Femtosecond laser ablation ICP-MS of fluid inclusions: Validation and prospects

Clement Courtieu, Damien Guillaume,
Stefano Salvi and Remi Freydier

LMTG, Université de Toulouse, CNRS, IRD, OMP , 14 Av. E. Belin, F-31400 Toulouse, France

Experimental Protocol

LA-ICP-MS is now a commonly used analytical technique in the study of fluid inclusions. Unlike typical nanosecond UV laser ablation systems (Ar:F or Nd:YAG), the new femtosecond ablation systems can provide athermic ablation. One advantage of this, is a lower risk of fluid loss due to thermal shock during opening of the inclusion. In our experiments, we used a femtosecond Ti:Sapphire 800 nm laser ablation system, following the analytical protocol outlined by Heinrich *et al.* (2003).

The fluid inclusions studied are hosted in quartz from the Trimouns talc-chlorite deposit (Ariège, France). Before ablating the inclusions, we performed petrographic and microthermometric studies, and calculated Na concentrations to be used as internal standard. For the LA-ICP-MS analyses we used the femtosecond laser and an Elan 6000 ICP-MS, with NIST SRM 610 as external standard.

Results and discussion

We could measure the concentration of a wide range of elements whithin the fluid, including major cations and anions (e.g., Na, Ca, K, Cl), minor elements such as Li, Mg, and REE (La, Nd). Reproducibility of NIST 610 data were 5% for every element studied, except for K (20%) and Cl (50%). We were able to measure a very large range of concentrations within a single analysis: from 200,000 ppm for major elements like Ca to about 5 ppm for the Rare-Earth Elements (La).

This study validates the use of a femtosecond laser ablation system used for LA-ICP-MS analysis of fluid inclusions. Femtosecond laser enabled both precise and reproductible ablation of fluid inclusions and NIST glasses. However, using a NIST glass as an external standard leads to important errors on some major elements in the fluid (about 50% on Cl), which are probably due to 1) very low concentration of some of the elements in NIST 610 compared to the sample, and 2) interferences or low output of the ICP-MS.

References

Heinrich C. A., Pettke T., Halter W. E., Aigner-Torres M., Audetat A., Gunther D., Hattendorf B., Bleiner D., Guillong M., and Horn I., 2003. *Geochimica et Cosmochimica Acta* **67**, 3473-3497.

Titan's current and future exploration

A. Coustenis[1], D. Jennings[2], A. Jolly[3], Y. Bénilan[3],
S. Vinatier[1], D. Gautier[1], C. Nixon[2], M. Flasar[2],
G. Bjoraker[2], P. Romani[2] and E. Royer[1]

[1]LESIA, Paris-Meudon Observatory, 92195 Meudon, France (athena.coustenis@obspm.fr,sandrine.vinatier@obspm.fr, daniel.gautier@obspm.fr, emilie.royer@obspm.fr)
[2]NASA/GSFC, Greenbelt, MD, USA; (Donald.E.Jennings@nasa.gov, conor.nixon@ssedmail.gsfc.nasa.gov, f.m.flasar@nasa.gov, paul.n.romani@nasa.gov, gordon.l.bjoraker@nasa.gov)
[3]LISA, Univ. Paris XII, France (benilan@lisa.univ-paris12.fr, jolly@lisa.univ-paris12.fr)

Titan's stratosphere has been studied in the past from the Earth and also from space with Voyager, ISO and more recently Cassini observations. In particular, spectra recorded by the Composite Infrared Spectrometer (CIRS) aboard the Cassini spacecraft became available during the Titan flybys spanning two years now since SOI (Flasar *et al*., 2005; Teanby *et al*., 2006, Vinatier *et al*., 2006, Coustenis *et al*., 2007). The spectra characterize various regions on Titan from 85°S to 80°N with a variety of emission angles. We have studied the emission observed in the CIRS detector arrays (covering the 10-1500 cm^{-1} spectral range with apodized resolutions of 2.54 or 0.53 cm^{-1}). We have used temperature profiles retrieved from the inversion of the emission observed in the methane nu$_4$ band at 1304 cm^{-1} and a line-by-line radiative transfer code to infer the abundances of the trace constituents and some of their isotopes in Titan's stratosphere (Coustenis *et al*., 2007). The composite spectra show several signatures of previously identified molecules: hydrocarbons, nitriles, H_2O and CO_2. Besides these well-known trace species, a firm detection of benzene (C_6H_6) is provided by CIRS at 674 cm^{-1} and allows for the study of its latitudinal variations. No longitudinal variations were found for any of the gases. Information is retrieved on the meridional variations of the trace constituents and tied to predictions by dynamical-photochemical models (Hourdin *et al*., 2004; Lavvas *et al*., 2007). Molecules showing a significant enhancement at northern latitudes are the nitriles (HC_3N, HCN) and the complex hydrocarbons (C_4H_2, C_3H_4). The D/H ratio on Titan was also determined from the CH_3D band at 8.6 micron and found to be about 1.5 ±0.2 10^{-4}. We have also identified the presence of C_2HD at 678 cm^{-1} (Coustenis *et al*., 2006). Constraints are also set on the vertical distribution of C_2H_2.

References

[1] Coustenis *et al*., 2006, *BAAS* **38**.
[2] Coustenis *et al*., 2007, *Icarus*, in press.
[3] Flasar *et al*., 2005, *Science* 308, **975**.
[4] Hourdin *et al*., 2004, *J. Geophys. Res.* **109**, E1205.
[5] Lavvas *et al*., 2007, *Plan. Space Sci.*, submitted.
[6] Teanby *et al*., 2006, *Icarus* **181**, 243.
[7] Vinatier *et al*., 2006, *Icarus*, in press.