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Simultaneous Measurements of Temperature and Pressure in Laser-Simulated Impact Vapor Clouds using Fe Emission Lines

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Impact processes may have played an important role of planetary evolution [e.g., 1]. Vaporization of both impactor and planetary crust due to shock heating is considered as one of the most important processes on the origin of Moon [2], the synthesis of prebiotic organics [3], and the K/P mass extinction [4]. However, a high energy density state of silicate rocks with phase changes and chemical reactions in impact processes is not understood well because direct measurement methods of temperature (T) and pressure (P) vapor clouds is still immature. In our previous studies, we have proposed the measurement methods of T and P of impact-induced vapor clouds using emission spectroscopy [6-8]. However, these methods have a number of problems, such as uncertainty in the degree of ionization and difficulty in measurement of the emission lines of hydrogen and hydrogen-like ions. In this study, we propose an improved method to simultaneously measure T and P of impact-induced vapor clouds using Fe emission lines. Iron is very suitable for measuring T of vapor clouds using Boltzmann plot because Fe has many emission lines in narrow ranges of wavelength with a wide range of upper energy levels. In addition, a width of each emission line is broadened due to mutual collisions of atoms in a vapor clouds and is proportional to P. Although the effect of pressure broadening is small, it is an indicator of P in the vapor clouds if we can detect the line broadening. We conducted laser ablation experiment using a Hematite target (Fe2O3) to use the proposed method. We observed laser simulated impact vapor clouds during adiabatic expansion and measured T and P of vapor clouds as a function of time. We could observe 15 emission lines of atomic Fe in a wavelength range from 380 to 385 nm and a decrease in a width of an emission line with time. The T and P of a vapor cloud is estimated as 10ˆ4 K and 10ˆ3 bar 290 - 390 ns after laser irradiations, respectively. Furthermore, the observed change in the T and P is consistent with a T and P expected by an adiabatic expansion. This result strongly suggests that the proposed simultaneous T and P measurement method works well. This method can estimate a T and P of vapor clouds using only one observed spectrum. Moreover, because both meteoritic materials and planetary crusts generally include a large amount of iron, the proposed method can serve as a powerful tool for measuring the thermodynamic state of impact-induced vapor clouds.

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