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Observations of Internal State in Oblique-Impact-Induced Vapor Clouds

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Organic supply processes on prebiotic Earth are thought to be contributed by chemical synthesis in the atmosphere, exogenic delivery via cometary/asteroidal impacts, and in situ production driven by impacts (Chyba and Sagan, 1992). Because organic synthesis process due to impacts occurs in limited periods of time and limited spatial extents, it would lead to a higher concentration of organics for a given total amount of organic supply and higher efficiency of sequent chemical reactions. Previous experiments show that most organics originally contained in meteorites are decomposed by intense shock heating at near-vertical impact angles (Mukhin et al., 1989). In the case of oblique impacts, it was suggested that the most organics also decomposed by intense aerodynamic heating during the downrange drifting (Sugita and Schultz, 2003a). Low-angle impact experiments using polycarbonate projectile within a nitrogen atmosphere, however, show that CN is formed efficiently from reduced carbon supplied from the projectiles and nitrogen in the atmosphere (Sugita and Schultz, 2009). However, there are neither time-series nor spatially-imaged detail observations of the interior thermochemical state of the vapor cloud. Therefore, the details of physical and chemical reaction within the vapor cloud, the distributions of compositional gas and fragment, and the region for chemical reaction with ambient atmosphere are still unknown. {cr/}

Thus, we performed the oblique impact experiments with a two-stage light gas gun at ISAS. Projectile, impact velocity, impact angle, and ambient pressure of nitrogen atmosphere are polycarbonate spheres (7 mm in diameter), 4.8-6.5 km/s, 30 degree from the horizontal, and 30 hPa, respectively. We observed the motion of self-luminous vapor clouds and gas/fragments distribution in the clouds using two high-speed cameras of framing rate at 2 us/frame with different band-pass filters. Transmission wavelength ranges of the band pass filters are 373 nm to 387 nm (CN), 400 nm to 410 nm (Blackbody) and 505 nm to 515 nm(C{sub}2{/sub}). A high-speed time-series spectrometer observed to measure time variation of spectrum and blackbody temperature of fragments in the vapor cloud.{cr/}

Thus, we revealed the spatial difference among distributions of projectile fragments and gas components. These three components are sequentially distributed; projectile fragment, C{sub}2{/sub} gas, and CN gas from the top to the back of the vapor cloud. The sequence suggests a scenario that the gas decomposed of projectile fragments within the top of the vapor cloud is flowed down with wake flow, and chemically changed to CN radical within the back of the vapor cloud. In addition, we measured the transitional velocity of the horizontally drifting vapor cloud which almost keeps its shape during its motion. First, instant acceleration of vapor cloud to 1.9 times the impact velocity is seen. Then it decelerates to the degree of impact velocity during almost 25 us due to air resistance. Additionally, we solved the equation of motion of the vapor cloud to analyze its motion. Because the measured vapor velocity is well explained when it was assumed constant mass and cross-section toward drifting direction, it was indicated that mass concentrated locally in the cloud.

Measured temperature is achieved to 5000 K at 10 us after impact when the vapor came into the field of view of the spectrometer, then it fell down to 2500 K at 45 us after the impact. Vaporization rate is estimated from the temperature and measured velocity based on heat balance on fragment surface. It is higher than Sugita and Schultz (2003b). The primary reason of such a difference is that they assume the downrange velocity of impact vapor clouds to be approximately the same as the horizontal component of the impact velocity, which is only about the half the actual value as revealed by the high-speed imaging observation in this study.

Keywords: impact, organic resynthesis, impact vapor cloud, aerodynamic heating