

EARLY-TIME TEMPERATURE EVOLUTION OF THE IMPACT FLASH AND BEYOND. C. M. Ernst and P. H. Schultz, Brown University, Department of Geological Sciences, Box 1846, Providence, RI 02912 (Carolyn_Ernst@brown.edu).

Introduction: When a hypervelocity projectile impacts a target, a light flash is produced at the moment of first contact. Time-resolved light intensity curves can be used to determine the starting conditions of the observed impacts [1,2]. For impacts into metal targets, the peak intensity of the flash occurs during the initial projectile penetration, with the signal quickly decaying [3,4]. Impacts into particulate targets produce a source of blackbody radiators in addition to the initial flash. This source extends the resulting light intensity profile well beyond the time of initial contact.

A time-resolved temperature profile is an additional useful tool for analyzing the early-time evolution of an impact based solely on its emitted light. Observed thermal signatures indicate that the increase in light intensity to a peak value is dependent on an expanding radiating source area, not on an increasing temperature. Impact temperature profiles evolve differently for various angles and projectile diameters.

Experiments: Hypervelocity impact experiments were performed at the NASA Ames Vertical Gun Range (AVGR) in order to study the evolution of the impact flash and the resulting thermal plume. Two high-speed photodiode systems recorded the time-resolved light intensity. The first system, also used in previous studies [1,2], consists of a single photodiode with a spectral range of 350-1100 nm. The second system consists of six similar photodiodes that can be used in conjunction with bandpass filters (50–80 nm FWHM). This multi-channel photodiode/filter system was calibrated using a carbon arc blackbody thermogauge.

The systems viewed the impacts through windows in the ceiling of the target chamber. The single photodiode system was used as an unfiltered channel. Filters used with the multi-channel system were centered at 500, 550, 600, 650, 700, and 880 nm. The recorded intensity data have a time resolution of 100 ns.

Spherical Pyrex projectiles (0.318–0.476 cm in diameter ($=a$)) were launched at velocities between 4.50–6.10 km/s and at angles of 30° and 90° (measured from the horizontal). The impact targets were pumice dust, which was used to simulate loose, particulate regolith material. All experiments were performed in near-vacuum conditions (< 0.5 Torr). At levels below ~ 10 Torr, ambient pressure does not change the observed light intensity for macroscopic impacts [5]. This has been confirmed with these experiments.

Data: The seven channels of raw data collected for a 30° impact are depicted in Figure 1. For all of the recorded impacts, the characteristics of the unfiltered channel include an intensity peak that occurs 10–50 μ s after impact (time = t_0) and lasts from 50–100 μ s, and a long-duration decay signal (timing depends on initial a ,

θ , and v). Prior to this broad feature is a brief intensity spike lasting less than 2–3 μ s. These features have been reported previously [1,2].

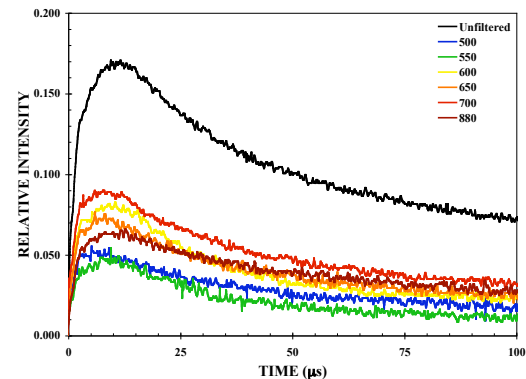


FIGURE 1. Seven channel raw intensity data from an impact of a 0.318 cm Pyrex sphere into a pumice dust target at 30° and 6.04 km/s. The unfiltered channel has the highest intensity and is shown in black. The filtered channels are represented by different colors.

Results: The filtered signals have the same overall shape as the unfiltered light curve but vary in relative intensity. Analysis yielded a thermal evolution curve for each impact based on ratios of the filtered channels. The calculated temperature profiles for several of the experiments are plotted in Figure 2. Curve fitting has been used to reduce the noise and this smooths the appearance of the signals. The peak intensity times are indicated for each curve by diamonds.

Experiments with similar starting conditions (a , θ) yielded similarly shaped temperature profiles. The highest temperatures were observed at the time of first contact. Higher temperature levels occurred for the 30° impacts. This contrasts with other results [6,7] but most likely indicates a difference in the emitting source (blackbody versus vapor). Temperature then decreased with time for all cases, though more sharply for 90° impacts than for 30° impacts. The 30° profiles exhibit a gradual decrease in temperature out to a time of ~ 50 μ s, where they begin to level off. The 90° profiles all exhibit very shallow slopes throughout the entire profile.

Source Area. Light intensity is dependent on the temperature of the radiating source as well as its surface area by the relation $I = A\sigma T^4$, where σ is the Stephan-Boltzman constant. Since the intensity and temperature of these impacts have been observed, the effect of source area on the light produced can be determined. The unfiltered intensity profile for the 30° impact from Figure 1 is plotted again in Figure 3. A theoretical intensity profile is also calculated from the known temperature evolution using an assumption that there was no source area growth to influence the light output ($I \sim T^4$).

