Oxidation of carbon compounds by oxygen released from SiO2 within large impact-induced vapor clouds

Ko Ishibashi[1]; Sohsuke Ohno[1]; Seiji Sugita[2]; Toshihiko Kadono[3]; Takafumi Matsui[4]

[1] Earth and Planetary Sci., Univ. of Tokyo; [2] Dept. of Complexity Sci. & Eng., Univ. of Tokyo; [3] IFREE; [4] Grad. Sch. of Frontier Sci., Univ. of Tokyo

When hypervelocity impacts on planetary surfaces occur, impact-induced vapor clouds are generated. The gases produced within vapor clouds are thought to affect the surface environment of planets. However, the composition of produced gases within vapor clouds is not understood well yet.

A typical approach of the previous theoretical studies on gases produced within impact-induced vapor clouds considers volatile element only and do not consider silicates. The reasons why they ignore silicates are the lack of detailed knowledge on behavior of silicates within vapor clouds and the idea that silicates condense at high temperatures and do not contribute to the reactions of carbon compounds. However, laser irradiation experiments on rocks and chondrites by Mukhin et al. (1989) show that the resulting gases were composed mainly of the oxidized species (CO and CO2). They propose that oxygen from silicates may oxidize carbon. However, since such an oxidation process has not been investigated in detail, we cannot tell whether oxygen from silicates react with carbon.

Thus, we had previously examined whether oxygen derived from SiO2 which is the main component of silicates and thermally decomposes to SiO and O2 at high temperature combines with carbon using laser irradiation experiments. The result indicates that oxygen from SiO2 combines with carbon within laboratory-scale vapor clouds.

However, since the quenching temperatures of SiO-O recombination reactions decrease as the scale of a vapor cloud increases, the recombination extends. Thus, if the oxygen left in the gas phase after SiO-O recombination reactions quench is used in the reactions with carbon compounds, the oxidation by oxygen from SiO2 may not occur at large scale. Thus, it is important to examine how the oxidation process may scale with the scale of impact.

In this study, we investigated the scale dependence of the oxidation of carbon compounds using laser irradiation experiments. The ratio of oxygen of SiO2 used in the reactions with carbon compounds was estimated for different vapor scales. We conducted laser irradiation on polyethylene-SiO2 mixture (PE-SiO2) targets of several mixing ratio and ethylene vinyl alcohol copolymer (EVOH) targets, and the resulting gases were measured with a QMS. Polyethylene consists of C and H (C:H=1:2). EVOH consists of C, H, and O (C:H:O=1:2:0.28). If a vapor plume is in thermochemical equilibrium until reactions quench, the composition of produced gases is determined uniquely by the elemental composition of vapor plume and the quenching temperature and pressure. Therefore, if quenching conditions are the same and the compositions of the produced gases are the same, vapor-phase elemental compositions of vapor plumes of different targets at quenching points are also the same. By comparing the composition of EVOH and that of PE-SiO2 from which the gases of the same composition as gases produced from EVOH are produced, the ratio of the oxygen of SiO2 used in reactions of carbon can be estimated. Three laser beam diameters 0.5mm, 1mm, and 2mm were used to change the scale of generated vapor clouds. The result shows that the ratio of oxygen used in the reactions of carbon compounds are ~15 % at the all beam diameters and that there is no systematic change. This result indicates that the amount of oxygen used in the reaction with carbon compounds is not determined by the extension of the SiO-O recombination reactions. This is supported by experimental results as follows. No oxygen is produced from pure SiO2 target while oxygen-bearing species are produced from PE-SiO2 target. This is consistent with what mentioned above. Oxygen released from SiO2 may be thermodynamically partitioned between SiO and carbon. Thus, the oxidation process may occur in the large-scale vapor clouds. The result of this study indicates that the effect of silicates should be considered.

Reference: Mukhin, L.M. et al. (1989) Nature 340, 46-48.