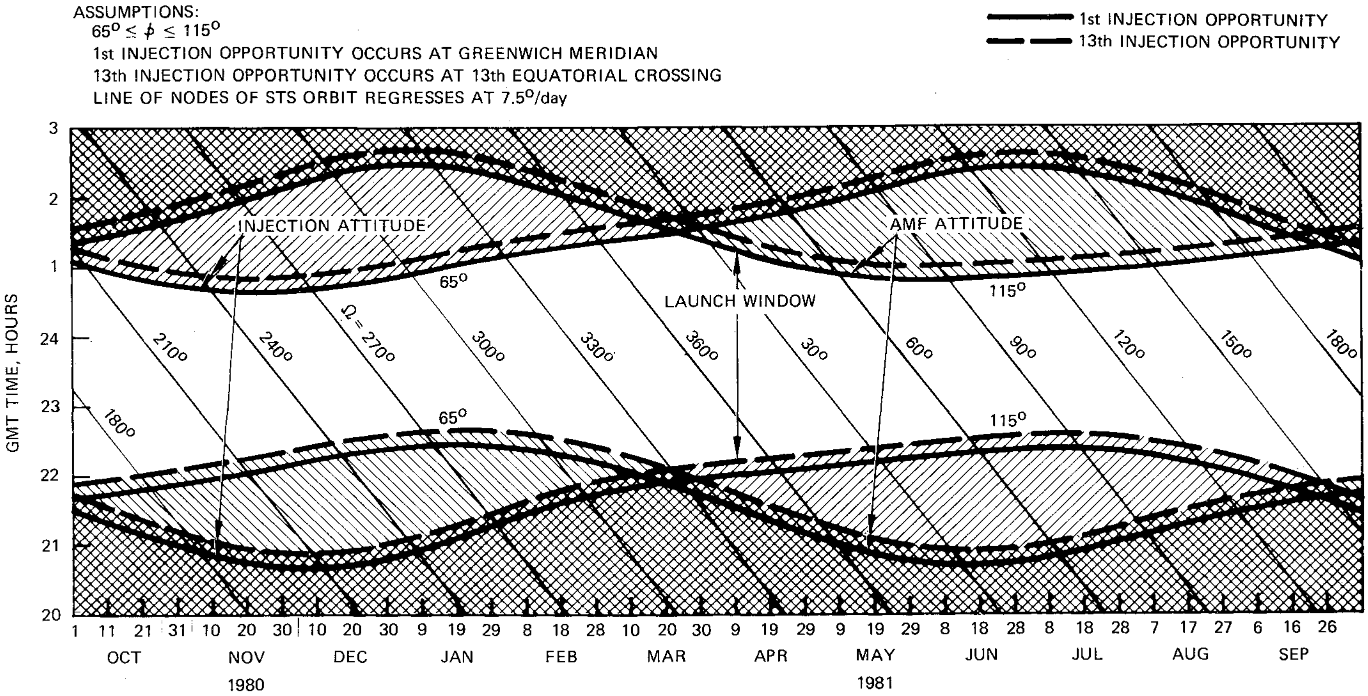

Fig. 4 Launch window duration vs time for STS liftoff.

fully defined) are imposed. This range of IO's defines an injection window (as distinct from a launch window), a concept that is useful since it stipulates the boundaries of injection in terms of time.

Launch Window and Additional Constraints

Midnight launch windows for IO's 1 and 13 are shown in Fig. 3 for Oct. 1, 1980 to Sept. 30, 1981. In generating these curves a sun angle range of $\phi = 90$ deg ± 25 deg was assumed, and it was further assumed that the first equatorial crossing (IO 1) takes place on the Geenwich meridian. It is evident from Fig. 3 that the launch window is reduced as more opportunities are included in the analysis. The window duration as a function of IO number is shown in Fig. 4, where it is seen that within four days of liftoff the window is less than the generally required minimum of 30 min. This effect results principally from nodal regression in the STS parking orbit, which causes the required injection and AMF $\Delta\vec{V}$'s to rotate, thereby changing the sun aspect angle ϕ.

For many of the spacecraft launched into geosynchronous orbit there is a 30-min limitation on the time that can be spent in eclipse per transfer orbit. This becomes an additional constraint in defining the launch window. The expected duration of these eclipses is a nearly constant 23 min for midnight injection, since eclipse occurs near perigee. Noon IO's have longer eclipse periods of up to approximately 140 min near the equinoxes. There are, however, times of the year when the noon injection is eclipse-free. If the launch date is removed from an equinox by more than 25 days, for instance, there is no eclipsing for injection right at noon. It is important to realize that long transfer orbit eclipses can occur even for a midnight launch. The governing factor is the time of injection, not of launch, so it is the noon injection that is constrained and not necessarily the noon launch.

