6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Dynamics of solvated electrons influenced by femtosecond laser-induced plasma in water

Noritaka Sakakibara[1,a], Tsuyohito Ito[1], Kazuo Terashima[1], Eisuke Miura[2]
[1] Department of Materials Science, The University of Tokyo,
[2] Operando-OIL, National Institute of Advanced Industrial Science and Technology
e-mail (speaker): sakakibara.n.ab@m.titech.ac.jp

In recent years, solvated electrons (e_{aq}^-) are attracting much attention when considering liquid-phase reaction field influenced by plasma [1]. Solvated electrons are stabilized electrons coordinated by water molecules, which has strong reduction power itself and highly influences chemical reactions and physical processes in aqueous media through charge transfer and charge transport. The properties and dynamics of solvated electrons have been established mainly in pulse radiolysis and photolysis studies in last six decades [2].

Femtosecond laser-induced plasma produced in liquid and aqueous media is leading to applications such as nanoparticles synthesis [3]. By tightly focusing an intense femtosecond laser pulse with an energy of 1 mJ or more, a high-density plasma with 10^{18}–10^{21} cm^{-3} electron density is induced by multiphoton ionization, tunneling ionization, and collisional ionization. The abundant free electrons are simultaneously solvated to form solvated electrons, which influences chemical reactions such as formation processes of gold nanoparticles synthesis [3]. However, there is no experimental investigation of the dynamics of solvated electrons during plasma generation by an intense femtosecond laser pulse. The dynamics of solvated electrons might be influenced and drastically changed by the abundant free electrons with femtosecond laser-induced plasma.

In this study, we observed the dynamics of solvated electrons during the generation laser-induced plasma in water by a pump-probe technique using femtosecond laser pulses. The density of solvated electrons was measured by monitoring absorption of solvated electrons with 800 nm probe pulse, where solvated electrons have broad absorption spectrum in visible wavelengths with a absorption peak around 700 nm.

Femtosecond laser-induced plasma is generated by focusing pump pulse (pulse width ~ 50 fs, wavelength 800 nm, pulse energy 5 mJ) in purified water filled in a quartz cell. Femtosecond probe pulse (pulse width ~ 50 fs, wavelength 800 nm, pulse energy < 0.2 mJ) was introduced into the plasma region from perpendicular direction to the pump pulse propagation. Shadowgraph images and the intensity of the probe pulse were recorded with a CCD camera and a biplanar phototube, respectively. Time-resolved measurement was performed by changing the optical delay of the probe pulse.

Figure 1 shows a shadowgraph image of solvated electrons during femtosecond laser-induced plasma generation. The shadow was confirmed to be the absorption of solvated electrons by performing the same experiment with adding solvated electrons scavenger KNO_3 into water.

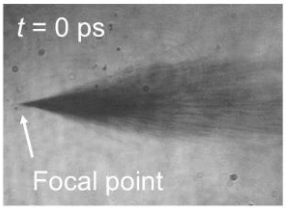

Fig. 1 Shadowgraph image of solvated electrons during the generation of femtosecond laser-induced plasma in water. Pump pulse was focused and propagated from the right side of the image.

Importantly, we found unique dynamics of solvated electrons in fast recombination process with counter ions and radicals (geminate recombination). In the femtosecond laser-induced plasma, geminate recombination occurred with a longer lifetime (0.5–1 ns) than that observed in previous pulse photolysis studies (10–100 ps) [4]. The decay dynamics of solvated electrons was attributed to the additional production of solvated electrons by abundant free electrons generated with laser-induced plasma. This result clearly demonstrates that the dynamics of solvated electrons are significantly influenced in plasma environment, especially in high density plasma such as femtosecond laser-induced plasma.

In the presentation, we will demonstrate the detail of the decay dynamics of solvated electrons in femtosecond laser-induced plasma in water [5]. In addition, dynamics of the production of solvated electrons by femtosecond laser-induced plasma is also planned to be presented, which is our very recent result in progress.

References

[1] P. J. Bruggeman *et al.*, Plasma Sources Sci. Technol. **25**, 053002 (2016).
[2] J. M. Herbert, Phys. Chem. Chem. Phys. **21**, 20538 (2019).
[3] V. K. Meader *et al.*, J. Phys. Chem. A **121**, 6742 (2017).
[4] H. Lu *et al.*, J. Phys. Chem. **93**, 27 (1989).
[5] N. Sakakibara *et al.*, Phys. Rev. E **102**, 053207 (2020).

[a] Current affiliation: Department of Chemistry, Tokyo Institute of Technology.