LASER GUN SHOCK EXPERIMENTS ON IMPACT VAPOR PLUMES AND ITS IMPLICATION FOR ORIGIN AND EVOLUTION OF PLANETARY ATMOSPHERE.

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Introduction: Atmospheric compositions and pressure are among the most important boundary conditions to investigate the evolution of the surface environment of planets [e.g., 1, 2]. Hypervelocity impacts are thought to play a key role in the origin and evolution of planetary atmospheres. Shock compression/heating and subsequent rapid decompression induce a variety of physical and chemical processes [e.g., 3]. The understanding of physical/chemical behavior of impact vapor plumes is important to investigate the number of geological events [e.g., 4-8]. Such events, however, have not been understood well because of the lack of reliable experimental data on impact-induced vaporization due to experimental difficulties.

In this paper, we describe our experimental approaches for understanding impact-induced vaporization. Recently, high-power lasers used in the studies on nuclear fusion allow us to address extreme conditions on a phase space produced by >10 km/s impacts in a laboratory. We conducted a series of laser gun shock experiments using geologic samples. Then, we applied the results to the geological problems, including atmospheric blow-off on the early Earth and a killing mechanism at the K/Pg impact event.

Experiments: Laser gun shock experiments were carried out using GEKKO-XII HIPER facility at Osaka University. The experimental setup and procedure are described in detail in our previous studies [9-13].

***P-T* Hugoniot measurement for Mg_2SiO_4:** We obtained the Hugoniot curve for forsterite on a pressure – temperature (*P-T*) plane up to 1.2 TPa using the direct drive technique. We captured time-resolved optical signal from a shocked sample using a streaked spectrometer and a VISAR. Figure 1a shows the obtained *P-T* Hugoniot curve for forstereite. The peak shock temperature at >400 GPa is much lower than the M-ANEOS prediction, suggesting that shock-heated forsterite has a higher heat capacity [13, 14]. Such high heat capacity leads to a higher entropy gain, resulting in a higher degree of vaporization after decompression than was previously thought.

Atmospheric blow-off on Earth: The eroded atmospheric mass due to an impact from planets can be calculated based on the *P-T* Hugoniot curve and the sector blow-off model [5]. We investigate the change in the atmospheric pressure on the early Earth during the late veneer phase with a stochastic model [15]. We found that the pre-existing atmosphere on the early Earth is likely to be in a complete loss during the late veneer phase [14].

Chemical composition of impact vapor plumes: We conducted the direct measurements of the chemical composition in impact vapor plumes using the flyer acceleration technique. A natural anhydrite ($CaSO_4$) sample was used as a target to investigate sulfur chemistry in vapor plumes. A quadrapole mass spectrometer (QMS) was used to measure the SO_3/SO_2 molar ratio. Figure 1b shows the SO_3/SO_2 molar ratio as a function of peak shock pressure. We found that SO_3 is the dominant species in impact-induced $CaSO_4$ vapor plumes at a wide range of peak shock pressure [12].

The K/Pg mass extinction due to acid rain: Our results indicate that a huge amount of SO_3 should be released into the atmosphere after the K/Pg impact. The high SO_3/SO_2 ratio leads to an intense global acid rain rather than global cooling proposed as the killing mechanism in the previous studies [e.g., 12, 15].

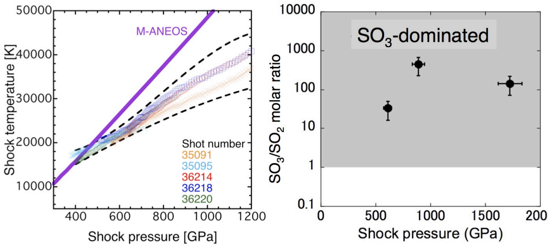

Figure 1. (a) The *P-T* Hugoniot curve for forsterite. (b) The SO_3/SO_2 ratio as a function of shock pressure.

References:

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