Growth of Mercury Cadmium Telluride Single Crystals

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This flight investigation (experiment no. MPS77F069) was originally selected based on the response to NASA OA–77-3 Announcement of Opportunity. The content of the effort is based on an amended proposal submitted in response to Announcement of Opportunity OSTA–77-3 (formerly OA–77-3). Some of the initial work was done at McDonnell Douglas Research Laboratories under contract NAS8–33107. The investigation is consistent with the committee recommendations resulting from the "Review of the Microgravity Science and Applications Flight Programs" conducted January through March of 1987. The majority of the ground-based studies are being performed in the Space Sciences Laboratory at MSFC. In addition to crystal growth and characterization, this work has included thermophysical property determination, thermal modeling, phase diagram determination, fluid flow modeling, transient and diffusion analysis, and electronic property modeling. The flight portion of the investigation is being conducted using the advanced directional solidification furnace (AADSF) developed by MSFC and manifested for flights on the United States Microgravity Payload (USMP) series of missions. The first flight of the instrument took place in March 1994 on STS–62, and it is manifested to fly on USMP–4 in 1997. The ground-based portion of the experiment consisted of growing crystals in several different configurations of heat pipe furnaces, AADSF, and a similar furnace incorporated in a superconducting magnet capable of operating up to 5T.[2]

The major objective of this research is to establish the limitations imposed by gravity during growth on the quality of bulk solid crystals having large separation between their liquidus and solidus temperatures. The important goal is to explore the possible advantages of growth in the absence of gravity. Such crystals are extremely difficult to grow on Earth due to large density variations in their melts which give rise to fluid flows that result in large compositional variations.

The alloy system being investigated is $Hg_{1-z}Cd_x$ Te with x-values appropriate for infrared detector applications in the 8 to 14 m region. Both melt and Te-solvent growth methods as well as growth in magnetic fields are being pursued. The study consists of flight experimentation and ground-based experimental and theoretical work needed to establish material properties and optimum experimental parameters for the ongoing flight experiment and to assist material evaluation. $Hg_{1-z}Cd_x$ Te is representative of several alloys which have electrical and optical properties that can be compositionally tuned to meet a wide range of technological applications in the areas of sensors and lasers with applications to optical computing and communications as well as the national defense. The investigation includes both Bridgman-Stockbarger and solvent growth methods, as well as growth in a magnetic field. The alloys are prepared by reacting pure, elemental constituents in evacuated, sealed, fused-silica ampoules. The crystals are gown in a multizone furnace. The hot zone is heated above the liquidus temperature of the given alloy and the cold zone is maintained at lower temperatures to provide temperature gradient sufficient to prevent constitutional supercooling. Crystal growth is accomplished by slowly moving the ampoule from the hot zone to the cold zone of the furnace.

Detailed microstructural and compositional analysis has been completed for the approximately 16 cm long $Hg_{0.8}Cd_{0.2}Te$ alloy crystal that was successfully grown over a period of 11 days during the USMP–2 mission. Equivalent analysis was done on a series of ground-control crystals. The space grown crystal was significantly different from crystals grown under similar conditions on the ground.[3] One clear difference was that there was no hydrostatic force pushing the material against the ampoule wall during the solidification as is the case on Earth. During the mission the orbiter was maneuvered into several different attitudes with the results that the residual acceleration vector caused by drag in on the orbiter and the distance of the ADSF from the center of gravity of the orbiter was aligned differently with respect to the growth axis of the solidifying material for distinct parts of the mission. Significant differences were observed during three long, but uninterrupted, periods at constant attitude. Compositional variations along the crystal circumference indicated residual fluid flows for the least favorable vector orientations. Identifiable regions exist in which a transverse vector has pushed the material against the ampoule wall and allowed it to readily contract away from the opposite wall. Such surfaces showed etch pits produced by preferential evaporation at defect sites. X-ray scattering showed that the regions pulled away from the wall tended to be less strained or of higher quality material that the opposite surface, and considerably better than the Earth-grown material. Composition determination on the surface of the material demonstrated significant difference, dependent on the direction of the residual acceleration vector. These are clear indications of three-dimensional fluid flow. A significant portion of the boule was grown with a component of the vector aligned in a direction from liquid to solid. Synchroton x-ray studies of this material showed it to be single crystal and of much less defect density that found in ground-based growths.

[1]Lehoczky, S.L.; Szofran, F.R.; Gillies, D.C.: "Growth of Solid Solution Single Crystals." Second United States Microgravity Payload: One Year Report, ed. by P.A. Curreri and D.E. McCauley, NASA Technical Memorandum 4737.

[2]Watring, D.A.; Lehoczky, S.L.: "Magnet Hydrodynamic Damping of Convection during Verical Bridgman-Stockberger

Growth of HgCdTe." *Journal of Crystal Growth*, in press, 1996.

[3]Gillies, D.C.; Lehoczky, S.L.; Szofran, F.R.; Watring, D.A.; Alexander, H.A.: "Effect of Residual Accelerations During Growth of Mercury Cadmium Telluride (MCT) on the USMP–2 Mission." *Journal of Crystal Growth*, in press, 1996.

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Biographical Sketch: Dr. Sandor Lehoczky is the chief of the Microgravity Science and Applications Division at MSFC.