VISTA: a miniaturized THERMOGRAVIMETER to detect planetary dust and volatiles. E. Palomba[1], F. Dirri[1], A. Longobardo[1], A. Galiano[1], D. Biondi[1], A.Boccaccini[1], E. Zampetti[2], B. Saggin[3], D. Scaccabarozzi[3]

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Introduction: VISTA (Volatile In Situ Thermogravimetry Analyser) is a μ-Thermogravimeter device, developed by a consortium of Italian institutes.

The thermogravimetry technique (TGA) has a wide set of applications, from Space mission to chemical and biological fields [1] as well as to investigate condensation/sublimation and absorption/desorption processes of volatile compounds [2]. TGA can be useful in planetary in-situ missions in order to measure water and organics desorption, whose presence is connected to habitability of the planet/satellite, and to monitor outgassing contamination [3].

The instrument core is a Piezoelectric Crystal Microbalance (PCM), whose crystal is equipped with built-in heater and built-in temperature sensor Crystal oscillation frequency linearly depends on the mass deposited on its sensible area, according to the Sauerbrey equation [4]:

$$\Delta f \propto \frac{f_0^2}{A} \Delta m$$

PCM temperature can be increased by means of an appropriate heater in order to allow sublimation/desorption of the most volatile component of the analyzed sample. This measure gives the volatile content while composition can be inferred by desorption temperature.

Because of the similar temperature desorption range of several volatile species, other physical-chemical parameter have to be obtained by TGA during the sublimation/desorption process, e.g. enthalpy of sublimation/evaporation $\Delta H_{sub,evap}$, entropy of sublimation/evaporation $\Delta S_{sub,evap}$, sublimation/desorption temperature T_{sub} and vapour pressures at a given temperature and pressure (P_{vap}), typical for each compounds [5,6].

VISTA space/planetary applications: VISTA instrument has been studied for space applications and proposed for planetary in-situ missions [7], i.e. it has been studied for Phase A of the ESA proposed missions Marco Polo and selected for MarcoPoloR [8], addressed to a primitive Near Earth Asteroid, and for JUICE (JUpiter ICy moon Explorer), in this case coupled to a Penetrator [9]. In a planetary in-situ mission, VISTA can accomplish the following tasks depending to the planetary environment:

- measurement of abundance of volatile (e.g. water, organics) in planetary/asteroidal regolith an cometary-like activity;
- measurement of dust and ice settling rate, water content in dust and humidity;
- discrimination between water ice and clathrate hydrates (basing on their different sublimation temperature) on icy satellite surfaces;
- determination of composition of non-ice materials on icy satellite surfaces;
- characterization of organic species by measuring its enthalpy of sublimation.

VISTA is composed by two different subsystems: the Sensor Head 1 (SH1), devoted to work at low temperaures (down to -200°C) and to perform heating cycles up to 100°C and the Sensor Head 2 (SH2), able to performs TGA measurements (large temperature range, i.e. >200°C) with a low power budget. The VISTA block diagram is shown in Fig.1.

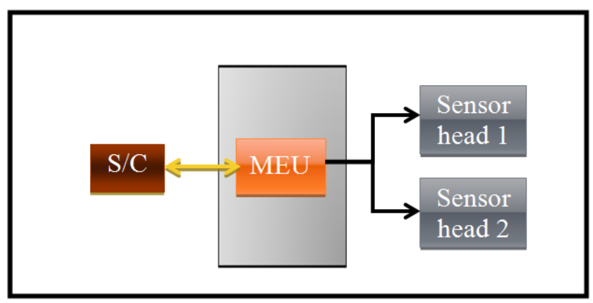

Fig.1. VISTA instrument composed by SH1 and SH2.

SH1 is currently at TRL 6 (Fig.2, *Left*), whereas a laboratory breadboard of SH2 is operative and under test (TRL 4-5) (Fig.2, *Right*). In particular, a dedicated setup has been used to evaluate the SH2 power budget performance: only 0.29 mW are required to obtain a ΔT_v~185°C in vacuum and ΔT_a~100°C in air, whereas to obtain a ΔT=250°C in vacuum only 0.43 mW are needed.