Conclusions

STS launched geosynchronous orbit payloads that are spin stabilized in their transfer orbits will be subject to restrictions on the time of day at which liftoff can occur. As with expendable booster launches, these times are near noon and midnight at the point at which injection into transfer orbit takes place. But there now are many opportunities to inject into this orbit from the 160-n.mi. STS parking orbit. The total number of these IO's is limited by [illegible]al regression in the parking orbit; however, a more practical limit is imposed by the nominal 3-day duration of STS missions. Since both ascending and descending node injections can be considered, there are two, rather than one, Earth-fixed attitudes for each of the injection and AMF events. For planning purposes a range of IO's will be selected for each payload leading in addition to the launch window, to an injection window.

Acknowledgments

The author is grateful for the programming assistance of B. Wandzura and the helpful suggestions of M. Neufeld and D. Horton.

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Growth of HgI_2 Single Crystals in Spacelab III

W.F. Schnepple,* L. van den Berg,† and N. Skinner‡
EG&G, Santa Barbara Operations, Goleta, Calif.

Introduction

MERCURIC iodide has been under development as a material for x- and gamma-ray detectors since approximately 1972. The main advantages of the material are

Presented as Paper 79-0307 at the 17th Aerospace Sciences Meeting, New Orleans, La., Jan. 15-17, 1979; submitted June 5, 1979; revision received Aug. 21, 1979.

Index category: Space Processing.

*Section Head III, Applied Science Dept.
†Scientific Specialist.
‡Technologist.

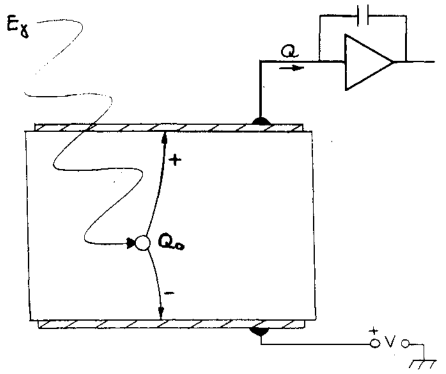

Fig. 1 Schematic of detector operation. Charge carrier drift length = $\lambda = \mu\tau\epsilon$, where μ = mobility, $cm^2/V\text{-}s$; τ = trapping time, s; and ϵ = electrical field, V/cm.

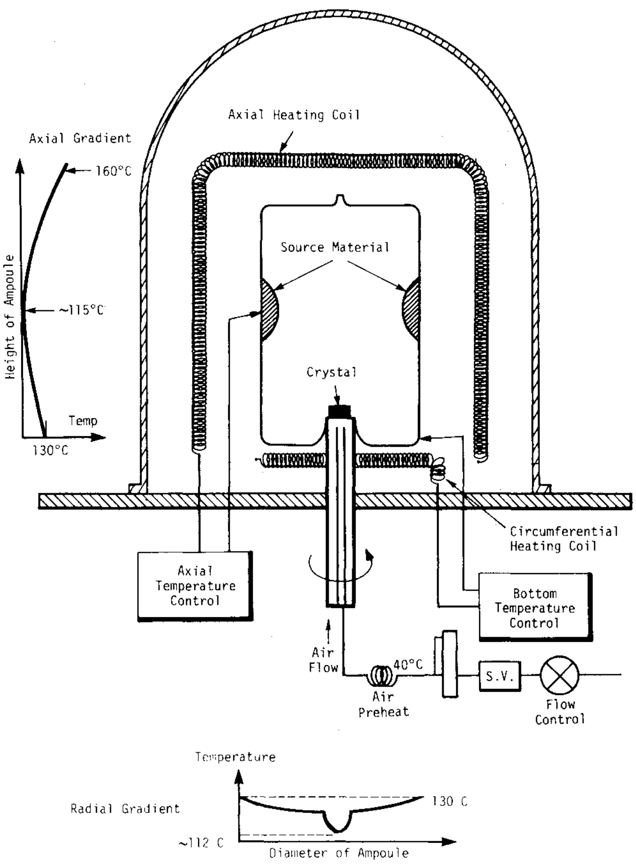

Fig. 2 Terrestrial furnace.

its high absorption coefficient, especially for medium-energy gamma-rays (100-600 keV), because of the high atomic number of the constituent elements, and its large band-gap (2.1 eV) which makes it suitable for fabrication of detectors that operate at room temperature.

