In-Situ Observation of Silicate Vaporization by Hypervelocity Impacts: The Phase Boundary of Impact-Heated Silicate.

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Silicate is the main constituent of planets and satellites in inner solar system. It has been considered that silicate is vaporized due to shock heating by the impact with a velocity higher than 10 km/s [e.g., 1]. Impact vaporization of silicate is one of the most important processes on atmospheric erosion [2], circum-terrestrial silicate vapor disk formation by a giant impact [3], atmospheric heating [4] and methane formation [5] by reentry of vapor condensate from large impacts. However, model parameters on impact vaporization of silicates are not well determined by laboratory experiments. In this study, we conduct impact experiments using a laser-driven launcher achieving such velocities to observe impact vaporization process of silicates. The laser-driven gun experiments were conducted at GEKKO XII-HIPER facility of ILE of Osaka Univ. The accelerated Ta sheet collides with either quartz or diopside target. The impact area of a thin silicate target on the side opposite from the flyer impact was observed by a high-speed spectrometer. A few high-quality emission spectra of impact flash from Ta impacting silicate targets have been successfully obtained. The flash from a quartz target exhibits a featureless continuum spectrum, most likely blackbody radiation. The flash from a diopside target shows a number of emission lines along with a strong continuum. Based on blackbody fitting of the continuum spectra, we can estimate the peak shock temperatures of the silicate targets; 13,000 K for quartz and 12,000 K for diopside. The pressure of peak shock can be calculated from flyer speed and the Hugoniot parameters of Ta, quartz, and diopside [6, 7], yielding 230 GPa for quartz targets and 280 GPa for diopside targets. The temperature (T) of vaporized diopside can be estimated by line intensity ratio method [8]. Calcium vapor temperature is most likely around 8000 K. When the individual emission line profiles are examined more closely, one can notice their extremely large breadth. The line profile is well fitted by a Lorenz function, strongly suggesting that this is due to pressure broadening [9]. If the broadening is due to mutual collisions among Ca atoms, then the vapor pressure (P) is estimated to be 4 GPa. Although the data are still preliminary, we can obtain a significant knowledge on silicate vaporization processes from the above results. First, diopside vapor is just vaporized from shock-heated melt. Thus, the observed P-T condition is on the vapor-liquid boundary of diopside. This will provide a very important data point regarding silicate vaporization at extremely high T and P, perhaps near the critical points. The location of the phase boundary of impact-heated silicates would have significant effect on the dynamic evolution of vapor plume produced by a moon-forming giant impact, for example. If vaporization occurs at a higher pressure along an isentropic decompression path of an impact vapor plume, it would be accelerated very efficiently, resulting in circum-terrestrial disk with larger mass and radius. Such change in the initial condition of the disk will influence the condition of formation for the Moon significantly.

References:

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