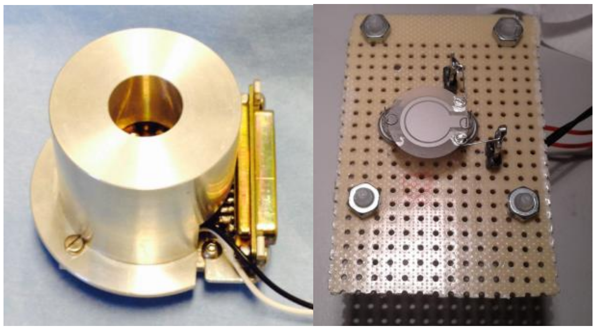

Fig.2. VISTA instrument. Left: SH1 breadboard. Right: SH1 breadboard.

Technical characteristics: VISTA has a very small mass, volume and power requirements and needs a quite small amount of material for the analysis, i.e. less than 1 mg. The main innovation concerns the special design of μ-thermogravimeter, equipped with a built-in heat-er and a built-in thermistor. SH1 and SH2 have its own proximity electronics (including the frequency counter and the temperature control system).

The Main Electronic (ME) board can be shared with other sensors of the scientific package, reducing the instrument load to the sensor heads, only. Technical characteristics of the sensor heads are summarised in Table 1.

Unit	***SH1***	***SH2***
Sensor type	*Quartz Crystal Microbalance*	*$GaPO_4$ Crystal Microbalance*
Resonant Frequency(MHz)	*10*	*5.8*
Mass [g]	*90*	*60*
Volume [mm]	*50x50x38*	*35x35x25*
Power [W]	*1 W (peak); 0.12 (mean)*	*0.62 (peak); 0.37 (mean)*
Data rate	*30 bit/ measurement*	*30 bit/ measurement*
Operating Temperatures [K]	*< 180*	*< 550*
TRL	*6*	*4/5*

Tab.1 VISTA technical characteristics.

Performance Test: a laboratory set-up has been developed in order to use PCM as cold sink (Deposition measurement) for volatiles, to obtain ΔH_{sub} and to perform heating cycles with integrated heaters (TGA measurement).

Deposition Measurement: due to the similar desorption temperatures of different volatile species, ΔH_{sub} has been measured for five Dicarboxylic acids in order to obtain a characterization of each volatile compound.

The sample and the PCM were placed inside a vacuum chamber: the sample, contained in an effusion cell, was heated up to 80°C by means of a resistor whereas the PCM was cooled at -72°C by a cold finger (i.e liquid nitrogen serpentine), in order to allow the molecules deposition coming from the sublimation process.

By measuring two different deposition rates on PCM, R_1 and R_2, at two different sample temperatures T_1 and T_2, it has been possible to infer the ΔH_{sub} of the samples by means of Van't Hoff relation [10]. The obtained results are in good agreement with literature, demonstrating the VISTA ability to measure ΔH_{sub}. Moreover, the presence of some these organic compounds inside meteorites [11] make VISTA useful to know the chemical composition of these samples associated to primitive asteroids [12].

TGA measurement: applying TGA it has been also possible to monitor a sublimation processes and to measure the corresponding ΔH_{sub}, of some Dicarboxylic acids present in Earth's atmospheric aerosol [13]. The exprimental procedure was to perform a deposition of the Adipic acid sample on the crystal's surface, heating the effusion cell up to 100°C, for a total of 29.4 $\mu g cm^{-2}$. Therefore, the cell has been switched off while the crystal was heated by using the integrated heater up to 80°C. Then, the difference in mass came back to "zero", i.e. all the deposited sample was desorbed from crystal's surface. The ΔH_{sub} calculated with Langmuir relation [14] is in agreement within 6% with the result calculated with Van't Hoff relation [13].

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