Detectors made from this material operate in principle in the same way as other energy-dispersive solid-state radiation detectors, e.g., LN-cooled Si and Ge. The radiation interacts with the material to create free electrons and holes which are collected at opposite electrodes under the influence of an applied field (Fig. 1). The charge Q induced on the electrodes is measured by a charge-sensitive device and is proportional to the energy $E\gamma$ of the radiation.

For the device to operate properly, it is required that the drift length λ of the charge carriers be larger than the distance between the electrodes. A critical factor in the production of semiconductor detectors is, therefore, the quality of the crystalline material, since any type of defect will reduce the drift lengths of the charges created by the absorbed radiation and will therby reduce the charge collection parameters ($\mu\tau$). Development of a system to produce large single crystals with minimum defects becomes a primary requirement.

Since 1974, further development of a crystal growth system based on the temperature Gradient Reversal Method originally suggested by H. Scholz in Aachen, Germany,[1] has been undertaken. This method makes it possible to grow large single crystals of mercuric iodide from the vapor phase at approximately 120°C. This relatively low growth temperature is required because mercuric iodide undergoes a destructive phase transformation at 127°C, so that crystals grown at higher temperatures break down when cooled to room temperature. In the apparatus presently used (Fig. 2), the furnace consists of two heating elements; a circumferential coil located in the lower part and an axial coil which forms a vertical arc. The evacuated growth ampoule containing the source material is placed inside this coil arrangment and is supported by a metal tube which fits in an indentation in the ampoule bottom. The tube, and thereby the ampoule, can be rotated to provide better thermal symmetry. The whole arrangement is covered with a glass belljar to provide some degree of heat insulation and to allow for continuous visual observation of the nucleation and growth process.

When power to the furnace is switched on, a temperature profile is established in the furnace, as shown at the left of Fig. 2. This makes certain that the source material collects on the ampoule walls at the low-temperature point. Nucleation can then be started by blowing cooling air against the pedestal bottom, which establishes a temperature profile over the lower part of the ampoule (shown in the figure).

Once a good nucleus is obtained, growth can be continued by either increasing the airflow or gradually reducing the power input to the bottom heating coil. Reversal of the temperature gradient between source material and the growing crystal is obtained by periodically increasing and decreasing the temperature of the source material. This has the effect that the crystal is subjected to alternating periods of growing and etching. The use of alternating periods of growing and etching has a two fold purpose: to avoid spurious nucleation and to improve the quality of the crystal by preferentially etching away less perfect areas of growth. A discussion of the thermodynamic principles underlying the Temperature Gradient Reversal Method can be found in Ref. 2.

It is a well-publicized fact that irregularities in the growth rate of a crystal cause defect regions. For this reason it is important for the crystal grower to understand in as much detail as possible the dynamics of the transport phenomena in the growth ampoule. The study of vapor transport dynamics presents its specific problems compared with liquid or solids, in that the two main transport mechanisms (diffusion and convection) are often of the same order of magnitude, so that both have to be considered simultaneously.

Experiments at near zero-*g* conditions will remove the main driving force for convection, and the resulting crystal growth conditions will be amenable to analysis on the basis of diffusion-controlled transport only.

Experimental Space Furnace

The purpose of the Spacelab III crystal growth experiment is twofold: to grow single crystals of mercuric iodide which have significanlty better electronic transport properties than those in Earth-grown crystals, and to obtain data which will lead to improved understanding of vapor transport.

Figure 3 shows a sketch of a 18-cm high by 13-cm-diam (outside dimensions) crystal growth furnace designed to

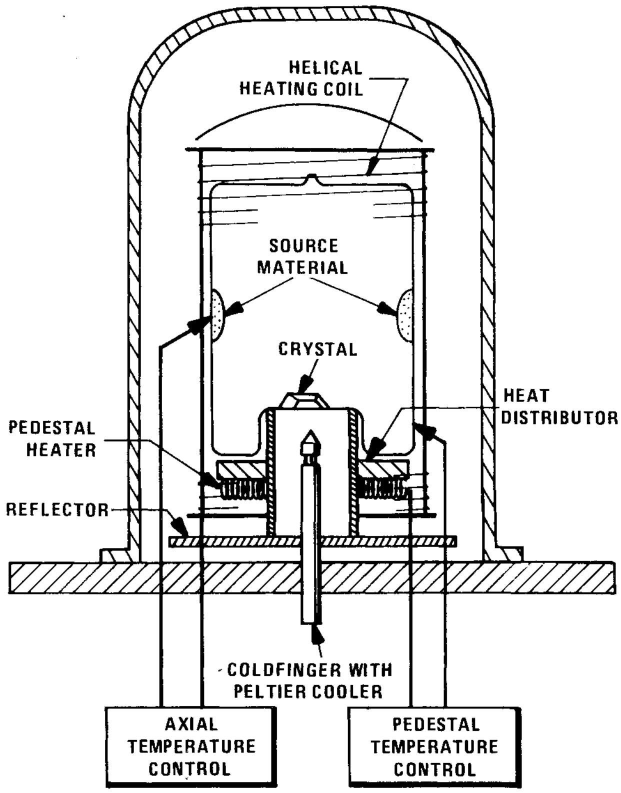

Fig. 3 Prototype Spacelab furnace.

