MICROGRAVITY RESEARCH AT THE UNIVERSITY OF MEXICO:

EXPERIMENTS IN PAYLOAD G-006

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ABSTRACT

This paper describes in some detail the experiments contained in the G-006 payload related to: thin film vapor deposition, vacuum variations in a chamber vented to space, solidification of a Zn-Al-Cu alloy, and multiple-location temperature monitoring for thermal model validation. A discussion of the expected results is presented, together with the methods selected to conduct the postflight analysis, and finally, a overview of our future activities in this field.

INTRODUCTION

In July of 1985, a group of researchers from the National University of Mexico (UNAM), started the development of our first set of automatic microgravity experiments. To ensure a diligent start, the project was begun with the assistance of experienced personnel from Utah State University (USU). The payload, G-006, was manifested as a backup for a March 6, 1986 flight, and has since been awaiting preflight certification at KSC.

The payload consists of several university experiments: four from UNAM, described here, and one from each: USU, the Florida Institute of Technology and the U. of Arizona, which will be published independently.

Microgravity research, as well as other activities in earth orbit, are seen as topics of considerable importance for the present and future advancement of scientific and technological frontiers; even though, their full implications are still a matter wide open to discussion. However, it is clear that orbital activities will grow steadily in the coming years, and that no country concerned with the future can afford to remain aside. Thus, the University of Mexico, through its Interdisciplinary Group on Space Activities (GIAE), has focused its attention in the development of microgravity science, satellite technology and extraatmospheric observations of earth and space. Consequently, this project is the first of several others, that allow for the initiation of such efforts, with a set of experiments tailored both: to solve problems of local importance, and to acquire the technological know-how for preparing self-contained space payloads.

The SSCP program at NASA represents, in our view, a novel and cost-effective opportunity to conduct exploratory microgravity research, as well as certain earth/space observations; specially for a country that has no present plans for rocket development.

Experiments included in G-006 were selected from a set of twelve, that covered those many fields of research. Among them, we chose an alloy solidification as a diagnostic method for microstructural formation, an epitaxial growth of a solid to solid interface for basic studies relevant to microelectronics, and two support measurements of temperature and vacuum for immediate use in the experiments, and also of future value in the design of later devices. In a second canister, G-599, we follow a plan to develop more elaborate biomedical, remote sensing and other experiments we are presently integrating.

EXPERIMENTAL ARRANGEMENT

The general arrangement of experiments in this 90kg canister is based in a multilayered sequence, five in all, of which the top four are occupied by the UNAM experiments. Each experiment is contained in a fibre glass hexagonal structure that provides: thermal isolation from the outside, protects the internal experiments, and also, structural fixtures for the various devices (see details in ref.1). The hexagons fit in a 48.2cm diameter circle. Two of the structures are 17.7cm tall, one 12.7 and the other two 10.4cm. All structures are held together by an aluminum structure which bolts to the canister mounting plate using the NASA provided 48cm bolt circle. Three bumpers at the bottom of the payload provide lateral stability to the structure.

A block diagram is provided in Fig 1 to illustrate the disposition of the hardware within the container. The experiments will be individually described in some detail in the next few sections.

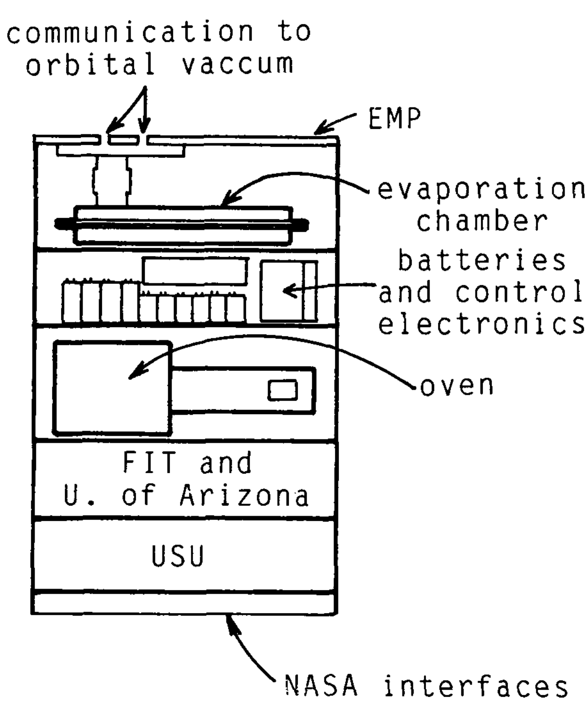

Figure 1. Disposition of hardware within the SSCP canister.

