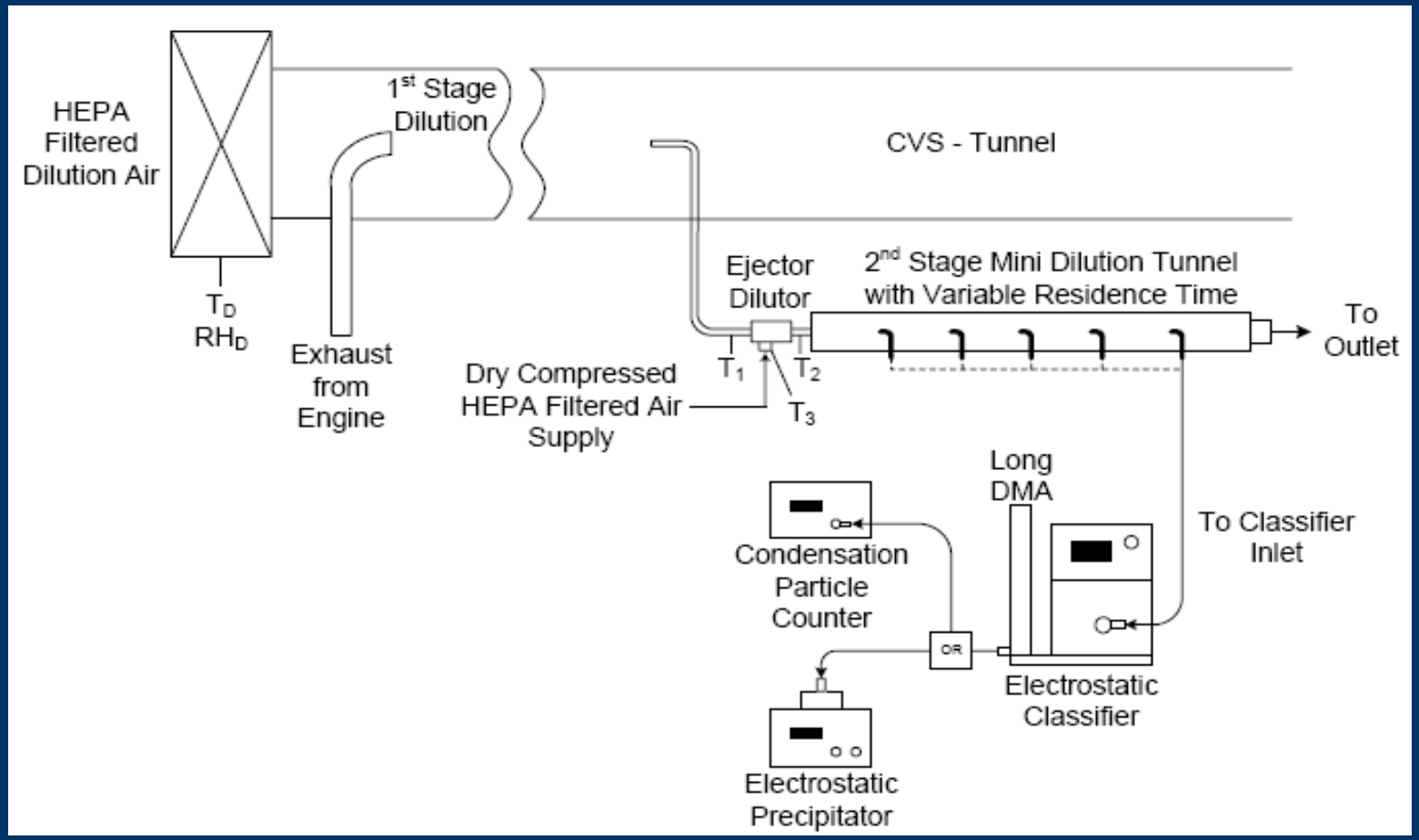
Figure 3

- Images (from our lab) show the continuous change in particle morphology with continuous exposure of sample to SEM vacuum and intensity of the electron beam.
- The evaporation pattern seen in this image is consistent with findings reported by Mathis et al. [2004]

Background

- Atomic Force Microbalance (AFM) imaging is performed at atmospheric conditions. This type of imaging would yield the most accurate morphological description of the volatile diesel PM.
- Image of the particle is constructed only through atomic level force interactions between the AFM tip and the sample and not by any physical interactions with the sample; hence, the shape, size and characteristics of the particles are preserved.
- AFM can be used for detailed imaging down to 1nm sized particle, provided the substrate roughness is smaller than the particle size.

