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Observations of impacted, frozen Lunar and Martian regolith simulants

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Abstract

An examination of impact flashes from frozen Lunar and Martian simulant (JSC-1A and JSC-1 respectively) was carried out in order to better understand the physical and chemical behaviour of the highly energetic, short-lived, ejecta cloud. The relative emission intensity and decay from the impact ejecta were examined across 10 spectral regions and a semi-quantitative analysis of the peak flash intensity and relative densities of the frozen targets carried out. Additional experiments recorded the emission spectra of the frozen target ejecta during the first ~15 μs after impact to more clearly understand the origin of any atomic/molecular emission.

1. Introduction

Interest in the chemistry of Solar System ices has increased significantly during recent years with several space missions and spectroscopic observations yielding clues to their dynamic behaviour [1-4]. Although the scientific community has a much better understanding of the chemical material found in these systems, very little is known about how impacts may have influenced them. These hypervelocity impacts (>3 km/s) deliver a substantial amount of energy and foreign material to the impacted body and are so energetic that the subsequent light flashes (e.g. on the Moon and Jupiter) can be observed using modest facilities [5-7]. Relatively little data exists on the study of impact flashes in the laboratory, meaning the interpretation of data from these observed events is hampered by poor understanding of the phenomena. It is likely, however, that impacts drastically alter the physical and chemical properties of icy bodies through several interacting processes (mixed phase flow, fragmentation, melting, ionisation, vaporisation, etc.).

2. Experimental

The University of Kent two-stage light gas gun was used to accelerate 3 mm Al sphere to ~5 km/s, which subsequently impacted frozen targets of a) pure water ice, b) pure CO_2 ice, c) a ~50:50 mixture of water ice and JSC-1A Lunar regolith simulant, d) a ~50:50 mixture of finely crushed CO_2 ice and JSC-1A Lunar regolith simulant e) a ~50:50 mixture of water ice and JSC-1 Martian regolith simulant, and f) a ~50:50 mixture of finely crushed CO_2 ice and JSC-1 Martian regolith simulant. A fine spray of water was required to bind the simulants to the crushed CO_2 ice before refreezing the mixtures.

The impact flash intensity and decay were monitored across 10 spectral bands (between 355 nm and 950 nm) using an array of photodiodes with optical/IR band-pass filters, placed slightly below the shot line within the target chamber (Figure 1). Photographs of the impact flash were also recorded using a FastCan digital camera with a frame rate of 2800 frames/s (Figure 2). In order to avoid obscuration from fast-moving, solid/liquid ejecta, the early-time (<15 μs) emission spectra were recorded through a side window of the impact chamber (at 90° to the shot line) using a Princeton Instruments ultra-fast, *PI-MAX4* intensified camera and *IsoPlane* spectrograph (Figure 3).

3. Figures

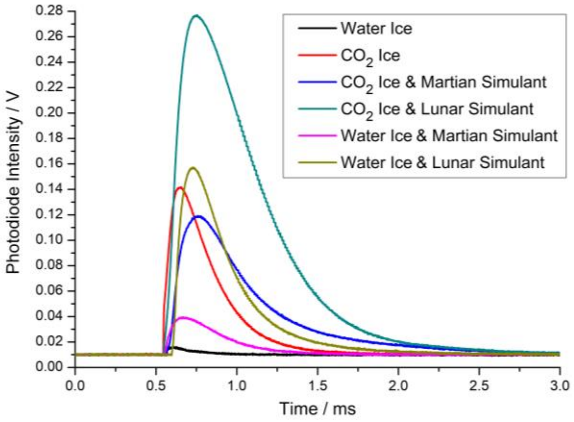

Figure 1: Temporal variation in the impact flash intensity from 840 nm to 860 nm of frozen target ejecta impacted by a 3 mm Al sphere at ~5 km/s.

Figure 2: Sequential digital photographs of the ejecta flash from a CO_2 ice target impacted at 4.81 km/s.

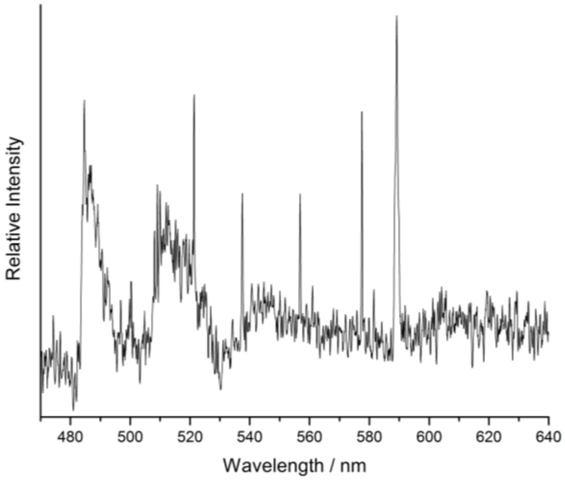

Figure 3: Early-time (<15 μs) impact ejecta emission spectrum from a CO_2 ice target impacted at ~5 km/s.

4. Results and Conclusions

A significant difference was detected both in the overall intensity of the emission and the relative temporal behaviour of the emitting species within the impact plume for each frozen target, as shown in Figure 1. The temporal variation in emission intensity was observed to behave differently across the various spectral bands, implying a wavelength dependence of the impact flash dynamics. The overall peak intensity of each impact was approximately correlated the relative densities of the frozen target materials when separately comparing the water ice/simulant and CO_2 ice/simulant mixtures. Digital photographs of the impact flash also indicated a change in the shape and colour of the ejecta emission over time, as shown in Figure 2.

The resulting emission spectra from impacts using CO_2 ice and simulant-based targets show bands across the full spectral range observed (470 nm to 640 nm), with consistent contributions primarily from AlO, CO and C_2. Interestingly, the spectra from impacts onto simulant-based targets show little evidence of strong emission bands originating from vapourised metal oxides (other than AlO from the projectile), perhaps due to insufficient energy from the relatively small-scale impact.

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