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Experimental characterization of meteoric material exposed to a high enthalpy flow in the Plasmatron

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Meteoroids, disintegrated during their entry in the atmosphere, contribute massively to the input of cosmic metals to Earth. Yet, this phenomenon is not well understood. Experimental studies on meteor material degradation in high enthalpy facilities are scarce and often do not provide quantitative data which are necessary for the validation of the simulation tools. In this work, we tried to duplicate typical meteor flight conditions in a ground testing facility to analyze the thermo-chemical degradation mechanisms by reproducing the stagnation point region conditions.

The VKI Plasmatron is one of the most powerful induction-coupled plasma wind-tunnels in the world. It represents an important tool for the characterization of ceramic and ablative materials employed in the fabrication of Thermal Protection Systems (TPS) of spacecraft. The testing methodology and measurement techniques used for TPS characterization were adapted for the investigation of evaporation and melting in samples of basalt (meteorite surrogate) and ordinary chondrite. The materials were exposed to stagnation point heat fluxes of 1 MW/m^2 and 3 MW/m^2.

During the test, numerous local pockets were formed at the surface of the samples by the emergence of gas bubbles. Images recorded through a digital 14bit CCD camera system clearly revealed the frothing of the surface for both tested materials. This process appeared to be more heterogeneous for the basaltic samples than for the ordinary chondritic material. Surface temperature measurements obtained via a two-color pyrometer showed a maximum surface temperature in the range between 2160 and 2490 Kelvins. Some of the basaltic samples fractured during the tests. This is probably due to the strong thermal gradients experienced by the material in these harsh conditions. Therefore, the surface temperature measurements suffered sudden drops in correspondence with the fracturing time.

Emission spectra of air and ablated species were collected with resolution in time and space thanks to a set-up counting three synchronized spectrometers with different line of sights. The spectra indicated dominant radiating molecules in the range from 240 to 450 nm [CN Violet and N2+ (1-)]. By analyzing the spectra of all tests, it was observed that the most volatile components Na and K were released more efficiently than the Si, Fe, Ca, Mg and Ti components. Also, some ionized atoms (Ca II, Mg II and Fe II) were identified, the lines of Ca II being the strongest in the range from 350 to 450 nm. The differences in composition between the two materials was highlighted by tracking the emission histories of the neutral elements. For example, the emission of the Si line (288.2 nm) was almost null for the ordinary chondrite compared to the basalt. Moreover, iron lines, which were present in the spectra collected for the ordinary chondrite, were not visible for basalt. These results are consistent with the different chemical composition of both materials.