Measuring the chemical composition of soot containing particles

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1 Aerodyne Research, Inc.; 2 Droplet Measurement Technologies; 3 Boston College

Introduction

- Black carbon (BC) particles
  - Absorb light efficiently, contributing to radiative forcing
  - Significant anthropogenic sources
- BC particles typically coated in the atmosphere
  - Primary combustion products
  - Secondary organic and inorganic condensates
  - Compositions and fate of BC containing particles are not well known
- Need new instruments capable of measuring the refractory and non-refractory mass and composition of soot particles

Instrument Concept

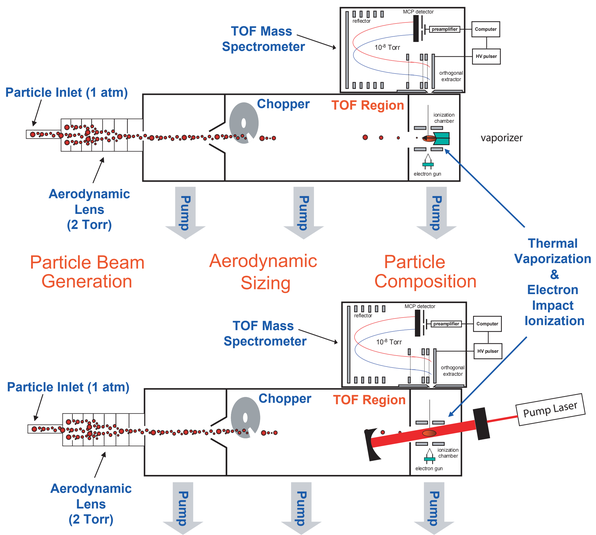
- SP2 + AMS => SP2-AMS

  SP2: Single Particle Soot Photometer
  (Droplet Measurement Technologies)

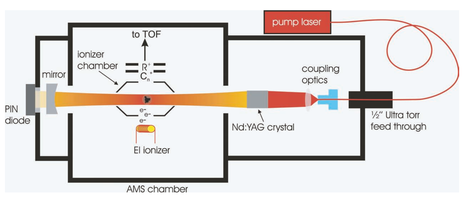
  - little information on absorbed compounds, particle chemistry

  AMS: Aerosol Mass Spectrometer
  (Aerodyne Research, Inc.)

  - Lack of sensitivity to refractory particles (i.e. black carbon soot)
- SP2-AMS: new combined instrument
  - Intracavity laser vaporization of the coatings and refractory cores of absorbing (λ = 1 μm) particles
  - Electron impact ionization
  - Measures both the non-refractory components of the coatings (e.g. Organics, sulfates, nitrates, etc.) and the refractory carbon cores (i.e. Black Carbon) via Time-of-Flight mass spectrometry

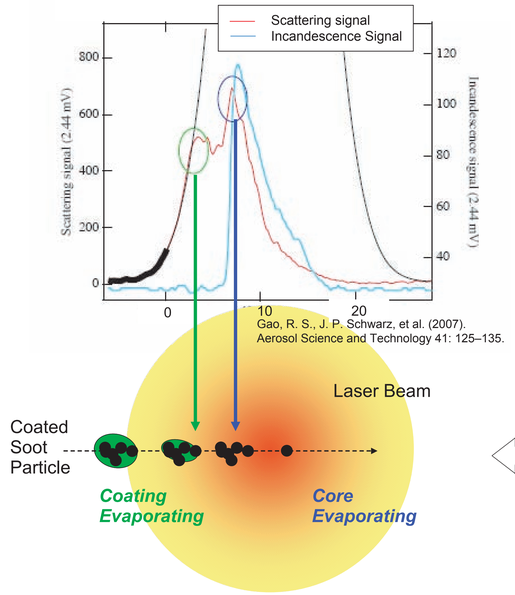


SP2-AMS Schematic



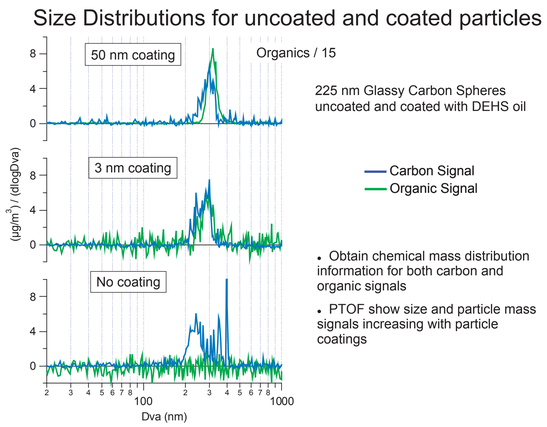
- Absorbing particles (coating and core) vaporize in laser
- Vapor is ionized by electron impact ionization
- Detection of the ions by Time-of-Flight mass spectrometry

