Laser ablation plasmas produced from metals and silicates in meteorite samples

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Meteorites represent the most accessible form of space matter available for laboratory investigation. They contain minerals and metal crystals nearly as ancient as the Solar system, in particular chondrulae (hard inclusions) in chondrite meteorites are pristine samples of the less volatile components of the early Solar nebula.

In this context 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] two kinds of substrates are involved: Fe/Ni (metal samples) and MgSiO₃/FeSiO₃ (rock samples), in both cases including additional minor and trace elements.

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 Tₑ 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.