SHOCK VAPORIZATION AND POST-IMPACT CHEMISTRY IN AN OPEN SYSTEM WITHOUT ANY DIAPHRAGMS. K. Kurosawa[1], T. Okamoto[1], H. Yabuta[2], G. Komatsu[3], and T. Matsui[1], [1]Planetary Exploration Research Center, Chiba Institute of Technology, 2-17-1, Tsudanuma, Narashino, Chiba 275-0016, Japan, kosuke.kurosawa@perc.it-chiba.ac.jp, [2]Dept. Earth and Planet. Sys. Science, Hiroshima University, Japan, [3]International Research School of Planetary Sciences, Università d'Annunzio, Italy.

Introduction: Impact-induced vaporization/devolatilization and post-impact chemistry may have played important roles in the chemical evolution on planetary bodies in the early solar system [e.g., 1]. Two-stage light gas guns are among the most suitable experimental apparatuses to investigate impact-driven processes because they can accelerate a macroscopic projectile (>0.1 mm in diameter) at room temperature up to several km s^{-1}. To avoid chemical contamination from the acceleration gases of the guns, most previous studies have been conducted in closed systems [e.g., 2-4], in which samples are completely covered by containers. In contrast, all natural impacts occur in open systems. The thermodynamic paths during decompression from shocked states to reference states in the closed systems are significantly different from that in the open systems because of following reasons; (1) the fast cooling of the shocked materials due to adiabatic expansion is prevented due to the limited volumes in the containers and (2) the total pressures in the closed systems are supported by the mechanical strength of the containers [e.g., 5, 6]. Thus, impact experiments in an open system are essential to accurately understand the impact-driven phenomena.

In our previous study, we have developed an experimental technique for two-stage light gas guns [6]. The method can prevent intrusion of the chemical contaminant gases from the gun and can measure the chemical composition of the produced gases [7] and the absolute amount of selected chemical species, accurately [6]. However, the procedure needed to use a plastic diaphragm, which leads to destruction of weak projectiles, such as quartz glass [6], and chemical contamination with a trace amount of carbon (ppm level). This weak point prevents further extension of the gun system, such as a detailed investigation of the generation of complex organics in an impact-generated vapor.

In this study, we present a modified experimental procedure without any diaphragms.

Experimental system: We developed the gun system for studies related to shock-induced vaporization and post-impact chemistry at the Planetary Exploration Research Center of Chiba Institute of Technology (PERC/Chitech), Japan. We newly introduced two automatic gate valves into the gun system. Figure 1 shows a schematic diagram of the system.

Experimental procedure: Prior to a shot, the valve #1 and #2 are closed and opened, respectively. The gun side (the upstream from the valve #1) is evacuated and the green shaded region is filled with a chemically inert gas, such as He and Ar. We produce a gas flow using a rotary pump. To keep the total pressure of the experimental chamber to be constant, the inert gas is continuously introduced into the experimental chamber with the same gas flux against the evacuation. Using a pulse generator, we input signals with time delays to the valves #1, #2, and the two-stage light gas gun. At the beginning, the valve #1 is opened, leading to the expansion of the inert gas into the dissipation chamber due to a strong pressure gradient. Then, the gun is operated and a projectile is launched to the target placed at the experimental chamber. The contaminant gas following the projectile is not able to intrude into the experimental chamber due to the outflow to the upstream of the gun. In contrast, the solid projectile is able to penetrate into the outflow and to collide with the target. Since the time required for the projectile acceleration is much shorter than the time duration of the outflow of the inert gas, the impact occurs under a pressure with 90% or more of the initial pressure. Immediately after the impact, the valve #2 is closed to keep impact-generated vapor in the experimental chamber. Subsequently, the gas generated by the impact is introduced into a quadrapole mass spectrometer (QMS, Pfeiffer vacuum, Prisma plus QMG220) by the inert gas flow produced by the rotary pump.

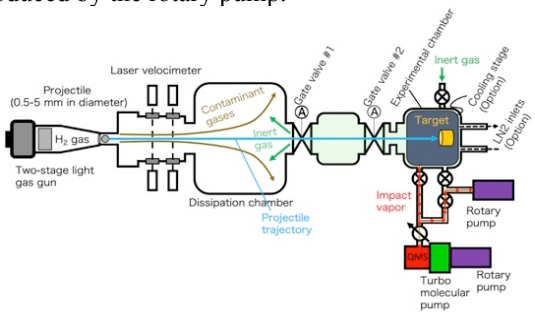

Figure 1. A schematic diagram of the system.

Experiments: We conducted three impact experiments using natural calcite samples to demonstrate the new system. We summarized the experimental condition as follows.