Experimental Setup

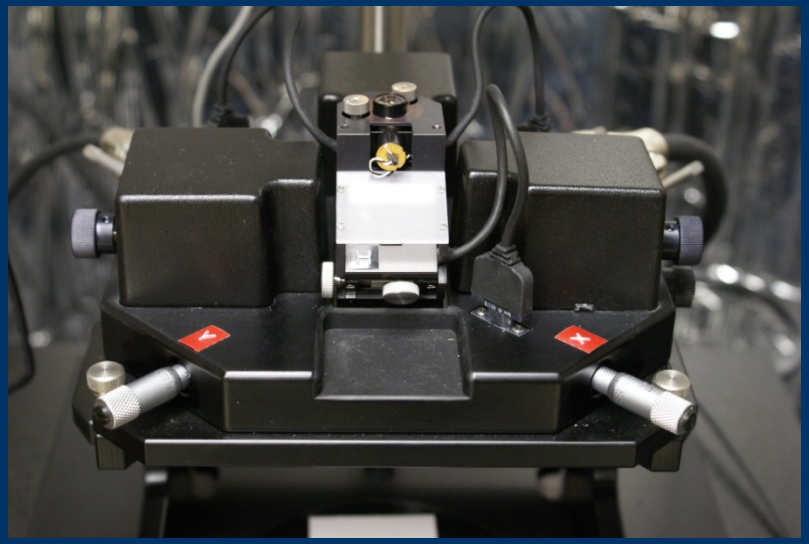


Sampling and Analysis Setup

- Monodisperse diesel PM is deposited on sample substrates.
- Three different substrates are being considered for sample collection
  - Cleaved Mica (rms-roughness 0.1nm)
  - High Order Poly Graphite (HOPG)
  - Copper grids

