IMPACT-INDUCED SULFUR RELEASE FROM A CARBONACEOUS CHONDRITIC IMPACTOR: IMPLICATION TO THE K/PG EVENT. S. Ohno[1], T. Kadono[2], K. Kurosawa[3], T. Sakaiya[4], H. Yabuta[4], K. Shigemori[2], Y. Hironaka[2], T. Sano[2], T. Hamura[5], S. Sugita[5], T. Arai[1], T. Matsui[1], [1]Planetary Exploration Research Center, Chiba Institute of technology (PERC/Chitech) (ohno@perc.it-chiba.ac.jp, 2-17-1 Tsudanuma, Narashino, 275-0016 Chiba, Japan), [2]Institute of Laser Engineering, Osaka University, [3]The Department of Complexity Science and Engineering, Graduate School of Frontier Sciences, University of Tokyo, [4]Department of Earth and Space Science, Graduate School of Science, Osaka University, [5]The Department of Complexity Science and Engineering, Graduate School of Frontier Sciences, University of Tokyo.

Introduction: A large impact is widely accepted as the cause of the K/Pg mass extinction [e.g., 1, 2]. However, the killing mechanism of the mass extinction are still controversy. Some previous studies have shown the importance of sulfur-bearing gasses which were released by the impact [e.g., 3]. The sulfur-bearing gasses would have converted to sulfuric acid aerosols and caused sunlight blockage and/or sulfuric acid rain.

Chemical composition of sulfur-bearing gasses in impact vapor clouds is a key to understand the mechanism and influence of the environmental perturbation caused by the impact-induced sulfur-bearing gasses [4]. One of a most important hypothesis of environmental perturbation of the K/Pg event is sunlight blockage and impact-induced winter, which was proposed by some previous studies [e.g., 5]. However, Ohno et al.[6] show that SO_3 was the dominant species in sulfate-composition impact vapor clouds. If the released sulfur-bearing gasses are dominated by SO_3, the estimated residence time of the released sulfur in the atmosphere is very short and intense acid rain would have acidified oceanic surface layer significantly [7]. SO_3 release indicates that the sunlight blockage and cooling caused by sulfuric acid aerosol would not have worked as killing mechanism efficiently because of the very short duration time [7].

Nevertheless, the sedimental sulfate is not the only source of the sulfur-bearing gasses released by the impact. Previous studies suggest that a carbonaceous chondritic impactor is consistent with the geochemical evidences [e.g., 8]. The estimated mass of sulfur-bearing gasses released from the carbonaceous chondritic impactor is not negligible. Although it is smaller than that released from the sedimental sulfate [e.g..9], the amount of sulfur-bearing gasses released from the carbonaceous chondritic impactor would have been large enough to cause strong climate forcing [9]. The results of thermodynamic calculation of chondrite-composition impact vapor suggest that sulfur-bearing gasses in carbonaceous chondritic impact vapor are dominated by reducing species such as H_2S and/or SO_2, not SO_3 [10,11]. The reducing sulfur molecules released into the atmosphere would have formed sulfuric acid aerosols gradually and caused long-term sunlight blockage and cooling. Thus, investigation of the molecular composition of sulfur-bearing gasses in carbonaceous chondritic impact vapor clouds is important to understand the environmental perturbation caused by the Chicxulube impact.

Recently, an experimental method of direct impact-induced vapor analysis using a high-power laser gun in Osaka University and a quadrupole mass spectrometer (QMS) was established [12, 13]. In this study, we applied the method to sulfur-bearing gasses in carbonaceous chondritic impact vapor and discuss about its implication to the K/Pg event.

Experimetnal method: Figure 1 shows the experimental setup of this study. We accelerate Ta flyer foil using a large powered and high speed laser gun (GEKKO XII-HIPER facility of Institute of Laser Engineering of Osaka University. Detail of the facility is described by Kadono et al. [12] and detail of the experimental system of gas analysis is described by Ohno et al. [6].). The flyer and the target sample are set in a large vacuum chamber and on a low pressure condition ($<10^{-3}$ mbar). We irradiated a laser pulse (1054nm, 10-20ns, ~1 kJ) on a 50 μm-thick plastic ablator, which is set in front of a 30 μm-thick tantalum flyer. The ablator is vaporized by the laser pulse and the generated high temperature vapor accelerates the flyer. The flyer impacts on a slice of murchison meteorite (CM2) target. A 200 μm-thick gold spacer is set between the flyer and the murchison meteorite target.

