Photophoresis of fractal-like aerosol particles: physical model and methodical approaches

M.V. Vasiljeva*, S.A. Beresnev, L.B. Kochneva and V.I. Gryazin

Ural Federal University, Ekaterinburg, 620083, Russia
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Presenting author email*: mary_ru@mail.ru

A unilaterally irradiated particle in a rarefied gas is affected by the photophoretic force. This force is of a radiometric nature and is the result of gas molecules interaction with the non-uniformly heated particle surface. To solve a photophoresis problem it is necessary to consider electromagnetic radiation absorbed by the particle (the electrodynamic part of the problem) and to calculate the photophoretic force and velocity (the gas-kinetic part). The possible applications of radiometric photophoresis in gases are rather extensive: particle transport in combustion environments, photophoretic separation of particles, photophoretic trapping, photophoretic velocimetry, photophoretic effects in optical tweezers, various astrophysical and meteorological applications.

Nowadays, the kinetic theory of photophoresis for spherical homogeneous particles developed by Beresnev *et al* (1993) has found confirmation in experiment for a complete set of determining parameters. In particular, on its basis it has been predicted that well-known radiometric photophoresis can be the significant mechanism of vertical transport for absorbing soot-like particles in the stratosphere (Beresnev *et al*, 2011; Beresnev *et al*, 2012). On the other hand, the most part of soot atmospheric particles have a fractal-like structure. From here it is necessary to expect changes of thermal-physics and optical characteristics of these particles in comparison with homogeneous spheres. Besides, the quantitative changes in photophoretic velocities of such particles are possible also. From here follows the necessity of new microphysical and optical models for fractal-like soot particles.

The rich information of such kind contains in laboratory photophoretic experiments with fractal-like soot particles (Karasev *et al*, 2004). It has been shown, that fractal-like soot particles demonstrate confidently the longitidunal photophoretic motion in the field of directed laser irradiation.

Comparison of theory for homogeneous spheres (Beresnev *et al*, 1993) gives the good agreement with experiment at unexpectedly high heat-conductivity coefficient for soot particles. Optical characteristics for fractal-like particles, apparently, insignificantly differ from similar characteristics for homogeneous spheres. It is possible to approximate with good accuracy the mobility radius of these particles R_m by radius of gyration R_g of the aggregate.

The sufficient information for new photophoretic model development are the fractal dimension of particles D_f and general characteristics for primary particles in aggregate (Fig. 1).

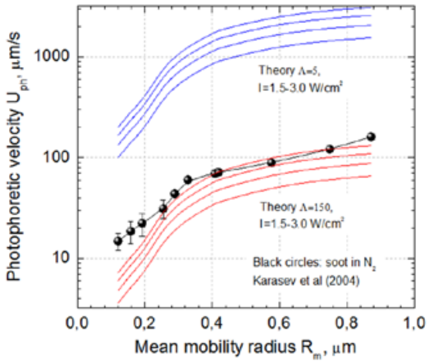

Figure 1. Comparison of measured photophoretic velocity for fractal-like soot aggregates with D_f =1.8 (Karasev *et al*, 2004) with theoretical predictions for spheres (Beresnev *et al*, 1993).

The principal propositions of new offered model are:

1. It is useful to keep the mathematical formalism used in model of homogeneous spheres (the general solution of fractal-like particle problem is extremely difficult).
2. For thermal-physics characteristics of fractal-like particles the model for estimation of effective heat conductivity of nanocomposites and nanofluids is used (e.g., Evans *et al*, 2008).
3. For calculations of optical characteristics for fractal-like particles it is possible to use methods of effective medium approximations (e.g., Chylek *et al*, 1988).
4. The determined above characteristics are used in gas-kinetic calculations for photophoretic force and velocity, where Knudsen number is determined on radius of gyration of aggregate R_g. Reliability and accuracy of suggested model is necessary to estimate by comparison with adequate experimental and theoretical data.

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