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Sub Topic: Soot and Nanomaterials

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Light scattering study of soot produced by burning liquid fuel inside and outside a combustion chamber designed for hazardous materials

Raiya Ebini[1], Christopher Sorensen[2], Dora Wiemann[1], Taylor Settecerri[1], Joshua Hubbard[1,]*

[1]Sandia National Laboratories, Albuquerque, NM, USA
[2]Department of Physics, Kansas State University, Manhattan, KS, USA
[*]Corresponding Author Email: jahubba@sandia.gov

The purpose of this work was to use a light scattering technique to study the physical properties of soot produced by burning fuel inside and outside a combustion chamber. The light scattering technique is based on small angle static light scattering (SASLS). The design of SASLS and the combustion chamber were based on the design of Ferri, F. (1997) and Hubbard, J.A., et al., (2020) respectively, where the chamber is used for hazardous materials research including samples containing depleted uranium. SASLS were performed on the flame of two different liquid fuels, with different threshold soot indexes (TSI): Kerosene and Toluene. Additionally, two forms of burning took place: burning with a simple wick lamp and in a beaker to represent an open pool fire. Experiments were conducted inside and outside the chamber to assess limitations associated with the current chamber design. Similarly, the scattering volume (SV) where the laser beam crosses the soot particles was located inside and outside the chamber as well.

(A). Burning and scattering volume outside chamber

For simplicity, kerosene and toluene wick lamps were used. Each lamp was placed on the optical table such that the laser beam hit the soot produced at 130 mm above the wick. This defines the scattering volume (SV). Here the laser beam was not hitting the plume. The soot produced by burning kerosene yielded an aggregate morphology with 1.7 ± 0.1 fractal dimension. The soot produced by burning toluene yielded an aggregate morphology with 2.6 ± 0.1 fractal dimension. This is consistent with the super-aggregate picture introduced by Kim, W. et al. (2004). Next, the wick lamp was replaced by a beaker to create an open pool fire. No distinguishing differences in the signal were detected. Plume flickering was observed. A glass funnel was added to help stabilize the plume. The scattering signal was clear for both toluene and kerosene. The soot produced by burning kerosene yielded the same morphology as the soot produced by burning toluene with 2.2 ± 0.1 fractal dimension.