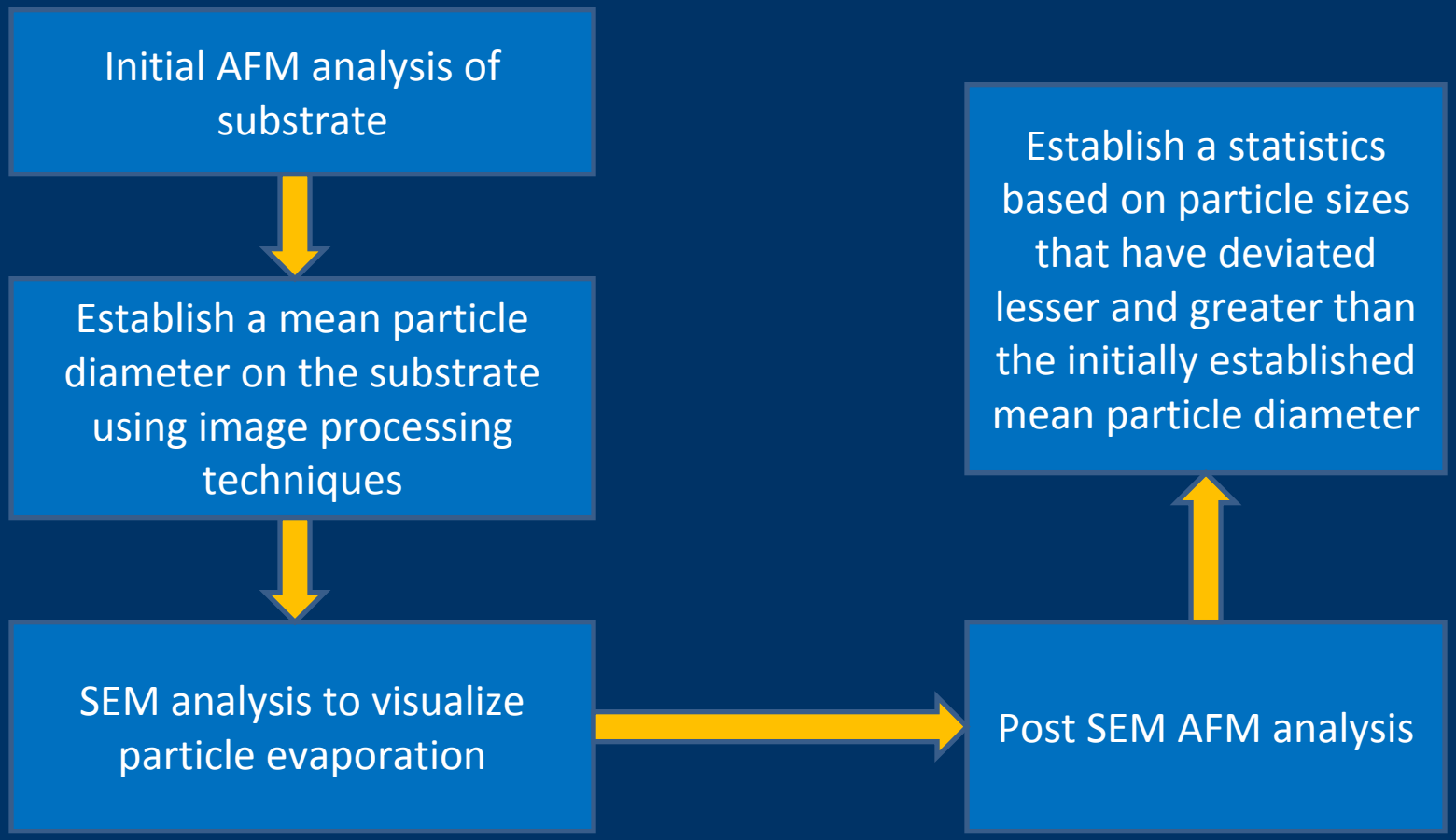
Sampling and Analysis Setup

- Pico SPM II model AFM is operated under tapping mode conditions.



Analysis Procedure

- Concurrent analysis using AFM and SEM



Analysis Procedure

- Atomic force spectroscopy can reveal useful information about surface atomic bonds.
- Force feedback statistics can be established in relation to the post SEM particle size statistics.
- This information would give insight into the different formations of volatile PM.

Preliminary Results

- The study involves choosing a suitable substrate, with good particle adhesion capabilities and also flat background topography.