Vapor Deposition Experiment

Attached to the experimenters mounting plate supplied by NASA we have a fixture provided with a bellow that is free to purge into space during ascent and orbital flight, through a filter installed to avoid possible contamination of the Shuttle environment. Immediately following, is the cold cathode vacuum detector of the chamber, where the evaporation of Al will be carried out onto a set of substrates, that include monocrystalline Si, Cu, GaAs, Ag and Silicon oxide. The substrates are mounted on a ceramic heating element for controlled heat treatment during and after vapor deposition (ref.2). The chamber is composed of three independent lobes, where evaporation of different amounts of Al may occur in a controlled sequence onto similar groups of crystals (see fig.2).

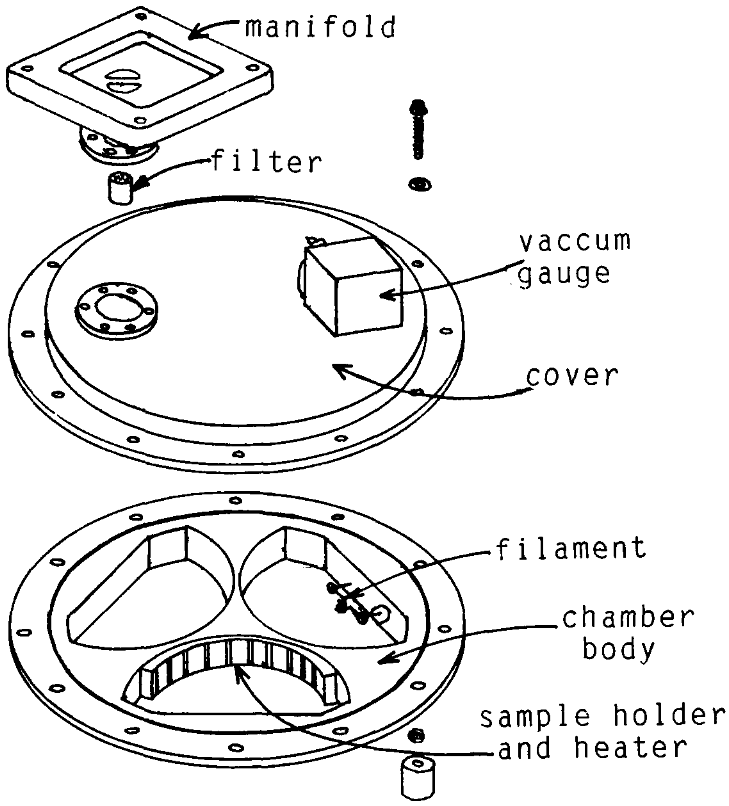

Figure 2. Diagram of metal evaporation chamber.

The Al is placed in a tungsten wire basket through which current can flow from a battery source in order to heat the metal until its evaporation is completed, whilst the substrates are fixed to the ceramic holders that may heat the crystals at the time or at a later period. Power to the heaters, and the evaporation source is controlled by a set of Mosfet transistors, that switch to on/off, instead of relays; since these suffer from carbon build-up at the contact points, with subsequent mechanical failure. Power is fed in short pulse trains to both heaters, thus saving energy, since such transistors consume little current when active and no current when open. Temperature sensors, thermocouples, are detecting the temperature of the substrate heaters in order to control the heat treatment parameters. All signals are monitored and controlled by an onboard microcomputer based on a 65C02 microprocessor with 16 analog input and 8 output ports. It is also equipped with several memories, 16K of Eprom for program and data storage for postflight analysis, as well as 8K of Ram for onboard preprocessing and temporary data management.

The controller may be placed on standby when no action is required. The program is driven by a table installed in ROM which stores the time at which each action must take place, and the function which must be performed. The table entry also contains information with respect to repetitive operations or sets of operations. This permanent table in ROM allows for the controller to be deactivated when a minimum amount of time is available during which no action is required. A survey of previous experiments indicates that this measure reduces the average power consumption by three or more orders of magnitude on most experiments. In order for the controller to be reactivated after a standby period, a clock provides an internal alarm pulse at the time of the next required action. The clock chosen uses approximately 60 microwatts of power. The controller performs the following functions under the command of its table driven program: It monitors up to 16 voltage sources through a multiplexer and an A/D converter (8bits), it can send up to 8 separate voltage pulses; each line has a driver on it capable of supplying three amperes of current, and it stores up to 32k bytes of data for later analysis. The power consumption when active is approximately 120 milliwatts except when performing I/O operations. Identical controllers are used in each of the three active experiments.

