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Positive and negative ion emission from microdroplets by MeV energy ions

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Synopsis We have developed a new experimental setup that allowed us to study collision interactions between fast ion beams and liquid droplets under a vacuum condition. Droplets of water and ethanol are irradiated with 0.4-1.5 MeV H^+ and 2.0 MeV C^{2+} ions. The droplet diameter is estimated from energy loss measurements of projectile ions penetrating through droplets. Time-of-flight mass spectra of positive and negative secondary ions exhibit a series of cluster ions generated via protonation and deprotonation.

Study on the interaction of fast ions in liquids is important to understand the initial physicochemical processes of radiation effects in living cells. Conventional experiments using liquid targets were limited mostly to irradiation under atmospheric pressure because of high vapor pressure in vacuum. Our group already succeeded in ion irradiation of liquid targets in vacuum by applying a liquid-jet technique and reported mass-spectrometric studies of secondary ions from liquid-jet surfaces [1]. In the present work, we have developed a new experimental setup using “liquid droplets” as an additional option to perform collision experiments between energetic ions and liquid targets under a higher vacuum condition. We obtained mass spectra of positive and negative secondary ions from water and ethanol microdroplets.

The experiment was performed by using the 2 MV tandem Pelletron accelerator at Quantum Science and Engineering Center, Kyoto University. Droplets of water or ethanol produced in atmosphere were transferred into a vacuum chamber through a differential pumping system and crossed with an ion beam of 0.4–2.0 MeV H^+ or 2.0 MeV C^{2+} ions from the accelerator. The collision chamber was kept the pressure around 10^{-4}–10^{-3} Pa during the measurements. To deduce size distributions of the droplets at the collision region, distributions of the energy loss of incident ions passing through water droplets were measured. As a result, the droplet sizes were found to be distributed around a few micrometers or less in diameter. Positive and negative secondary ions ejected from droplet surfaces induced by collisions were analyzed by time-of-flight mass spectrometry.

Figure 2 shows an example of mass spectra of negative secondary ions from ethanol droplets induced by 2.0 MeV C^{2+} ions. We observe fragment ions generated by deprotonation ($C_2H_5O^-$) and additional loss of two or four hydrogen atoms ($C_2H_3O^-$, C_2HO^-). Negative cluster ions which are also generated by deprotonation and additional loss of hydrogen atoms, $(EtOH)_n(C_2H_mO^-)$ (m=5,3,1), are observed up to n ~ 10, although the three peaks with different number of hydrogen atoms (m) are not resolved at higher n due to a limited mass resolution. It was found that negative cluster ions seem to be produced more effectively from droplet targets than from an ice target. This might be due to different charge delocalization time scale depending on the phase and/or temperature.

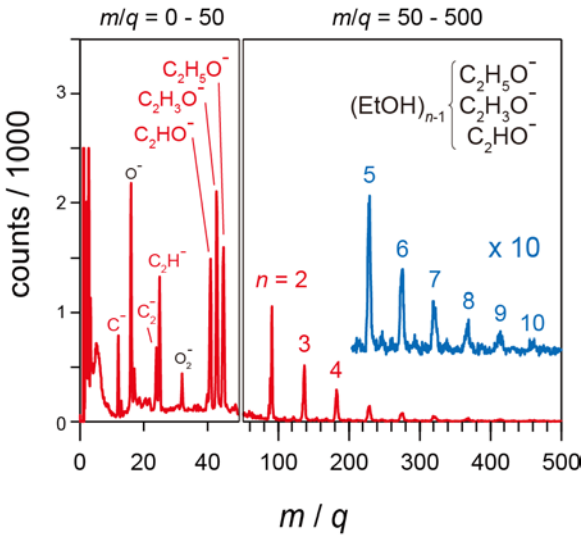

Figure 1. Mass spectrum of negative secondary ions from ethanol droplets induced by 2.0 MeV C^{2+}.

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References

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