accommodate the Spacelab III facilities. The single vertical heating coil of the previous furnace has been replaced with a helical coil which winds around the growth ampoule over its entire height. The better circumferential heat symmetry of the helical coil makes it unnecessary to rotate the ampoule. A heat-reflecting dome installed on top of the helical coil reduces energy losses through the belljar. The pedestal heater coil is covered with a metal heat equalization ring to distribute heat equally over the bottom of the growth ampoule; a second heat-reflecting shield is installed under the pedestal coil. The growth ampoule is 10 cm high and 6 cm in diameter, and the pedestal which supports the growing crystal is 3 cm in diameter. These dimensions make is possible to use approximately 30 g of source material and to grow from that amount one single crystal with a volume of about 5 cm^3. A cold finger with a built-in Peltier cooler is used to cool the pedestal center. This removes the necessity to use a separate air compression and temperature regulation system.

A single crystal has been successfully grown in this system. However, many more ground-based experiments must be made before it is reasonably certain that this system will perform under zero-*g* conditions. The next step will be to evacuate the space between the growth ampoule and the belljar to remove the convective cooling provided by the air currents between the heating coils and the belljar walls. In this way, it is to some degree possible to simulate near zero-*g* conditions where gravity-driven convection is virtually eliminated. It is not at all certain that under those conditions a temperature profile in the furnace can be maintained which is suitable for the growth of single crystals.

Because of the limited time available in space (maximum seven days) and Payload Specialist timeline considerations, it will be necessary to make the experimental procedure in space as simple as possible. It will therefore be necessary to provide the Spacelab crew with an ampoule that already contains a seed crystal. This requires that a fully automatic control system be developed which brings the ampoule to the growth temperature within a reasonable time without destroying the seed, and which subsequently starts the growth sequence automatically.

Payload Specialist Activities

Although automatic sequencing will be provided for heat-up, crystal growth, and cool-down, it is expected that a high degree of Payload Specialist interaction may be required. At the very least, periodic microscope observations of the crystal will be necessary to insure that growth is proceeding smoothly and without development of spurious nucleation. (A TV downlink to the Payload Operations Control Center will also allow the investigators to monitor the crystal in near real-time.) The payload Specialist's role becomes extremely important should experimental anomalies develop which require a judgmental decision. In that situation, process adjustments are best done by a well-trained, on-the-spot operator. Other Payload Specialist activities will involve measuring crystal growth rates, checking process variables, and properly stowing the crystal for landing.

Expected Results

The goal is to obtain a zero-*g*-grown crystal which will then be compared to the best earth-grown control samples. The earth samples will be grown by procedures and apparatus identical to the space experiment. The following are some of the parameters of interest that will be compared:

1) Vapor transport: linear growth rates and mass transport rates.

2) Crystal properties: impurity distribution, morphology, optical microscopy (etch pits, inclusions, voids, etc.), polariscope analyses, SEM analyses, X-ray topography, and mechanical properties.

3) Electronic properties: mobility μ, trapping time τ, and resistivity ρ

4) Nuclear detector response: If the space-grown material is consistently and significantly of higher quality than the best Earth-grown material, this will be an incentive to consider establishment of a production facility for mercuric iodide crystal growth in space. To a large degree, this will be decided by how critical the need is for very high performance material.

Summary and Conclusions

Mercuric iodide represents a new and useful electronic material for applications in x- and gamma-ray spectroscopy. To date, however, its full potential has not been achieved. Crystalline defects which might be produced by weight stresses or convective transport instabilities should be drastically reduced in number in space-grown crystals. The space crystal should provide a benchmark for comparison for Earth-grown crystals.

It is reasonable to expect, however, that even prior to obtaining a zero-*g* crystal, the ground-based research will yield useful information such as 1) data on the mechanical properties at elevated temperatures, 2) better understanding of the furnace requirements, 3) improved apparatus, and 4) development of techniques such as seeding. All of this seems certain to lead to more appropriate conditions for growing the crystals, not just in the Spacelab III module, but also on Earth.

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