SP2-AMS Detection of Carbonaceous Particles

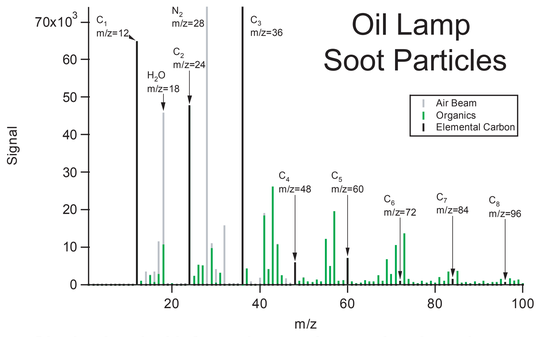


- Coatings evaporate first at relatively low temperatures (<600^{o}C) potentially dependent upon vapor pressures
- Core evaporates last at high temperature (>1000^{o}C) under SP2-like incandescence conditions
- 5-20 microsecond evaporation time

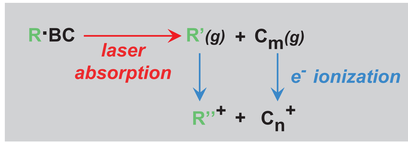
Size Distributions for Core and Coating Material



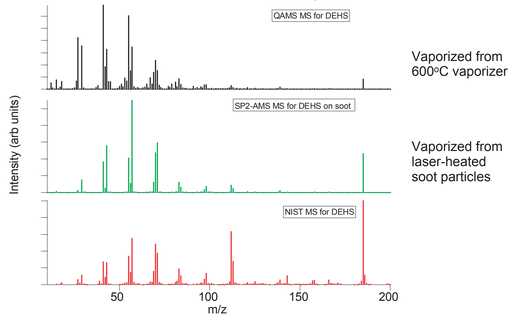
Mass Spectra contain Core and Coating Information



Obtain chemical information on elemental carbon clusters and organic compounds coating the soot cores

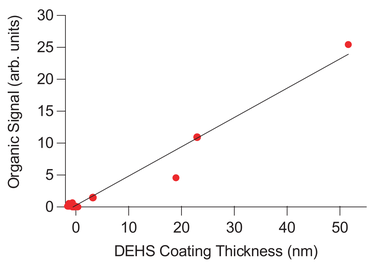


NIST-like MS Fragmentation



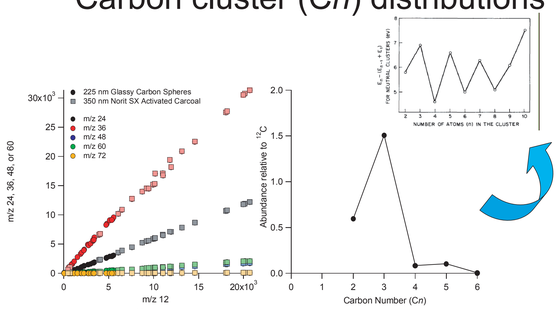
- Less fragmentation in SP2-AMS than in Q-AMS
- Large parent ion signal and fragmentation pattern more similar to NIST data base spectrum
- Coating evaporating at temperatures < 600^{o}C

Linear response to coatings



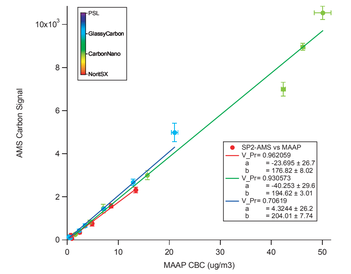
- AMS organic signal is linear with respect to coating thickness

Linear response to black carbon



- The ratio of C*n* to ^{12}C is observed to be nearly constant for a range of soot particles
- The relative abundance of carbon clusters formed (C*n*) follows the predicted stability pattern of odd number of carbons in the cluster

Raghavachari and Binkley, 1987



- AMS Carbon signal is constant for different monodisperse soot particles
- Chemical measure of the amount of elemental carbon in soot particles

Summary and Outlook

- SP2AMS: Successfully adapted SP2 module into AMS
  - Separate volatilization and ionization mechanisms
  - Only sensitive to absorbing particles (soot or metals)
  - Chemical and size information obtain for elemental carbon cores and non-refractory organic coatings
- Measure of particulate elemental carbon mass and size
  - Linear correlation between MAAP absorption and carbon cluster ion signals from SP2-AMS
  - Constant for several different types of soot particles
  - Appear to fully vaporize up to at least 350 nm soot particles under typical laser powers
- Measure of organic coating mass and size
  - Shows less fragmentation than standard AMS spectra
- Optimizing laser configuration to maximize power
  - Maximize laser beam diameter (laser-particle beam overlap)
- Planning summer BC instrument intercomparison study
  - Comparisons with other Black Carbon measurement techniques

Slowik, J. G., E. S. Cross, et al. (2007). "An Inter-Comparison of Instruments Measuring Black Carbon Content of Soot Particles." Aerosol Science and Technology 41(3): 295 - 314.

Acknowledgements

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