Solidification Experiment

The metal studied is a Zn,Al,Cu alloy that is presently under industrial development in our country, however, certain microstructural properties of this superplastic metal remain a topic of study. In the microgravity environment, with an absence of convection currents and crucible contact effects, we expect to produce a sample where the impurities are the sole determining factor of the microstructure; since the other factor participating in the process, the cooling rate, is a controlled variable in this experiment. See fig.3.

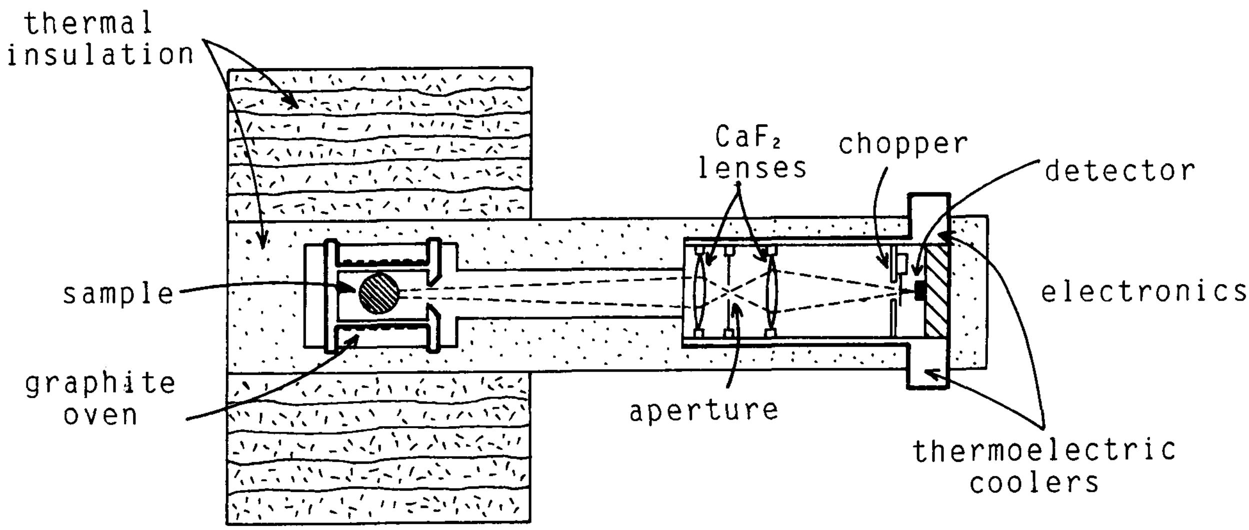

Figure 3. Schematic diagram of alloy solidification experiment.

The test device consists of an oven that contains the sample, an infrared -non-contact- temperature detector, and the control electronics. Grafite was chosen as the oven material due to its thermal characteristics and ease of machining. To avoid wetting of the walls by the melted sample, an inside cover of boron nitride was provided.

The heating element is a resistance heater which surrounds the oven's outside surface. The thermal insulation for the oven consists of a Maranite structure. The temperature of the alloy is measured by using an infrared detector and maintained within predetermined values by the controller. The temperature of the oven is measured by using a thermocouple. The melting point of the alloy is 480 degrees C. This temperature will be exceeded by approximately 40 C and allowed to cool at a precise rate to approximately 50 C.

Vacuum Measurement Experiment

Vacuum measurements are conducted with a cold cathode tube, in view of its linear response, from 10E-3 to 10E-7 Torr., and its drift-free long-term stability; it is also resistant to atmospheric pressure operation. The tube is powered by 12Vdc from the battery pack, that is fed to a DC/AC converter with a 127Vac output. The sensor requires 1.5KV that is obtained from a transformer, and produces a 10mV output signal which is preamplified before relaying it to the data memory. The power source for this experiment is capable of delivering 160W-hrs and is diode protected; a maximum of 200A at 200W may be obtained in extreme conditions from this lead-acid power pack.

The purpose of this experiment is to determine vacuum pressures at different times during flight, including the variations that result from a change in attitude of the shuttle. Pressures inside of a chamber in the GAS/CAN that is venting through the battery purge ports and a filter are not well known yet; however, this information is of considerable importance in many of our future experiments, and may be of interest to other researchers using the STS.

