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Dynamics of Laser-Ablation Plume and Ambient Gas Visualized by Two-dimensional Laser-induced Fluorescence[†]

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For synthesizing new materials by laser ablation in reactive-gas atmosphere, understanding on the hydrodynamic behavior of ablation plume and ambient gas is important. To date, several techniques such as a shadowgraph method are used for visualizing the expansion dynamics of laser-ablation plumes and shock waves. In addition, two-dimensional laser-induced fluorescence (2DLIF) is used for visualizing density distributions of various species in plumes. However, the dynamics of ambient gas interacting with laser-ablation plume has not been understood well. In the present work, we visualized the dynamics of laser-ablation plume and ambient gas by 2DLIF. A graphite plate installed in a vacuum chamber was irradiated by Nd:YAG laser pulses at a wavelength of 1060 nm. The YAG laser beam was focused using a lens, so that the fluence of the laser pulse on the target surface was approximately 3 J/cm^2. The duration of the YAG laser pulse was 10 ns. The vacuum chamber was filled with C_4F_8 at various pressures. Tunable laser pulses having planar beam shapes were injected into the laser-ablation plume. The image of the laser-induced fluorescence was taken using a charge-coupled device with a gated image intensifier. We visualized the density distribution of C_2, which was a typical species ejected from the graphite target. To visualize the dynamics of ambient gas, we decomposed C_4F_8 partly to produce CF_2 radicals. A compact plasma source was used for the decomposition of C_4F_8. The density distribution of CF_2 was visualized by 2DLIF. Clear pictures representing the density distributions of C_2 and CF_2 were obtained. After the irradiation of the YAG laser pulse, the density distribution of C_2 expanded rapidly into the ambient gas. The density distribution of CF_2 had a deep dip, which corresponded to the location of C_2. In other words, the laser-ablation plume and the ambient gas located exclusively. Mixing between ablated species and ambient gas was seldom observed. This result means that chemical reactions between ablated species and ambient gas, which is essential for synthesizing new materials, are expected only in the interface layer between laser-ablation plume and ambient gas. We observed a compressed layer in the density distribution of CF_2, which was due to a shock wave excited by the expansion of the plume. The expansion dynamics of the plume and the shock front was explained well by a conventional theory.

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