# Effects of the Pre-Ablation Spark on the Signal Enhancement in the Orthogonal Double-Pulse Laser-Induced Breakdown Spectroscopy

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Double-pulse laser-induced breakdown spectroscopy (LIBS), initially introduced by Cremers et al. [1], have provided higher sensitivity and more reliable analytical capability. The double-pulse LIBS can be performed in two different ways: the collinear and orthogonal schemes. In view of field applications, the collinear scheme is better because its optical alignment is simpler than that of the orthogonal scheme. Moreover, a single laser device, which provides delayed two pulses, are enough for the collinear scheme. Although the optical alignment is more complicated and two laser devices are necessary for the orthogonal scheme, this attracts more attention from the researchers, interested in the mechanism of the signal enhancement in the double-pulse LIBS. Using the orthogonal scheme, we can separate the effectsof the ablating and signal-enhancing laser pulses. According to the interpulse delay, two configurations have been proposed: the reheating pre-ablation spark dual-pulse configurations [2]. In the reheating configuration, the first pulse generates plasma of the target material and the second pulse enhances the LIBS signal by reheating the plasma. In the pre-ablation spark dual-pulse configuration, the first pulse generates the air breakdown above the target surface before the second pulse ablates the target material. Although several experimental observations has been reported on the reason of the signal enhancement in the pre-ablation spark dual-pulse configuration so far, the physical mechanism occurring in this configuration has not been elucidated yet [3.4].

In this work, we have performed the orthogonal double-pulse LIBS experiment on the aluminum metal target using the pre-ablation spark dual-pulse configuration. Two Q-switched nanosecond Nd:YAG lasers were employed. The wavelengths of the ablation laser and the other laser were 532 nm and 1064 nm. The laser pulse at 1064 nm was triggered 20 ㎲ earlier than the ablation pulse ($t_p$ = 20 ㎲). The signal enhancement factor dependent on the interpulse delay showed broad maximum between $t_p$ = 15 and 50 ㎲. In this experiment we fixed $t_p$ to 20 ㎲. The laser pulses at 1064 nm and 532 nm were focused parallel and perpendicularly to the target surface ($f$ = 70 mm), respectively. The pulse energy of the ablation laser was 7 mJ/pulse and that of the other laser was 26 mJ/pulse. The distance between the laser focuses and the target surface, $d$, and the ablation point on the aluminum target surface were varied by the motorized sample stage. The plasma emission was collected by the top view geometry and sent to a 50-cm Czerny-Turner monochromator with an intensified charge-coupled device. The laser pulses and the ICCD were synchronized by external pulse generators. All the experiments were performed under atmospheric pressure.

We observed the effect of the distance between the pre-ablation spark and the target surface on the signal enhancement. There was the optimum distance between the pre-ablation spark and the target surface, where the signal enhancement factor was maximized. When the pre-ablation spark was closely located to the target surface, the signal was rather decreased. This indicates that the propagation of the shock wave produced by the pre-ablation spark has a significant effect on the ablation or the plasma dynamics. Also, we observed the effect of the pre-ablation spark on the plasma emission linewidth. The pre-ablation spark narrowed the emission linewidth. This indicates that the electron density in the plasma is lowered by the pre-ablation spark. In this presentation, we will discuss more details on the physical mechanism in the double-pulse orthogonal pre-ablation spark LIBS.

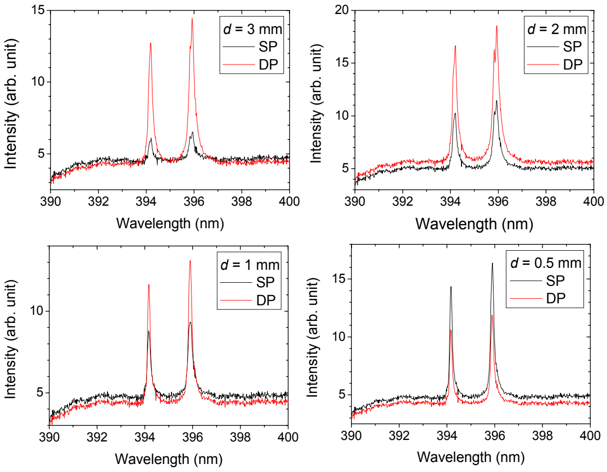

Fig. 1. Al I emission spectra obtained by single and double pulse LIBS. The distance between the laser focuses and the metal surface was varid.

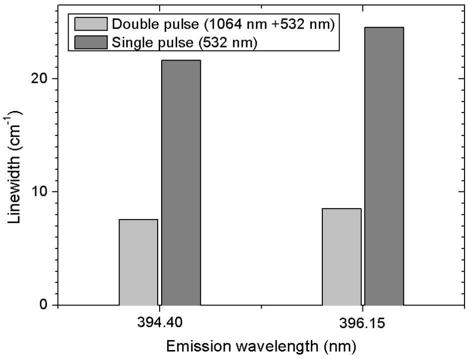

Fig. 2. Linewidths of the Al I emission at 394.40 nm and 396.15 nm.

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