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A μThermogravimetry/biosensor system for the Penetrator Surface Elements for the EJSM Space mission

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Abstract

The Europa-Jupiter System Mission (EJSM) is a joint ESA/NASA mission under study, within which there will be orbital platforms targeted to both Europa (JEO) and Ganymede (JGO) [1]. We describe here a μThermogravimetry/biosensor system designed to measure volatile (water/organics) compounds and detect possible biosignatures from Europa and Ganymede surface or subsurface. The instrument is studied in the framework of the Penetrator Surface Elements proposed to EJSM.

1. Introduction

Thermo gravimetric analysis (TGA) is a widely used technique to investigate condensation/sublimation and absorption/desorption processeses of volatile compounds in different environments (Fig.1). TGA analyzers are used to investigate outgassing contamination in Space, dehydration and organic decomposition in minerals, as well as to measure moisture content in foods or develop temperature profiles for firing ceramics [2,3,4].

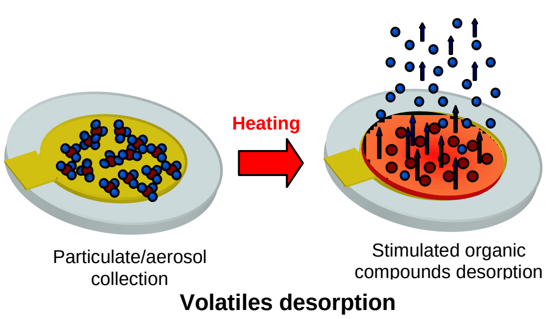

Figure 1. Induced volatiles desorption.

TGA is often coupled with other analytical techniques (e.g., mass spectroscopy and FTIR) in order to determine the specific off-gas materials [5,6]. Molecularly Imprinted Polymers (MIPs) are crosslinked polymers, which are synthesized in the presence of template molecules. The production process uses a target molecule to construct a template of cavities inside the polymer. The cavities so created are then used to trap uniquely (or specifically) the target molecule.

2. Instrument concept

The instrument will consist in two subsystems, the thermogravimetry (S1) and the biosensor systems (S2), and one electronic box. S1 and S2 are composed by a sensitive element and a proximity electronic and will address different objectives:

- Thermogravimeter (S1) to detect and discern volatile species and to determine the refractory to volatile compounds ratio;
- Biosensor (S2) to assess the presence of possible biogenic material.

The core of both the subsystems is a piezoelectric microbalance which converts mass changes in frequency variations following the Sauerbrey equation [7]. S1 is equipped with a built-in heater to perform μTGA. This special design dramatically reduces the total mass and the power required to perform thermal cycles (Figure 2).

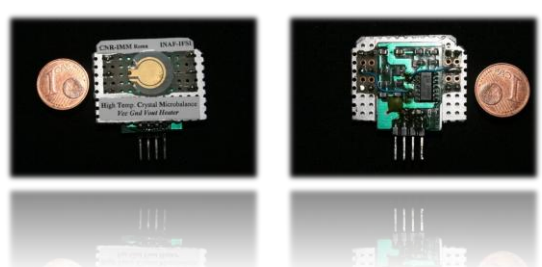

Figure 2. S1 Breadboard (Thermogravimetry Unit).

The biosensor will capture biogenic molecules by means of MIPs that are first produced with specific binding properties and then coupled with the microbalance sensitive area to measures the captured biogenic molecules (overall mass increase).

Table 1: Characteristics of the proposed instrument. The power needed to increase the sensor from the environmental temperature (ΔT) depends on the presence and characteristic of a planetary atmosphere. The values here reported are evaluated for a 1 bar terrestrial atmosphere.

Parameter	**Value/Description**
Mass	40 g
Volume	4 x 2.5 x 3 cm3
Power for TGA thermal cycles	Peak = 2 W (ΔT~500 K) Mean = 0.5 W (ΔT~100 K)
Power (passive mode)	0.1 W
Sensitivities	10 – 100 ppm 0.01 – 1 (ng cm^{-2} s^{-1})
Responsivity	1 ng Hz^{-1}
Telemetry data rate and volume	256 bit each sampling 1 typical thermal cycle = 1 Mbit

3. TGA Power requirements

The actual design of the instrument allows two different configurations:

- Only one built-in heater connected to the power supply (Configuration 1-C1);
- Two built-in heater, using the thermistor as an additional heater connected in parallel with the other heater to the power supply (Configuration 2-C2).

We performed these measurements using both configurations C1 and C2, by placing a thermocouple in contact with the microbalance and varying the applied voltage. The power required by the two configurations to reach the same temperature is the same, as displayed in Fig. 5. The W vs T behaviour is well fitted by a linear regression (R^2 = 0.99). Two different tests in air and in vacuum were performed. While a power of 500 mW is needed to obtain a ΔT of 70°C in air, only 70 mW are sufficient to produce a similar temperature gradient in vacuum conditions.

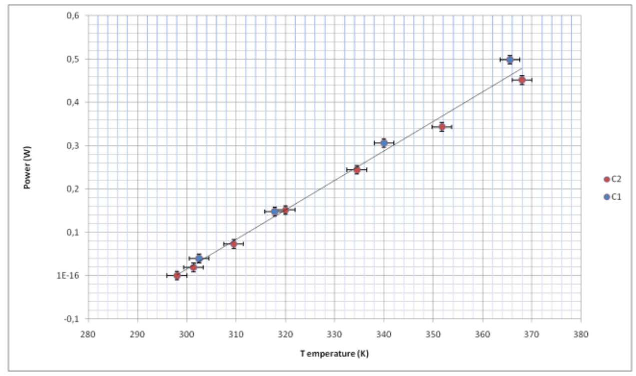

Figure 3. Power budget laboratory tests. (T vs W). The blue dots are for the C1 configuration. The red dots for C2. The fit has been applied to all the data (i.e. C1 and C2 data).

4. Perspectives

The thermogravimetry unit breadboard is fully functional and TGA water desorption measurements from clay minerals are currently ongoing. The design of a mechanical structure able to reach very high temperatures and containing the thermogravimeter with its proximity electronics is in progress. Concerning the biosensor Unit, MIP membranes specific to some amino acids, such as Proline and Alanine are under development and will available very soon for laboratory tests.

References

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