

HIGH TEMPERATURE EMISSIVITY OF METEORITES RELATED TO ASTEROID ATMOSPHERIC ENTRY. D. R. Ostrowski^{1,2} and K. L. Bryson^{1,2}, ¹NASA Ames Research Center, Moffett Field, CA, USA., ²Bay Area Environmental Research Institute, Ames Research Center, Moffett Field, CA, USA, E-mail: daniel.r.ostrowski@nasa.gov.

Introduction: Meteorites provide vast amounts of information on the make up and history of the solar system. Thermal properties are an important fundamental characteristic of the meteorites; an indicator of both their chemical and physical nature. The physical properties of the meteorites are needed to determine the likelihood of meteoroids survivability during atmospheric entry. The Asteroid Threat Assessment Project (ATAP) has been set up to investigate the full risk and outcomes that near Earth asteroids pose to the planet. One of the tasks of this program is to study the physical properties of meteorites that pertain to how a meteor behaves during atmospheric entry. Ablation models require the input of emissivity [1,2,3].

Meteorites contain both high and low thermally conductive materials. For darkening material emissivity will increase as temperature increases until peak temperature is reached and then begins to decrease [4]. The metal components will slowly increase the emissivity as temperature increases, while the non-metallic material's emissivity will decrease. It has been determined for urelites that emissivity decreases as a function of temperature above 500K [4].

Experimental: Total thermal emissivity for the selected meteorites has been measured over a broad wavelength range of 8 to 14 μm from $\sim 20^\circ\text{C}$ up to 600°C . Emissivity values for up to atmospheric entry temperatures are needed for modeling. For lower temperatures the emissivity is measured at 15°C increments, 50°C increments for intermediate temperatures, and 100°C increments at higher temperatures. At elevated temperatures meteorites are heated in a nitrogen atmosphere to limit the effects of oxidation. Emissivity is measured by dual laser infrared thermometers that have an accuracy 1% of measured temperature + 1°C . With the infrared temperature gun set to an emissivity of 1, the temperature of both the sample and a black body are measured. In these experiments the black body is a titanium cube coated in carbon black high temperature paint. The ratio of the meteorite temperature to the blackbody temperature is calculated as the emissivity.

Results: All meteorites analyzed in this study have higher emissivities at 20°C compared to their analogs and the individual materials that makeup their composition. The average emissivity of ordinary chondrite falls and Antarctic meteorites at 20°C is 0.988 ± 0.008 , in agreement with previously published values for or-

dinary chondrites [5]. For the howardite and eucrite finds the average emissivity is 0.997 ± 0.03 at 20°C .

As the temperature increases to 100°C the emissivity decreases then rebounds and stabilizes for the next 100° (Fig. 1). The rebound emissivity value for most of the chondrites is around half of the initial 100°C decrease. The largest change is observed between 20°C to 40°C , with the average emissivity dropping 0.045. Nearly all chondrites heated to between $300/350^\circ\text{C}$ have emissivities below 0.90. Heated chondrites range in emissivity between 0.85-0.95. When comparing values between ordinary chondrite falls and Antarctic meteorites no notable differences are observed.

Trends for howardite NWA 2060 and eucrite NWA 7874 are similar to the ordinary chondrites. However in the case of the howardite and eucrite the drop and rebound in emissivity at the lower temperatures is shallower. One sample of NWA 2060 does not follow the trend. Cube 1 of NWA 2060 emissivity drops slightly upon heating and remains constant out to 100°C . Then emissivity decreases in a broad u-shaped feature out to 180°C , having a higher emissivity than other basaltic meteorite samples. The variation in emissivity within NWA 2060 is likely due to its inhomogeneity. Continued heating results in all howardite and eucrite samples with emissivity values just below 0.90.

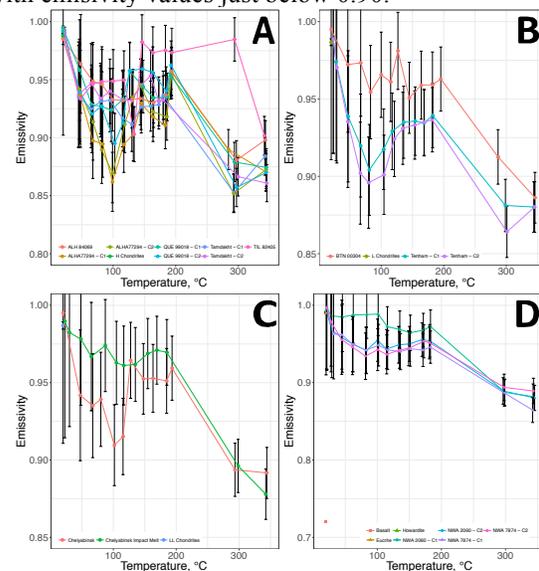


Figure 1. Emissivity for low and intermediate temperature. Emissivity for H chondrites (A), L chondrites (B), LL chondrites (C), howardite and eucrite (D).

| Meteorite | Type | Temperature (°C) | Emissivity |
|----------------------|------|------------------|-------------|
| Tamdakht | H | 577.2 | 0.941±0.005 |
| Tamdakht in Nitrogen | H | 527.7 | 0.94±0.01 |
| BTN 00304 | L | 581.2 | 0.847±0.005 |
| TIL 820405 | H | 580.0 | 0.932±0.005 |

Table 1. High temperature emissivity measurements of ordinary chondrites at standard atmosphere and nitrogen atmosphere.

The heating of samples to temperatures near 600°C results in an increase in emissivity for the H ordinary chondrites (table 1) compared to measured values at 350°C. In comparison, the L chondrite BTN 00304's emissivity continues to decrease compared to lower temperature measurements. Oxidation occurs in all three non-nitrogen atmosphere measured samples as noted by the dark reddening of the material (Fig. 2). It appears that for Tamdakht, oxidation has no effect on the emissivity with the two different atmosphere samples having the same emissivity within error.



Figure 2. Tamdakht samples used for high temperature emissivity. Before heating (A), after heating in standard atmosphere (B), and after heating in nitrogen atmosphere (C).

Conclusion: Thermal emissivity is a uniform trend across both falls and Antarctic finds. All meteorites show a broad decrease and rebound in emissivity below 200°C with a minimum around 100°C. The lowest emissivities are between 0.84 and 0.90 across all meteorite types. Decreasing emissivity at intermediate temperatures and at high temperatures for BTN 00304 would result in an increased rate of ablation for its parent meteoroid. Similar results have been observed in ureilitic material [4]. The opposite trend is observed in the emissivity of H chondrites at elevated temperatures. This implies H chondrite meteoroids will have a greater rate of energy transfer and thus lower ablation rates.

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