Emerging Aerosol Measurement Technologies

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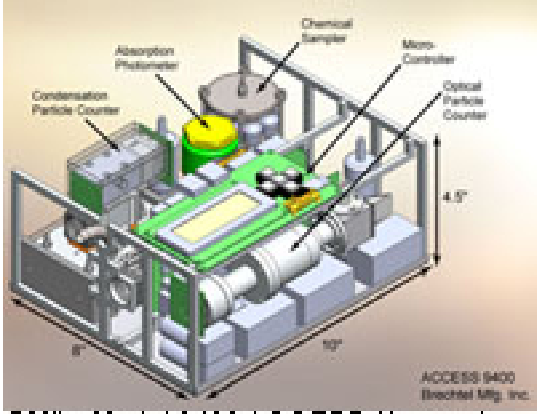
Particles thousands of times smaller than the diameter of a human hair transform materials, micro-sensors and energy-producing processes. And they can also severely pollute air quality and the integrity of technology products, like integrated circuits.

Airborne aerosols in the air we breathe can damage our health; especially particles containing trace amounts of metals--largely from burning fuel--can wreak havoc on our nervous systems. Research revealed at the October annual conference of the American Association for Aerosol Research in Minneapolis shows how we can better detect these pesky particles. That was just one of numerous revelations from scientists around the world all pointing to the increasingly important field of aerosol science and its fast-emerging science cousin: nanotechnology.

Historically, aerosol measurement technologies have focused on satisfying regulatory compliance mandated by the Environmental Protection Agency, as well as industrial monitoring needs like clean rooms, occupational safety and health monitoring requirements and high-end tools for air-quality researchers. Emerging trends are moving in a quite a different direction.



BMI's Model 9400 ACCESS (Aerosol Counting Composition Extinction and Sizing Spectrometer) allows simultaneous measurements of airborne particle concentration, chemistry, light absorption and size. Integrated into one compact and portable 8"x10" system, the device will find extensive use in industrial monitoring, air quality and climate change applications.

With the growing awareness of climate change and the health impacts of small particles that play a key role in the nanotechnology revolution — a new technology trend has emerged focused on compact, inexpensive sensors that can be deployed across broad sampling networks. These networks will be useful in industrial nanoparticle monitoring applications, long-term climate change monitoring studies, intensive urban area monitoring and in applications like monitoring exposures of mothers and children to diesel engine and cooking stove exhaust in low-income regions.

1. Nanoparticles and Energy — Researchers at Washington University in St. Louis have been exploring ways to control the surface properties of solar cells to increase their photon capture efficiency and extract more energy from sunlight. By building nanoparticle “stalagmites” on surfaces, incident photons are more effectively captured. Even if the efficiency only increases by 10 percent, multiplied by the large amounts of solar power we will soon be generating, the impact will significantly add to our renewable energy resources.
2. “Lab on a chip” chemical sensors - To understand how nanoparticles impact our air quality, climate and industrial processes we need information on their size, concentration and chemical composition. Currently available chemical analysis systems, like Ion Chromatography or Mass Spectrometers, are about the size of your dishwasher but cost 10 times more.
   Researchers at Colorado State University, as well as others, are working on very small chemical analyzers that fit on a microscope slide and cost pennies on the dollar. Using microscopic channels for the fluid containing dissolved particles, the “lab-on-a-chip” technique can detect very small changes in the fluid electrical conductivity that can be correlated to the concentration of known species.
   One problem with the method is lack of sensitivity. Manufacturers are partnering with researchers at University of California at Davis and other

schools to develop the next-generation sensors to detect even smaller levels of nanoparticles.

3. Health issues — For decades, air-quality regulations have focused on particles larger than 1 micron diameter, about 100 times smaller than the diameter of a single strand of hair. The increasing use of nanoparticles (smaller than 0.1 microns), and new studies pointing to their health impacts, are revealing the importance of developing new technologies to measure the very smallest particles in our air.
   A number of scientific revelations shared at the AAAR conference underscored the urgency of analyzing the nanoparticle health impacts of air inhaled by many thousands of people. Currently, however, such studies are cost-prohibitive until affordable, easy-to-use sensors are developed.
   Products using this new technology are going through beta phases and are expected to reach the market in 2010.
4. Diesel engine monitors — Current diesel engine emission regulations are tied to the mass of particulates emitted, but the emissions levels are becoming so small that new measurement techniques are needed to meet more precise standards. In the near future, diesel engine emissions will be regulated according to the number concentration, and not mass, of particles leaving the tail pipe.
   Although the mass emission rates of diesel engines have dropped by a factor of 200 over the last few decades, the new number-based emission standard will still regulate at a level of about 600 billion particles emitted per kilometer driven – a huge number by just about any stretch of the imagination!
   To keep up with the changing standards new technologies are needed that can capture the rapidly changing properties of emitted particles. What do we need? A compact sensor that can be installed on the tail pipe of our cars and trucks and reports results over wireless or cell phone networks could be one future solution. A number of companies are working on this solution.
5. Ion selective techniques — Between 30 and 80% of airborne particulate matter is water-soluble, so numerous techniques have been developed that deposit particles to surfaces that are continuously washed with ultra-pure water. The liquid sample is subsequently analyzed by Ion Chromatography, Mass Spectrometry or by using some other technique.
   For example, investigators at the Georgia Institute of Technology have shown that Ion Selective Electrodes can be used to determine the chemical composition of the dissolved aerosol. Ion Selective Electrodes use a very thin wire electrode positioned behind a membrane that passes only the species of interest, like calcium. The electrodes are inexpensive, costing only a few hundred dollars, but currently do not have the sensitivity for routine atmospheric measurements.
   Future electrodes with improved membranes and even smaller sizes will hopefully exhibit the sensitivity needed for air-quality instruments.
6. Satellite measurements of air quality — Even the smallest and cheapest instruments won't be deployable everywhere we need measurements. Remote sensing techniques, sensors on satellites in orbit around the earth, will supplement ground and aircraft-based sampling networks in the future to provide near global air-quality coverage. By measuring the light scattered

from the atmosphere, satellite sensors can reveal certain aerosol properties like size, concentration and chemistry.
A key limitation of the technique is interference from non-aerosol species like water vapor and ozone as well as layered aerosol structures (think clouds) in the atmospheric column sampled by the device. Researchers at NASA Ames Research Center presented a novel technique that tries to improve the quality of information derived from satellite measurements.

7. Shift in new particle formation paradigm — Where particles come from is a fundamental question in the world of aerosol technology. Organic gases are now believed to play an important role in creating the ‘infant’ particles upon which other gases collect to grow pre-existing particles to larger sizes. This revelation is radically shifting the way we think about how new particles are formed, previously thought to be mainly dominated by sulfur, ammonia and water vapor.

Organics comprise hundreds if not thousands of species in our atmosphere; the complex mix of species places a new technology development emphasis on techniques to measure the chemistry of nanometer-sized organic particles. Investigators at the NSF-sponsored National Center for Atmospheric Research (NCAR) have developed a new technique capable of depositing very small nanoparticles on to a needle as a function of the particle size. The needle can then be inserted into a mass spectrometer and heated to vaporize the particles to determine their chemical composition.

Although there will always be a need for large and costly high-end research tools, an increasing emphasis is being placed on lower-cost, portable technologies that integrate novel front-end samplers with new sensor solutions that can be networked in the thousands. These sensors will find application in our homes, in our workplaces, across large urban areas, as well as in statewide, national and global monitoring networks. Together with the information sharing power of the Internet, over the next two decades air quality information will be made widely available to everyone.

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