Influence of polydisperse distributions of both primary particle and aggregate sizes on soot temperature in low-fluence laser-induced incandescence

F. Liu[1], M. Yang[1], F. A. Hill[2], G. J. Smallwood[1*], and D. R. Snelling[1]
[1]ICPET, National Research Council Canada, Ottawa, Ontario, Canada
[2] Department of Systems Design Engineering, University of Waterloo, Waterloo, Ontario, Canada

An improved aggregate-based low-fluence laser-induced incandescence (LII) model was developed. The *shielding effect* on the heat conduction between aggregated soot particles and the surrounding gas was modeled using the concept of the equivalent heat transfer sphere. The diameter of such equivalent sphere was determined from detailed direct Monte Carlo simulation in the free molecular regime as functions of the aggregate size and the thermal accommodation coefficient (TAC) of soot. The effect of primary particle diameter polydispersity is in general important and should be considered. The effect of aggregate size polydispersity is relatively unimportant when the heat conduction between the primary particles and the surrounding gas takes place in the free-molecular regime; however, it becomes important when the heat conduction process occurs in the transition regime. Application of the model was also applied to re-determine of the TAC of soot in an atmospheric pressure laminar ethylene diffusion flame.

Introduction

It is shown by thermophoretic sampling/transmission electron microscopy techniques that flame-generated soot consists of polydispersed primary particles and aggregates. There is currently lack of a quantitative understanding of the shielding effect on heat conduction between aggregated soot particles and the surrounding gas. This study made an attempt to develop an aggregate based low-fluence LII model to investigate the shielding effect and examine the implication of such effect to LII based particle sizing techniques.

LII Model

The low-fluence LII model formulated for a soot aggregate was developed by introducing the concept of heat conduction equivalent sphere. The diameter of such sphere was determined from detailed direct Monte Carlo simulation in the free molecular regime as functions of the aggregate size and the TAC of soot. Heat conduction loss rate from the soot aggregate to the surrounding gas was calculated using the Fuch's approach. The distributions of the primary particle diameter and the aggregate size were assumed log-normal.

Results

The relative importance of aggregate size (N) and primary particle diameter (d) distribution under conditions of a typical flame, where heat condition occurs in the free-molecular regime, is shown in Fig. 1. It shows that the polydispersity of aggregate size is relatively unimportant while the polydispersity of primary particle diameter is more important.

Fig. 2 shows the relative importance of the distribution of N and d under the condition of a low gas temperature where the heat conduction takes place in the transition regime. While the polydispersity of d is still more important that that of N, the effect of polydispersity of N becomes more pronounced compared to the results shown in Fig.1. The results shown in Fig. 2 implies that the LII based nanoparticle sizing techniques for primary particle diameter measurement suffers ambiguity when applied to situations where the polydispersity of N is significant.

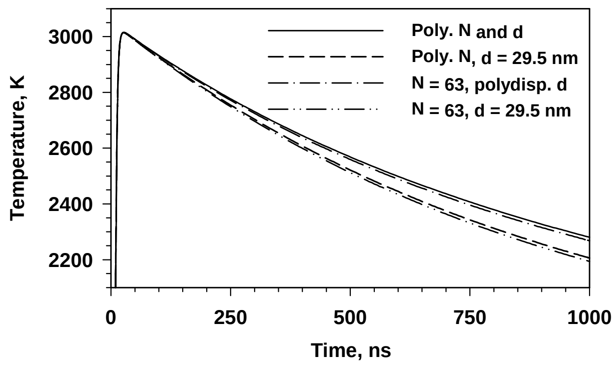

Fig. 1 Relative importance of N and d distributions in the flame case: T_g = 1720 K.

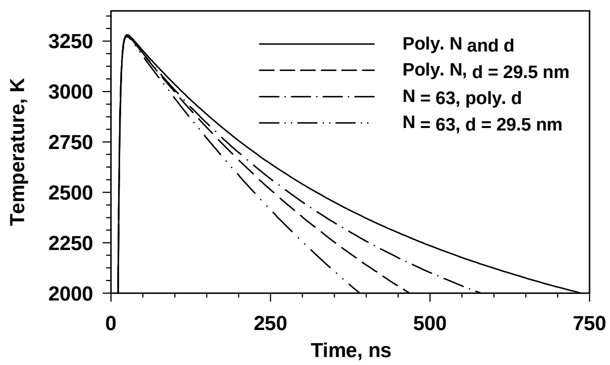

Fig. 2 Relative importance of N and d distributions in the low gas temperature case: T_g = 440 K.

Application of this aggregate based low-fluence LII model to analyze our data found that the TAC of soot to be 0.38.

* Corresponding author: greg.smallwood@nrc-cnrc.gc.ca
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