AN OPTICAL PYROMETRY STUDY OF THE SIZE EVOLUTION AND TEMPERATURE KINETICS OF CONDENSED-PHASE FLYING PARTICLES IN SAPPHIRE LASER ABLATION PRODUCTS

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Abstract: Optical two-color pyrometry was used to investigate the temperature kinetics and size evolution of individual emitted microparticles of condensed aluminum oxide formed during the laser ablation of sapphire in a vacuum. To analyze the experimental results, a mathematical model was developed to describe the cooling rate of an isotropically radiating melt droplet via radiation and surface evaporation. Among the recorded particles, ranging in size from 20 to 300 μm, certain particles exhibited cooling rates exceeding those predicted by the model. This discrepancy enabled the estimation of their effective heat capacity and made it possible to draw conclusions regarding the morphology of the emitted particles — specifically, distinguishing hollow closed shells (bubbles) inflated by aluminum suboxides from solid droplets. To further study the properties of these bubbles and the aluminum suboxides inflating them, a design improvement for the dual-beam pyrometer was proposed accompanied by mathematical modeling of its optical system. The results of this study have important implications for both fundamental and applied problems related to the high-temperature formation of aluminum oxides as well as high-energy processing methods, including laser irradiation, of aluminum-containing substances and materials.

Keywords: aluminum oxide; laser ablation; thermal explosion; aluminum suboxides; temperature kinetics of laser ablation products; aluminum suboxide recombination; heat loss; optical pyrometry

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Figure Captions

Figure 1 Visualization of the droplet surface temperature change rate as a function of its radius and temperature. Contour lines delimit cooling rate intervals of 10 K/ms; the grid is aligned with the radius and temperature scales

Figure 2 Schematic diagram of the experimental setup: (*a*) diagram of the laser stand (side view); and (*b*) diagram of the optical system of the dual-beam pyrometer (top view)

Figure 3 Photographs of flying luminous particles obtained with an exposure start delay time of 200 (*a*) and 500 μs (*b*); (*c*) kinetic dependences of the particle glow intensity in the “blue” (*1*) and “red” channels (*2*) obtained for the particle in photo (*b*); *3* — the calculated particle temperature. The particle radius is about 20 μm

Figure 4 Dependence of the ratio of the heat capacity of a model melt droplet to the effective heat capacity of an experimentally studied particle with the same radius and temperature as the model particle (the ordinate axis is a logarithmic scale)

Figure 5 A variant of the optical scheme of a two-channel pyrometer providing the possibility of using Schlieren method photography

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