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The EXTASE thermal probe: Laboratory investigation and modelling of thermal properties.

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Abstract

In recent years scientists show an increasing interest in the structure and behavior of extraterrestrial surfaces and subsurface layers. Various missions, like *Rosetta* to comet 67P/Churyumov-Gerasimenko, include landing devices to investigate the physical properties of planetary surfaces as well as the surface of the Moon, satellites, asteroids, and comets.

EXTASE – a spin-off project of *Rosetta*/MUPUS - is a thermal probe able to measure the temperature and to inject heat into the selected material at 16 different positions. We present first results of measurements done at various pressure levels and a comparison with mathematical models.

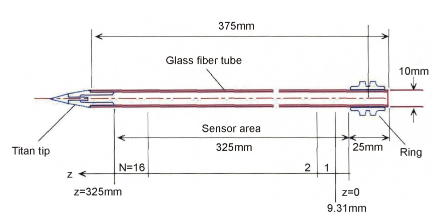
1. Introduction

The material of comets is considered as the least altered one since the formation of the solar system and serves therefore as reference for its original composition. The properties at the surface and the upper layers of comets and their variation with the intensity of solar irradiation are therefore of particular interest. The *Rosetta* mission, which includes an orbiter and a lander, is the first one that will perform a soft landing on a comet nucleus and make *in situ* measurements at the surface. The thermal and mechanical surface properties will be measured with the MUPUS-probe (MUlti-PUrpose-Sensor for surface and subsurface science [2]). This probe is designed to measure the physical properties of the comet nucleus down to a depth of about 30 cm. The EXTASE probe has a similar technical design as MUPUS, but its functionality is restricted to thermal measurements. Unlike MUPUS it has no active hammering mechanism for soil penetration.

At the Space Research Institute in Graz several measurements with EXTASE using different sample materials under various pressure conditions were done. The results were compared with results obtained from modeling and measurements with *Line Heat Source* sensors [1].

2. The EXTASE probe

Same as MUPUS, EXTASE consists of 16 single, cylindrical shaped, short heating elements with the same diameter and increasing length from top to bottom. This configuration allows measuring the temperature and the thermal conductivity as a function of depth. As a design feature, each sensor can be heated individually. Due to this flexibility in the heater operation, it can differentiate between single layers with potentially different thermal properties. Sketch and picture of EXTASE are shown in Figure 1.



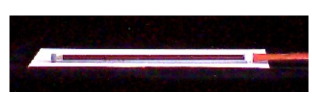


Figure 1: Sketch and image of the EXTASE probe.

With this probe several measurements with different materials like glass beads and snow at atmospheric pressure and under vacuum conditions were done. The experimental results were compared with results obtained from numerical simulations done with

COMSOL, a software to solve scientific problems based on partial differential equations using the Finite Element Method. The use of these models should lead to a better understanding of the possible operation modes of MUPUS.

3. Measurements and modelling

The general measurement principle is the same as for *Line Heat Source* sensors. The thermal conductivity is obtained by a temperature measurement at a certain point along the sensor at two points in time. For the interpretation of the obtained results, ΔT measured over a particular time interval is plotted versus the logarithm of time. After an initial phase, ΔT rises linearly with $\ln(t)$. From the inclination of the linear part the thermal conductivity can be calculated from measurements at two different points in time.

With the different sample materials several measurements were done at different pressure levels:

- only the temperature was measured, no active heating applied;
- measurements where only one sensor was heated;
- measurements where each sensor was heated separately for a certain time, the probe was cooled down and afterwards the next sensor was heated with the same heating power density

Simulations with a finite element software accordant to the different modes were done. Since the single components of the EXTASE probe have thicknesses in a range from µm to mm a model has to be found were the number of grid points is high enough to get appropriate values and low enough not to exceed the numerical limits of COMSOL. Therefore, two different approaches were used, a 3 dimensional one with precise geometry but only few sensors and based on these results, a 2D-axisymetric one including all sensors but a simplified geometry.

As an example for the results obtained, Figure 2 shows the temperature profile of sensor 14 (close to the lower end of the probe) when the probe was inserted in a sample of glass beads with a grain size range 0.25 – 0.5 mm. As can be seen, a quite good agreement between the measurement and the modeling result is obtained in this case.

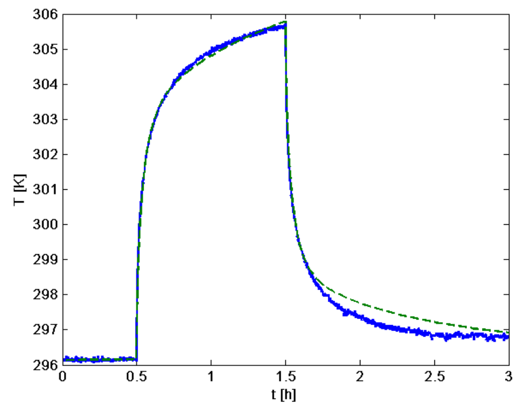


Figure 2: Comparison of the measured temperature of sensor 14 (solid line) and the results of the 3D-simulation (dashed line).

4. Summary

These first measurements and simulations performed in Graz have lead to reasonable results. The temperature and thermal conductivity values are comparable to results from other investigations done with *Line Heat Source* sensors. To get a reliable method for the interpretation of measurement data from EXTASE or MUPUS type probes, further measurements, especially with layered samples consisting of snow-dust mixtures under vacuum conditions, are necessary.

References

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[2] Spohn, T., Seiferlin, K., Hagermann, A., Knollenberg, J., Ball, A.J., Banaszkiewicz, M., Benkhoff, J., Gadomski, S., Grygorczuk, J., Hlond, M., Kargl, G., Kührt, E., Kömle, N., Marczewski, W., Zarnecki, J.C.: MUPUS – a Thermal and Mechanical Properties Probe for the Rosetta Lander Philae, *Space Science Reviews*, **128**, Issue 1-4, 339-362, 2007.