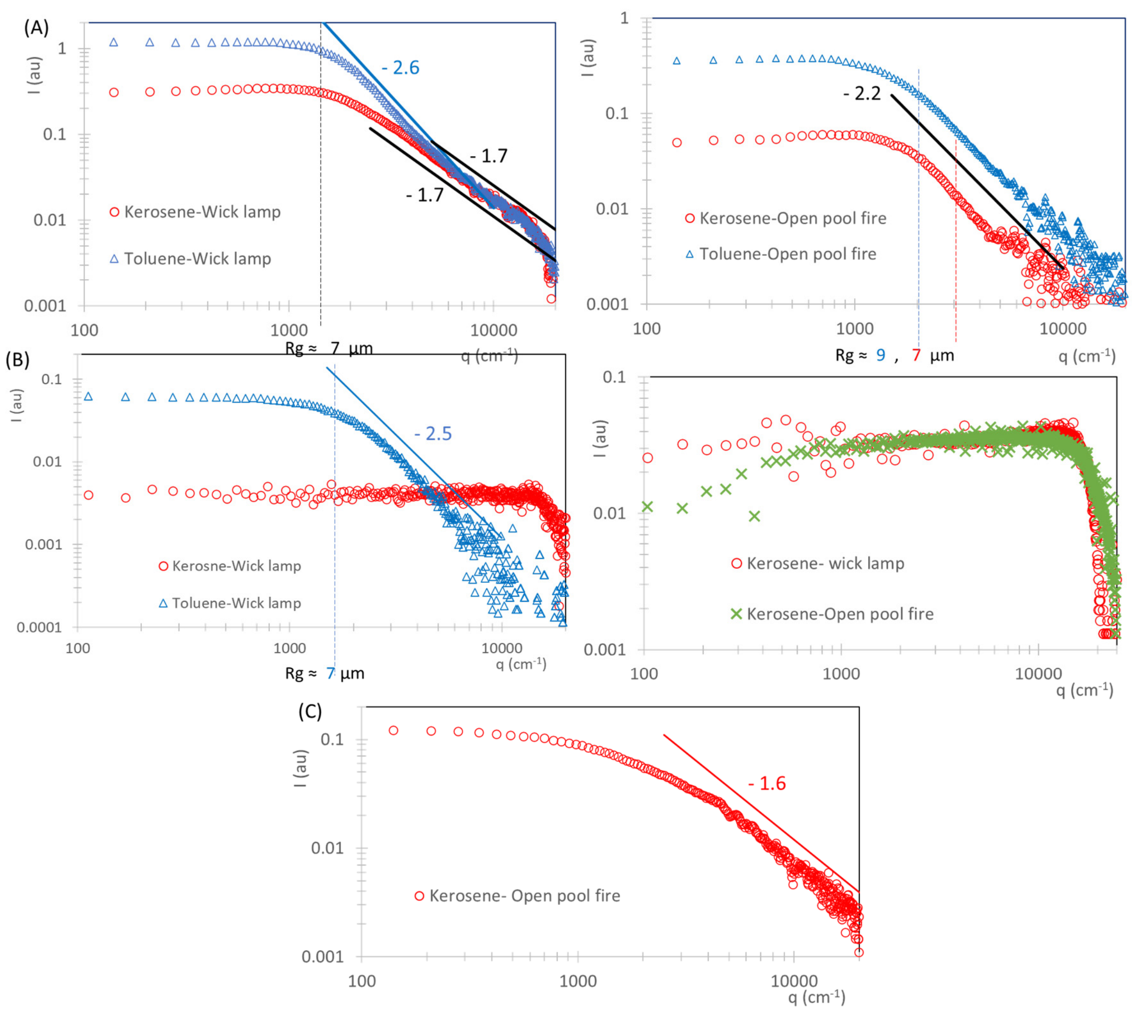
(B). Burning and scattering volume inside the chamber

The wick lamp was then placed inside the chamber. The kerosene signal was independent of the scattering wave vector q. This indicated that the soot size produced was below the measurable size of the instrument. which is about 700 nm. In contrast, the soot produced by burning toluene yielded an aggregate morphology of 2.5± 0.1 fractal dimension. Toluene was noticeably sootier than kerosene. Toluene soot was clearly depositing on the chamber wall. A kerosene open pool fire was also performed inside the chamber and yielded soot of size smaller than the minimum measurable size of the instrument.

(C). Burning inside the chamber but scattering volume outside the chamber

Soot produced by kerosene, when the scattering volume was inside the chamber, gave a soot size smaller than the detection limit of the instrument. To allow the soot particles to grow in size they needed to travel longer distances which allowed the aggregates more time to cluster. Thus, even though the open pool fire was made inside the chamber the scattering volume was placed outside the chamber. The soot was directed through 1.5-inch stainless steel vacuum tubing entered a glass tube where the laser beam hit the soot. In this case kerosene was the only fuel used as toluene was very sooty and toluene deposits were quickly formed on the interior surface of the glass tube. As hypothesized, kerosene aggregate morphology gave a 1.6 ± 0.1 fractal dimension. The Guinier regime of the structure factor appeared more extended and indicated a higher degree of polydispersity in the aggregate size distribution.

The optical components of SASLS were changed every time the SV was changed from scattering outside or inside the chamber. For a SV outside the chamber, either passing through the glass tube or not, the instrument was able to detect scattering angle ranges from 0.1-14 degrees. Meanwhile, when the SV was inside the chamber, the chamber size and view windows put a limit on the largest detected angle to be 9 degrees. Furthermore, a band pass filter was used to eliminate the black body radiation detection from the luminous part of the plume. The SASLS specifically measures the forward scattering, hence small angles. In the future, it is planned to modify our instrument to contain side scattering (~ 15 – 160 degrees) and back scattering to include a scattering angle as close to 180 degrees as possible.



Keywords: Small Angle Static Light Scattering, Super-aggregates, Fractal dimension, Guinier regime.

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