Crystal nucleation of ice and sodium acetate by laser ablation with a single laser pulse

Hozumi Takahashi[1], Satomi Ebihara[2], Yusuke Takaoka[1], Yuka Tsuri[3], Mihoko Maruyama[1,4,5], Masashi Yoshimura[6], Seiichiro Nakabayashi[2], Teruki Sugiyama[7], Yusuke Mori[1], Hiroshi. Y. Yoshikawa[1]

[1]Graduate school of engineering, Osaka University, Japan.
[2]Graduate school of science and engineering, Saitama University, Japan
[3]Graduate school of science and technology, Nara Institute of Science and Technology, Japan
[4]Institute for advanced co-creation studies, Osaka University, Japan
[5]Graduate school of life and environmental science, Kyoto Prefectural University, Japan
[6]Institute of laser engineering (ILE), Osaka University, Japan
[7]Department of Applied Chemistry, National Yang Ming Chiao Tung University, Taiwan.
Email: takahashi@mp.ap.eng.osaka-u.ac.jp

Laser ablation of liquid has recently attracted much attention as a means of enforcing crystal nucleation of various materials such as proteins and small organic compounds [1]. As for the mechanism, past studies suggested that laser ablation-accompanied phenomena such as a shock wave, cavitation bubbles, and long-lasting bubbles may trigger crystal nucleation [1-4]. In this work, to further clarify the underlying mechanism, we demonstrated crystal nucleation by laser ablation with a single laser pulse, which enables us to monitor detailed spatio-temporal dynamics of laser-induced crystallization. For this purpose, crystallization of water and sodium acetate by laser ablation was investigated because these materials can be instantly crystallized upon external stimuli. Fig. 1 shows the macroscopic images of crystallization dynamics of ice induced by focused irradiation with a single laser pulse (λ = 800 nm, E = 240 μJ/pulse, Δt = 5 ps). Ice crystals formed radially from the laser focus, and the entire glass vial was finally filled with the crystals. From the microscopic observation of crystallization dynamics, we found that crystals always appeared next to the long-lasting bubbles, suggesting that laser-induced bubbles may play a crucial role as a site of crystal nucleation.

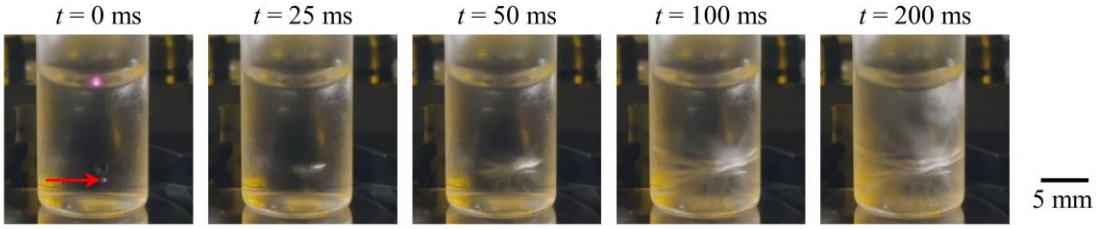

Fig 1. Representative crystallization dynamics of ice triggered by a single laser pulse (λ = 800 nm, E = 240 μJ/pulse, Δt = 5 ps). Red arrow indicates laser focus.

[1] H. Y. Yoshikawa et al., *Chem Soc Rev.* **43**, 2147 (2014). [2] H. Takahashi et al., *Appl. Phys. Express* **14**, 045503 (2021). [3] K. Ikeda et al., *Appl. Phys. Express* **8**, 045501 (2015). [4] N. Mirsaleh-Kohan et al., *Cryst. Growth Des.* **17**, 576 (2017).