The chemical compositions of the impact-induced vapor plumes were measured directly using a quadrupole mass spectrometer (QMS). We introduce the released gasses to the QMS through a SUS inhalation tube. We use an hollow aluminum sphere in order to avoid dispersion of the released gas to the vacuum chamber and to improve the S/N ratio of the QMS analysis.

Results: Figure 2 shows an example of time series data of the QMS measurements. We observed significant amount of SO_2, OCS, and H_2S gas released by the foil impact. The blank level, the QMS currents before the impact, is much lower than the QMS current values of the impact-induced SO_2, OCS, and H_2S gas. H_2S was the most abundant species and no small amount of SO_2 and OCS were also observed in all the shots of this study. On the other hand, QMS signals derived from SO_3 were not detected in any the shots of this study.

Our experimental results suggest that sulfur-bearing gasses in carbonaceous chondritic composition impact vapor does not contain SO_3 gas, which is the dominant sulfure-bearing species in the sulfate-composition impact vapor. More than half of the impact-induced sulfur-bearing gasses would have been molecular species other than SO_2, such as H_2S and OCS. These results consistent with the results of theoretical studies of thermodynamic equilibrium in impact vapor [10, 11].

Implication to K/Pg event: The sulfur-bearing gasses other from SO_3, released from the carbonaceous chondritic composition impactor, would have been oxidized in the atmosphere and converted into sulfuric acid aerosol gradually. It would have resulted in long-duration sunlight blockage and cooling [e.g. 5] although it would have not contributed to the global intense acid rain just after the K/Pg impact and the ocean acidification proposed by Ohno et al.[7]. Furthermore, the domination of the reducing species in the sulfur-bearing gasses in carbonaceous chondrite composition impact vapor would have resulted in duration time of the sunlight blockage and cooling caused by sulfuric acid aerosols longer than previous estimates based on SO_2 and/or SO_3 release [e.g., 9]. The formation of sulfuric acid aerosols in the atmosphere would have laseted for 10 years or longer, because the timescale of conversion to the sulfuric acid aerosols from the reducing sulfur-bearing species are longer than that from SO_2. Longer duration of sunlight blockage and cooling should have affected more severely on the ecosystem.

References:

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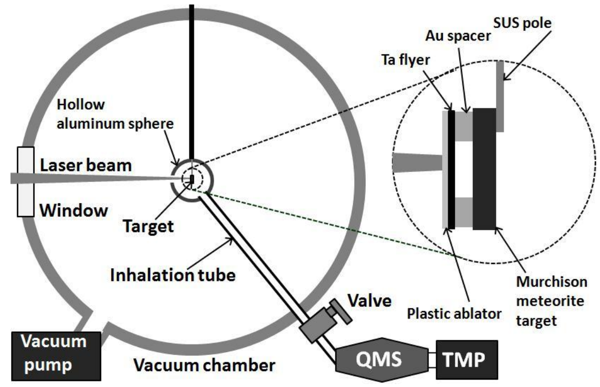

Figure 1: A schematic diagram of the experimental system. Detail is described by Ohno et al. [6].

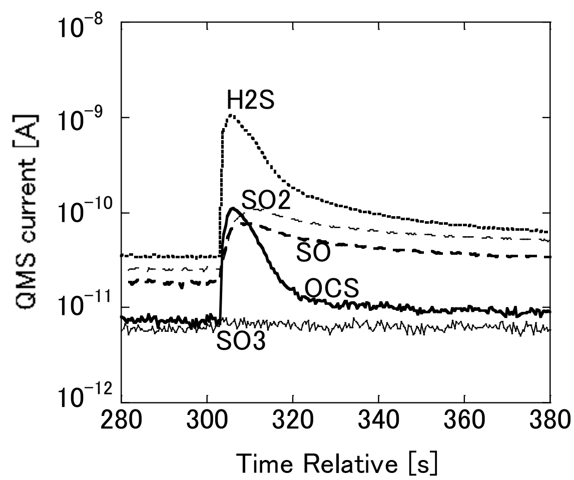

Figure 2: An example of the time-series data of the QMS measurements. The QMS currents of SO (mass number 48), SO_2 (mass number 64), SO_3 (mass number 80), H_2S (mass number 34), and OCS (mass number 60) are plotted against the time. The QMS currents of SO, SO_2, H_2S, and OCS increased significantly at the timing of the impact. No significant signals of SO_3 were detected although the sensitivity of this experimental method is high enough to analyze the impact-induced SO_3 quantatively [6].