In normal operating conditions, the measurements from the cold cathode are used by the vapor deposition experiment to trigger some of its key events, otherwise it is collecting data continuously until its power source runs out. Several additional advantages of the vacuum gage are that the sensor has no filament that can burn or break, and it may withstand up to 400 degrees C without damage; it also presents the advantage that it will not sputter; it is constructed of aluminium and is designed such that electrical leakage is prevented by the presence of insulation between cathode and anode. It is aiso equipped with a solid state controller that can be turned off from various ports in the microcomputer which can, in turn, be programmed in advace to start or to stop its functions.

EXPERIMENTAL SEQUENCE

Once in orbit and with the proper switches active, the microcomputer starts a supervision routine in order to establish the condition of all components, in particular the energy sources. The first experiment to start operations is the vapor deposition. The controller allows for a current to flow to the basket, one at a time, and starts the substrate heater, leaving some time in between for battery recuperation. Simultaneously, measurements of vacuum pressures are being recorded for use in earth-bound validation experiments.

The alloy solidification experiment starts some time later after the first is completed and has its own power source. The sequence of events is as follows: a) all components are supervised for normal preoperational values, b) the heating coil is fed with a controlled current, whose values were determined in ground tests, c) the thermocouples are activated, following the temperature rise until it reaches 100 degrees C, at which time the IR detector is turned on to control the heaters (ref 3 describes this detector in detail). During this time temperature data is stored, whilst also used for active-adaptive control. When the temperature reaches the desired values, cooling begins at a predetermined rate, one of the key parameters of this experiment. In the case of a failure in the IR detector, backup thermocouples would monitor and provide the necessary control data to the controller. After the sample, as established by the detector, has lowered its temperature to about 60 C, the experiment is considered complete.

During most of the flight, temperatures are being recorded in about 15 test stations distributed over the entire canister. This activity is mostly of use for supervision of overall temperatures in the case of an uncontrolled situation, in order to stop all power to heaters, but it is of considerable value in the validation of thermal models of the canister, that will be tested also in the ground. The design of aerospace equipment, and its life cycle is directly proportional to power management thus, thermal models, however inaccurate, must be developed to gain practice in the operation of such devices, for which theoretical models are rather limited in practice. This is specially true in the case of satellites which occupy presently our attention.

EXPECTED RESULTS

From the thin film evaporation activities we expect to study space grown samples with several techniques, among them electron microscopy, both transmission and scanning, to determine the size distribution and crystallography of island formation and coalescence processes. It is also of importance to study the defect structure and density, since several previous microgravity experiments report, see for example ref. 4,5, different growth rates and defect density. Surface studies by means of Esca analysis is also planned, to clarify the structural growth nearby impurities. We expect these results to be useful in microelectronic manufacture and design.

The solidification experiment has also a multirole benefit, mainly in the clarification of microstructural formation in an impurity determined solidification. Previous studies in superplastic alloys found that the phase mixture is related to behaviour at high temperatures, particularly with respect to strength loss and corrosion resistance, up to this point, everyone agrees that something is occuring at the microstructural level, but few offer a plausible explanation. This experiment will produce a sample that presents a structure with nucleation starting at the impurities, and with a growth pattern that suffered little transport effects in the abscence of convection; also, stresses that remain embedded in the structure due to crucible contractions will be totally abscent; thus, the microstructure of this particular sample wiil be studied in great detail, by means of the above methods, together with additional techniques such as x-ray microdiffraction, Moessbauer spectroscopy, and mechanical properties evaluation.

CONCLUSIONS

This first scientific-technological experiefce in direct space research has been already of valuel despite the fact that our equipment rests at the Cape. The reasons are quite varied; they start with the experience gained by a group of engineers and physicists in a field considered, even in this day and age, as a luxury for a developing country. The spinoffs have produced already various solutions of interest to industry and other research projects, eveñ before the experiments are spaceborne; in particular, we can mention the IR detector, the controller, which at present we develop further, and the use of new materials to solve old problems.

These activities have also generated other interests, as mentioned above. Our incursion into satellite technology is focusing on several projects such as a data collect/dump satellite, a remote sensing experimental satellite, and an ultraviolet all-sky survey satellite, some in combination with resources from other developed and developing countries. Finally, we see this type of work slowly gaining support from other institutions in the country, and because of a future increase in payload-to-orbit transit, we perceive a future of highly motivating work.

ACKNOWLEDGEMENTS

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