Line emission from ionized meteorite surfaces: experiments and models

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LIBS (Laser Induced Breakdown Spectroscopy), based on optical emission spectroscopy of a laser-produced plasma, is a technique of surface and bulk analysis of increasing importance. By acquiring the atomic and ionic emission spectra LIBS enables measuring the atomic composition in a fast way with minimal sample preparation.

In its application to meteorite samples in the authors' laboratory [1,2] both Fe/Ni (metal samples) and $MgSiO_3/FeSiO_3$ (rock samples) including additional minor and trace elements are involved. In particular, samples of Toluca, Sahara 98222, Dhofar 019, Sikhote Alin, Campo del Cielo, Dhofar 461 have been analyzed.

Theoretical considerations about laser induced plasmas and Local Thermodynamic Equilibrium (LTE) are essential in order to obtain definite conclusions from a limited set of results. For example, to calculate the total number density of the different forms in which an element is present (typically the neutral atom and singly charged ion), the ionized fraction of its atoms must be evaluated. To this aim, the Saha equation is applied, therefore the electron temperature T_e is needed. This last is obtained by a Boltzmann plot of excited species. Populations are estimated from the emission intensity of transitions, Einstein coefficients, energy of the emitted photons and degeneracy of the upper levels. The electron density is determined from the Stark broadening of emission lines.

Results are in good agreement with traditional chemical analysis and microprobe results but can be obtained in much shorter time and with a technique usable in space applications [3].

Besides this obvious application to geochemistry, in perspective laboratory plasmas produced from meteorites may provide an analogue of the ablation plasmas in the atmospheric entry of meteoroids, helping to improve standards in use for meteor spectroscopy. These plasmas also reproduce primordial solar systems conditions prior to the start of the condensation sequence. In exploring these analogies, theoretical models are expected to play an important role. To check the concept, simple meteor entry models are implemented based on flight dynamics, thermodynamics and kinetic theory, allowing to estimate the surface temperature, the ablation rate and the ratio of intensity of Fe I lines during the entry trajectory.

References

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