Optical emission analysis during Laser Joining using decomposition and recombination on hydrogenated amorphous carbon films

K. Hase[1], C. Nara[1], Y. Aono[1], Y. Hirata[1], N. Ohtake[1], H. Akasaka[1]
[1]*Department of Mechanical Eng., Institute of Science Tokyo, Japan*

Abstract: Hydrogenated amorphous carbon films, which is one of the inorganic carbon materials films can be joined by laser irradiation and it may relate to the plasma plume generated during laser irradiation. In this study, the plasma plume during the laser joining of a-C:H films was analyzed using optical emission spectroscopy. The emission from C, N, and O radicals were observed in the during the laser joining.

1. Introduction

Laser welding is one of the methods of joining materials directly by melting them, however, it cannot be applied to inorganic carbon materials without melting point at ambient pressure. Graphite sublimates rather than melt at ambient pressure, and melts only at high pressure and at temperatures of 4000-5000 K[1]. On the other hand, for hydrogenated amorphous carbon (*a*-C:H) film, which is one of the inorganic carbon coating and consisting of sp^2 and sp^3 hybridized bonding carbon networks and hydrogen[2], we found that two films can be joined by defocused laser irradiation[3]. Since the optical emission from plasma plume is observed near the joining area, it is believed that part of the films is decomposed by laser irradiation to form plasma, and then recombined to form the joined film. In this study, we analyzed the plasma plume during the laser joining of *a*-C:H films for understanding of the joining mechanism.

2. Methods

The *a*-C:H films were synthesized from C_2H_2 (Godo Acetylene Corp.: 98%) on Si(100) and optical glass (Corning: #7059) using the pulsed plasma chemical vapor deposition. To understand the relationship between the optical emission during the laser joining and the presence of the *a*-C:H films, two types of samples were prepared; (a) glass and Si overlapped ("No films"), and (b) *a*-C:H films synthesized on both of glass and Si overlapped so that films were in contact with each other ("Films on both sides"). Then, an Yb fiber pulsed laser (Panasonic: LP-S500) with 1064 nm was irradiated from the glass side. The irradiation condition was an power of 8.4 μJ and an irradiation time of 20 μs, and the sample was placed 3.5 mm below the focal point at the defocus condition. The emission during the laser joining was measured using a multichannel spectrometer (Hamamatsu Photonics: PMA-12) for an integration time of 133 ms. The probe of the spectrometer was placed perpendicular to the laser.

3. Results and Discussion

In the case of" No films", no optical emission was detected during irradiation, whereas in "Films on both sides", optical emission was observed. In order to reduce noise, simple moving average was applied in the range of 3.755 nm since the spectrum as measured showed low *S*/*N*. Figure 1 shows the optical emission spectra during the laser irradiation after the treatment. In spectrum of (b) "Films on both sides", it was observed that the peaks around 435, 465, 516, and 552 nm attributed to C_2, and the peaks at 392.4, 407.0, 426.7, 513.7, 588.8, 615.1, 645.9, 657.6, and 723.6 nm attributed to C^+. This spectrum indicated that the absorption of photon energy from the laser, resulting in temporary decomposition of the *a*-C:H film's components. Furthermore, the peaks at 744 and 777 nm can be attributed to N and O emission, respectively. These results indicate that *a*-C:H films was decomposed to plasma by laser irradiation, and these species recombined during short time. And finally, it makes the joining of films.

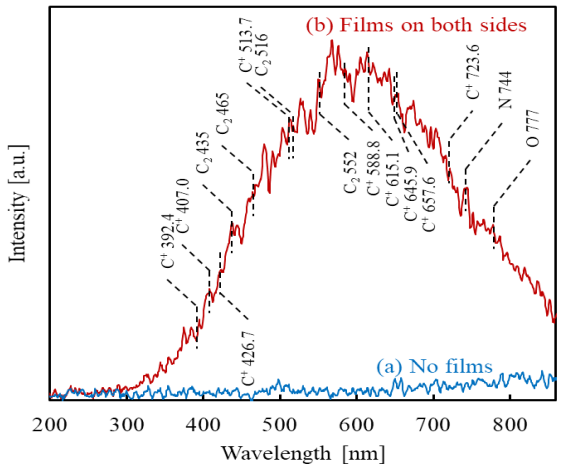

Fig. 1. Optical emission spectra during the laser irradiation; (a) "No films", (b) "Films on both sides".

4. Conclusion

A plasma plume contained carbon species during the laser irradiation to *a*-C:H films, it was indicated that the film temporary decomposes and recombines to join them.

Acknowledgement

This research was supported by The Amada Foundation and the The Precise Measurement Technology Promotion Foundation.

References

[1] A. I. Savvatimskiy, *Carbon*, Vol. 43 (2005).
[2] N. Ohtake *et. al.*, *Materials*, Vol. 14 (2021).
[3] K. Hase *et. al.*, The 84th JSAP Autumn Meeting (2023).