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Characterization of amorphous carbon films by X-ray magnetic circular dichroism

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Upon pulsed laser annealing (PLA) with a laser energy density above threshold value, amorphous carbon films are melted and then transformed into allotropes such as Q-carbon, nanodiamond, and reduced graphene oxide, depending on the quench rate during liquid-phase regrowth [1, 2]. Q-carbon, which was recently discovered, has a high sp^3 contents of about 80% and shows excellent physical properties such as hardness superior to that of diamond, room-temperature ferromagnetism, and even high-temperature superconductivity when boron is doped with Q-carbon. Since it has peculiar physical properties, Q-carbon is of interest in terms of both fundamental and application viewpoints [3].

Q-carbon is prepared by irradiating ArF and KrF excimer lasers to the amorphous carbon films. A challenging study is to prepare the Q-carbon by using a YAG solid-state laser with a wavelength of 355 nm. This is because the wavelength of 355 nm is longer than those of excimer lasers (193 nm for ArF laser and 248 nm for KrF laser) and is close to visible light. The successful preparation of Q-carbon by using the 355 nm YAG laser will help expand the preparation condition and accelerate the research for Q-carbon. In this experiment, the 355 nm YAG laser was applied to the PLA treatment for amorphous carbon films and X-ray absorption and X-ray photoemission spectroscopies were employed for characterization of the obtained films .

Amorphous carbon films were prepared using a YAG laser with a wavelength of 355 nm. The same laser was employed for PLA treatments. X-ray absorption spectroscopy measurements were performed at HiSOR BL14. Photoemission spectroscopy measurements were conducted at Spring-8 BL25 SU. All measurements were performed at room temperature.

Figure 1(a) shows XAS spectra at C *K*-edge for amorphous carbon films before and after PLA. A signal related to the sp^3 state was seen at 290 eV. A decrease in the intensity at 290 eV was observed for the film after PLA, suggesting the reduction of sp^3 contents in the film after PLA. Figure 1 (b) shows the photoemission C 1s core-level spectra of the films before and after PLA. Clearly seen was the decrease in the intensity at 285.3 eV which corresponds to the binding energy of sp^3 states in carbon. The sp^3 content was estimated from the area ratio of the sp^2 and sp^3components to be approximately 40% for the film before PLA and 20% for the film after PLA. The sp^3 content in the film is reduced by PLA, which is consistent with the result of XAS measurements.

The sp^3 content in the films is decreased by PLA. The estimated sp^3 content for the film after PLA is smaller than that of Q-carbon. The results show that the quenching rate required for Q carbon formation is insufficient, and suggest that a higher quench speed is needed for obtaining the Q-carbon. Laser energy density for PLA and/or film thickness are effective experimental parameters to improve the quench speed. We believe that Q carbon can be prepared using a YAG laser with a 355 nm wavelength by optimizing experimental conditions.

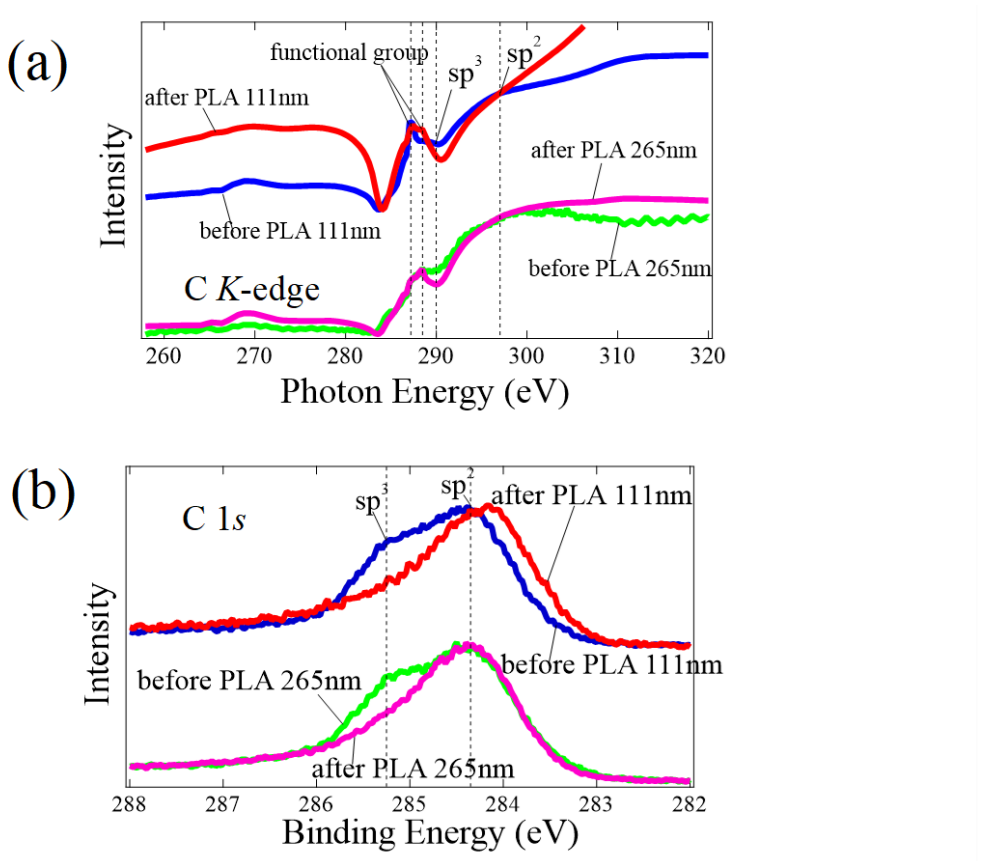

FIGURE 1. (a) XAS spectra at C *K*-edge for amorphous carbon films before and after PLA. The spectral intensity is normalized at 298 eV which corresponds to the signal related to the sp^2 states. (b) Photoemission spectra of C 1s core-level for amorphous carbon films before and after PLA. Photon energy of 1330 eV was used for measurements.

REFERENCES

1. S. Gupta *et al.*, *Appl. Nano Mater.* **3**, 5178 (2020).
2. S. Gupta *et al.*, *JOM.* **70**, 450 (2018).
3. J. Narayan, and A. Bhaumik, *J. Appl. Phys.* **118**, 215303 (2015).