§35. Laboratory Experiments on Aerosol Formation by Colliding Ablation Plumes (LEAF-CAP) and the Application for Nano-materials Production

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It is widely recognized that along with DT-pellet implosions, IFE reactor chamber wall components will be exposed to short-pulses of 14 MeV neutrons, intense X-rays, high-energy unburned fuel particles and pellet debris such as CD complex ions. As a result, wall materials will be subjected to ablation. This may lead to the formation of aerosol and/or the redeposition (i.e. condensation) of ablation-ejected particles. These processes will directly affect the implosion pulse frequency, i.e. reactor power output, and also the wall lifetime as well for the reason to be mentioned next.

Whether the wall material is a solid or liquid, one predicts that, in the periphery region, ablation-ejected particle flows cross over each other, leading to the formation of local density maxima, which then results in the formation of aerosol[1]. In addition, aerosol formation can also take place at the center or on the axis of symmetry of a reactor chamber in the shape of sphere or cylinder.

Importantly, the airborne time of these aerosol particles could be orders of magnitude longer, compared with that of particles to be recondensed. These airborne aerosol particles are likely to absorb or reflect the subsequent laser beams intended for pellet implosion, affecting directly the reactor power output. It follows from these arguments that the pellet implosion frequency must be controlled to avoid the aerosol effects. Despite its critical importance, this technical issue has not yet been clearly addressed in the IFE research community.

The present work is intended to investigate the materials ablation behavior, including redeposition and aerosol formation. A new experimental setup has been put together for this purpose and is named LEAF-CAP for the Laboratory Experiments on Aerosol Formation by Colliding Ablation Plumes. A schematic diagram of the LEAF-CAP facility is shown in Fig. 1-(a). A ~1J YAG laser (~50ns, 10Hz) is employed as the energy source and is converted into the third harmonic so that the wave length is 355nm at which the energy absorption by materials is more than 80%. This laser beam is optically split into two equal-power beams to generate ablation plumes from two arc-shaped targets, i.e. double-target setup shown in Fig. 1-(b), with the cross section shaped into a rectangle of about 0.5mm x 10mm. The power density under these conditions is of the order of $1 J/cm^2$, well above the threshold for plume formation via ablation.

A comparison between the single and double target experiments is shown in Fig. 2. In the case of Cu one can clearly recognize that the plume from the single target is longer than that observed in the double target setup. This suggests that recombination takes place due to the collision of plumes. In contrast, one sees rather strong emission nearby the colliding center in the case of C targets, indicative of some radiative reaction. To corroborate these observations, visible spectroscopy measurements show Swan band structure, as shown in Fig. 3, characteristic of C_2 molecules. Therefore, we conclude that the emission is due to the radiative association of carbon atom. From these observation, one predicts that even as no visible lights are detected, other C_n molecules might be formed. As shown in Fig. 3, transmission electron micrographs of carbon deposits collected during C-double target experiments have exhibited interesting structures, which one might call carbon nanotube and/or carbon onion.

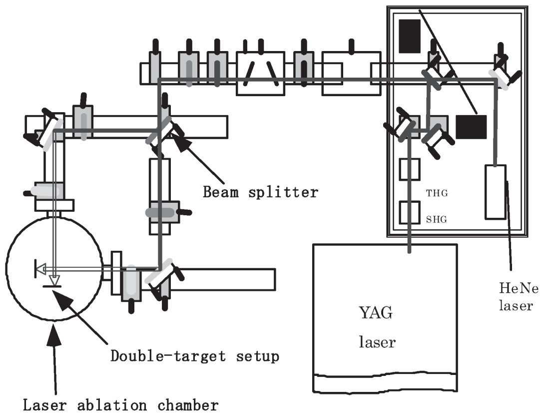

Fig. 1 A schematic diagram of the LEAF-CAP facility.

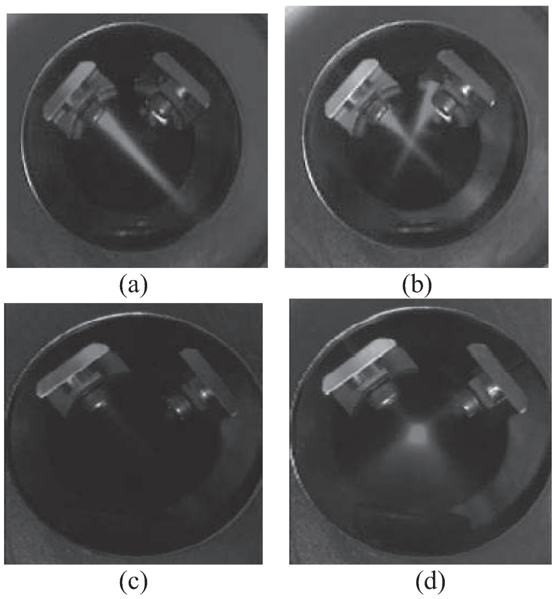

Fig. 2 Laser ablation plumes; (a) single Cu-plume; (b) colliding Cu-plumes; (c) single C-plume; and (d) colliding C-plumes.

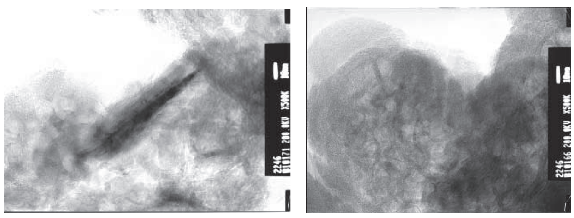

Fig. 3 Nano structures found in the deposits generated during double C-target experiments in the LEAF-CAP facility.