Experimental conditions. An Al_2O_3 sphere with the diameter of 2 mm was used as a projectile. A nylon-slit sabot [8] was used to accelerate the projectile. The impact velocities were from 5.4 km/s to 5.7 km/s. A high-

speed video camera (Shimadzu, HyPer Vision-X) placed at the side of the experimental chamber was used to observe an impact event. We used Ar as the chemically inert gas. The pressure in the chamber under a steady state of the Ar gas flow was varied from 500 Pa to 3000 Pa. Natural calcite samples with the masses of ~2 kg were used as targets. The density of the samples is closed that of crystalline calcite (2.67 g/cc). Calcite was chosen because we have already studied the devolatilization from calcite in the previous study using the previous experimental system [6]. The total pressure inside the QMS was fixed at 10^{-4} Pa.

Results:

Projectile: We confirmed that the launched projectile was intact prior to the impact. Thus, the new method allows us to use an arbitrary combination of a solid projectile and a target with strength. In fact, we were able to use a quartz glass projectile of which strength is much smaller than Al_2O_3 sphere in another on-going series of experiments.

Characteristics of the system: Figure 2 shows the temporal change in the total pressure of the experimental chamber in the case of the Ar pressure of 500 Pa. The total pressure gradually decreased with time after the valve #1 is opened down to ~450 Pa. We observed a small rise in the pressure (~10 Pa) around 0.1 s after the impact. The fluctuation in the pressure of this shot was within ~10%. Figure 3a shows the time variation of the ion currents for M/Z = 2 (H_2) I_2, which is the major contaminant gas from the gun, with different pressures of the Ar gas flow. Although a small amount of molecular hydrogen was detected, the peak values of the ion current were in order of 10^{-12} A to 10^{-11} A, which were 4–5 orders of magnitude smaller than the dominant ion current for M/Z = 40(^{40}Ar). Figure 3b shows the ion currents for M/Z = 36 (^{36}Ar) and for M/Z = 44 (CO_2), I_{36} and I_{44}, as a function of time. The time profile of the ion current for M/Z = 44 was close to that obtained in our previous study [6]. A lower Ar pressure leads to a higher current ratio of I_{44} to I_{36}, suggesting that a higher signal-to-noise ratio (S/N) was obtained at a lower Ar pressure because the CO_2 productions for the three shots discussed here are expected to be similar due to the fact that the impact velocities for the three shots are close to each other. Thus, we should choose Ar pressure by considering a trade-off of the degree of chemical contamination and the S/N.

Future plan and Conclusions: The measurement of the absolute amount of the vapor is still a problem for the system. Now, we are developing a calibration system to quantify the sensitivity of QMS or the other measurement devises. This system contains a chamber for preparing a gas mixture with a known mixing ratio,

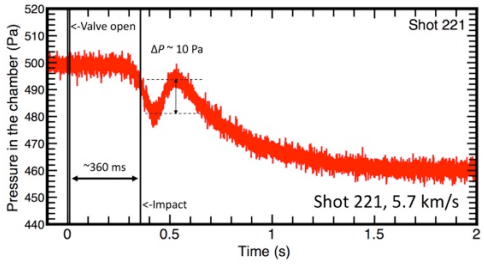

Figure 2. The temporal change in the total pressure of the experimental chamber. The timings of the open of the valve #1 and the impact are indicated as vertical lines.

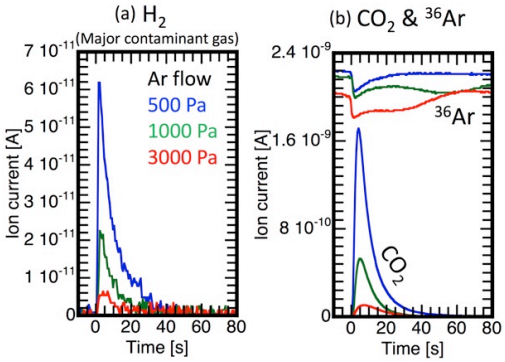

Figure 3. The ion currents for selected species. (a) M/Z = 2. (b) M/Z=36 and 44. The equilibrium pressures of the Ar gas flow are indicated in the panel (a).

a small volume accurately measured, and another automatic gate valve. The system can introduce the gas mixture with a known volume within a short duration. This situation is similar to actual impacts.

We demonstrated that the new system allows us to investigate shock vaporization/devolatilization and post-impact chemistry in an open system without (1) the intrusion of the contaminant gases from the gun, (2) projectile destruction prior to the impact, and (3) the contamination from the plastic diaphragm used in the previous study. The new system can apply the measurements of the chemical composition of vapor generated by a collision of any combination of a projectile and a target.

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References: [1] Mukhin et al. (1989) *Nature,* **340**, 46. [2] Boslough et al. (1982) *EPSL*, **61**, 166. [3] Furukawa Y. et al. (2008) *Nature Geoscience*, **2**, 62. [4] Martins Z. et al. (2013) *Nature Geoscience*, **6,** 1045. [5] Ivanov B. A. and Deutsch, A. (2002) *PEPI*, **129,** 131. [6] Kurosawa K. et al. (2012) *EPSL*, **68,** 337-338. [7] Ishibashi K. et al. (2017) *LPS XLVIII*, #2141 [8] Kawai N. et al. (2010) *RSI*, **81,** 115105.