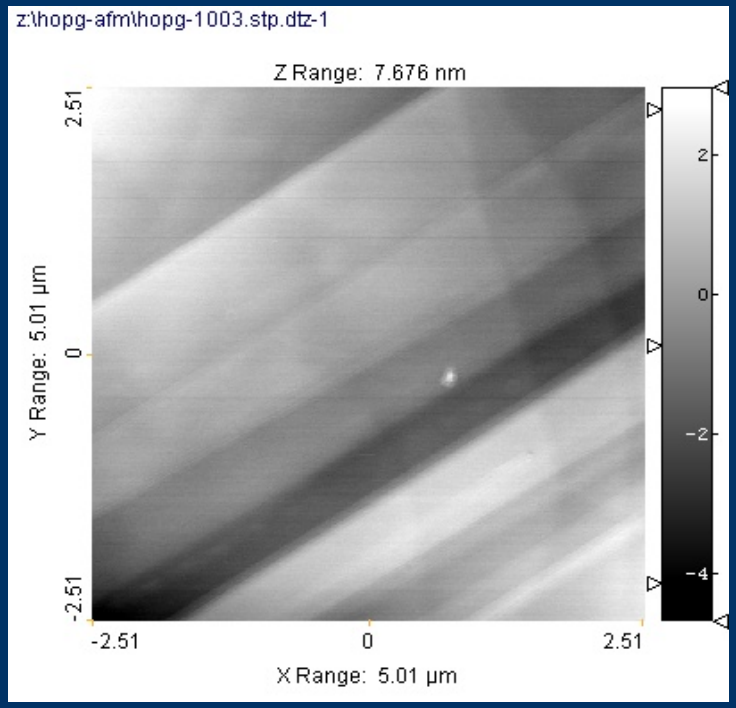
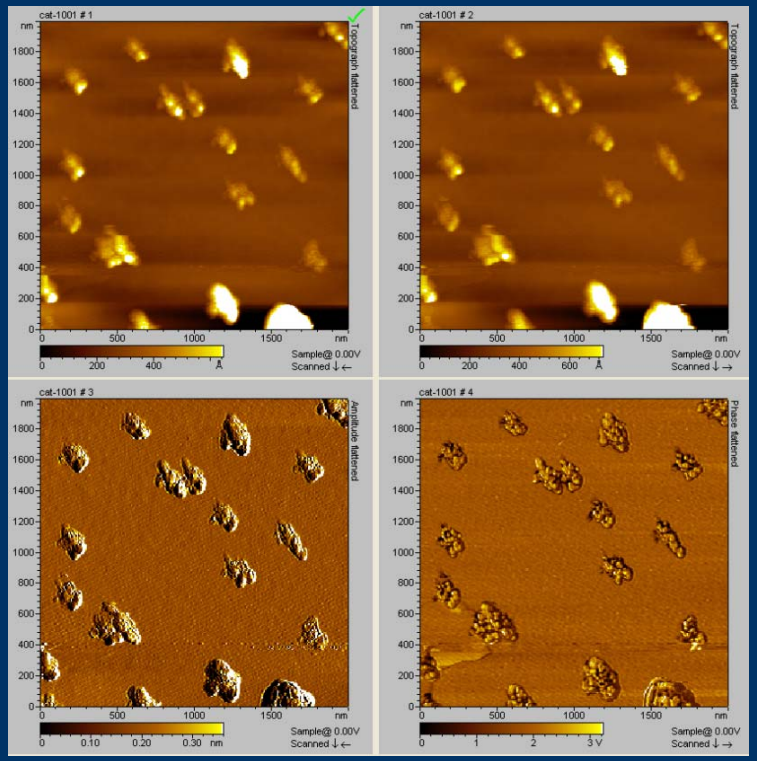
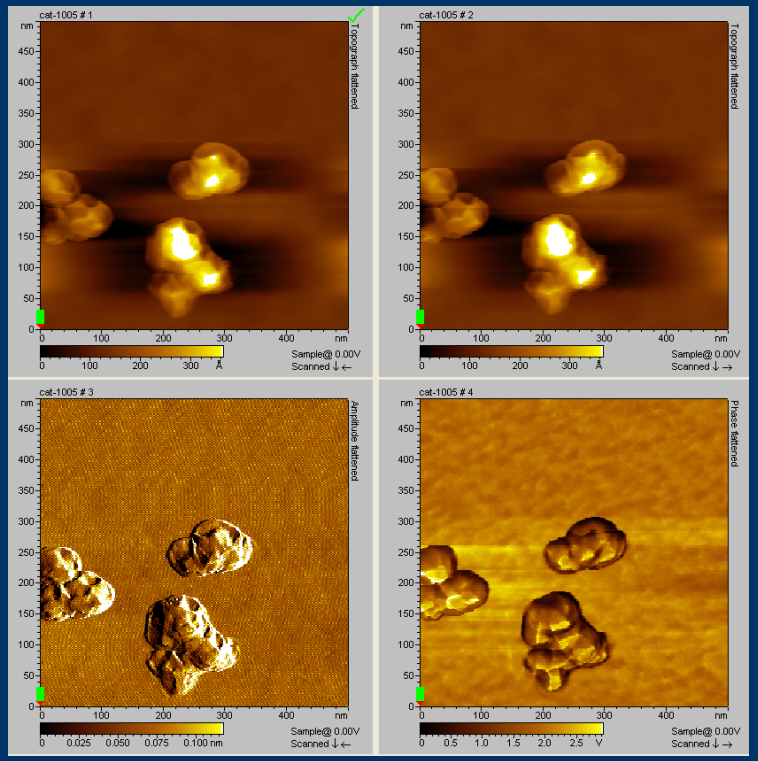


Figure:
HOPG substrate
rms-roughness = 1.18nm

Preliminary Results

- Detailed images of diesel soot were obtained





Conclusion

- Atomic force microscopy has proven to be a very useful tool in analyzing diesel PM under atmospheric conditions.
- Determination of a suitable metric for volatility will depend on particle size statistics that would be obtained from concurrent AFM/SEM.
- Image processing analyses (in progress) will provide information on changes in surface area and volume of particles.

Acknowledgements

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