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ADVANCES IN DIAGNOSTICS FOR THE STUDY OF SOOT FORMATION

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The presence of soot is essential in some processes: it is the product in carbon black; it provides the source of light radiation in pyrotechnic and pyrophoric flares; and is the dominant source of radiant heat transfer in boilers and furnaces. However, it is also an undesirable product in many combustion processes where it is expelled with the exhaust, contributing to air pollution. Soot is often combined with condensed organics, sulfates, and metallic ash to form the particulate matter to which humans are exposed. Recent studies of the health effects of air pollution show that the levels of soot and other tiny particles found in large and midsize cities increase the risk of premature death from cancer and heart disease. Not only the mass of the particulates but also the chemical composition, size and number density play a significant role in the health effects on humans. Furthermore, black carbon (soot) has been identified as the second largest contributor to radiative forcing in atmospheric warming, and particulates are acknowledged to be the largest source of uncertainty in the climate change models.

To develop processes and techniques for limiting the emission of soot, we must first possess suitable means for reliably measuring various soot-related parameters. Many of the current and future needs for soot and particulate matter measurements can be achieved by an assortment of diagnostics based on irradiation of particles with high-energy pulsed-laser light. These techniques offer the possibility of real-time measurements *in-* or *ex-situ*, at concentrations exceeding ppm levels in-flame to sub-ppt levels in the ambient atmosphere. Recent advances in laser-induced incandescence (LII), elastic light scattering (ELS), laser-induced desorption with elastic light scattering (LIDELS), and laser-induced breakdown spectroscopy (LIBS) are discussed, along with techniques applied to further our understanding of the fundamental nature of soot.

LII is used to measure the volume concentration, specific surface area, and primary particle diameter of soot. When combined with scattering, further information on the morphology of the soot aggregates can be determined, including the distribution of the number of primary particles per aggregate, and the number concentration of aggregated soot particles. LIDELS provides a measure of the volatile organic fraction (VOF) of particulate matter, relating the solid-to-total particulate volume. LIBS identifies elemental species and measures their concentration, and is well-suited to investigate the metallic ash present in particulates formed from the combustion of heavier oils. Supporting these laser diagnostic techniques are an array of other methods, including two-line atomic fluorescence (TLAF) for measuring gas temperature, transmission electron micrography (TEM) for determining aggregate size, and numerical simulation of nanoscale heat transfer for interpreting the measured LII signals.

The combination of these many techniques has led to substantially increased capabilities in measuring the relevant properties of soot and particulate matter.