importance but will also find engineering application for improving the on-board cooling systems (using the effect of phase transition), cryogenic fuel storage and pumping-over systems.

The second stage of HERUBIM scientific experiments is dedicated to quantum effects in superfluid helium physics under MG conditions. A relevant program of experiments is being worked out by the ILTPE experts.

«Morphos» Experiment

EXPERIMENTAL STUDY OF SOLID-LIQUID INTERFACE IN TRANSPARENT SUBSTANCES

Nemoshkalenko V. V., Fedorov O. P., Zhivolub E. I., Bersudsky E. I., Chemerinsky G. P.

G. V. Kurdyumov Institute of Metal Physics of the NAS of Ukraine
36 Academik Vernadsky Blvd., Kyiv-142, 03680 Ukraine
tel: (380) + 44 + 4441005, fax: (380) +44 + 4442561, e-mail: metall@imp.kiev.ua

Experimental study of crystallization processes under microgravity is one of the priority fields of materials science in space. It will take one of the most prominent places in the ISS program. The peculiarities of the solidification process are determined largely by the level of gravity convection. In view of the almost complete absence of this type of convection under microgravity, it is important to conduct experiments for study of fundamental physical mechanisms of the solid phase formation from the melt. Further development of the ground technologies of manufacturing single-crystal materials, composites, foundry, etc. is impossible without valid experimental data on the influence of gravity convection on structurally sensitive properties of the crystalline materials. One of the goals of the experiments is application of transparent model substances for study of the crystal growth process and, in particular, of the morphology of the crystallization front during directional solidification [1—4].

A complex of problems related to directional crystallization of transparent model substances in a three-dimensional sample under microgravity conditions studied in this work is proposed for the first time. Directional crystallization is the basic method of future production of materials under the space conditions due to comparative simplicity of the technique, possibility of maintaining a stable growth environment, as well as due to numerous applications, i. e. growing single-crystals of various materials and production of composites and metal alloys.

Since the first studies [5, 6], ground-based experiments with quasi-two-dimensional samples have been a widely used methods. Improvements proposed in these studies, allow investigation of transparent single-crystals and various crystallographic directions of growing, as well as comparison of the data of laboratory model experiments with the data on the actual processes and structure of metal single-crystals.

The following logic step in this direction is complete reproduction of the solidification process in a three-dimensional sample with a model substance. It will provide direct data on development of unstable crystallization front, typical sequence of the morphology change at variation of the growth conditions (in particular, increase of growth rate) in the actual three-dimensional sample where the processes of convective heat-mass transfer are one of the controlling factors.

An important problem is the interaction of the crystallization front with gaseous inclusions. As is known, there is no outgassing from the material being crystallized under microgravity and, therefore, direct observation of the interaction of the crystallization front in the melt bulk with the gas bubble which does not float at the crystal growing in space is possible. Earlier such experiments were completed only in two-dimensional preparation, where a number of unexpected effects have been revealed, in particular, accelerated growth of crystals (dendrites and cells) along the gas-melt interface, compared to their growth in melt far from the interface [7]. However, it is still not clear whether the mentioned and some other effects are related to the peculiarities of crystal growth in a thin preparation or whether they result from fundamental properties of three-phase crystal-melt-gas interface. A correct experiment on establishing the parameters of the crystallization front interaction with a gas bubble can only be conducted under microgravity, where direct observation of the three-phase crystal-melt-gas interface is possible, without applying an external force to hold a gas bubble at the interface.

Aging (or coalescence) of dendrites is the major component of the solidification process, which is of the greatest importance for the technology of production of metal ingots and which is controlled essentially by the melt stirring process. For the latter reason, extensive experimental and theoretical research and, in particular, space research, is devoted to coalescence of dendrites. The essence of this process is described in detail in metallurgical literature, for example in [8]. It causes vanishing (dissolution) of thin branches and thickening of large ones. For metals the coalescence results in formation of the so-called plate-like structure which is a casting defect. In the absence of macro-stirring (convection), the described process is governed only by diffusion. Therefore, it is possible to understand the mechanism of the process and to study its kinetics only under microgravity conditions, excluding convection. Hypothesizes and assumptions in this respect have been verified experimentally in our ground-based research, where isothermal conditions were created and there was practically no convection [9, 10]. The final verification of assumptions made, and the search for the final answers as regards the conditions of separation of the branches and refinements of the cast structure require a carefully formulated space experiment.

Furthermore, the most informative and correct method of research is direct observation of the process on transparent models in the absence of convective stirring.

The feature of the authors' approach consists in parallel study of substances characterized by various mechanisms of crystal growth from the melt, namely continuous and layer-by-layer. That is, the same effects are investigated in so-called metal-like substances (succinonitrile and its alloys) and in faceted crystals modeling crystallization of semiconductor substances (benzophenone and its alloys).

Solving the defined scientific problems is united by one technique, namely the directional crystallization of transparent alloys by Bridgeman and recording of the structural elements of the crystallization front by the optical methods. The main part of the experiments is focused on observation and recording of the solid-liquid interface.

The experiments to be carried out using the «MORPHOS» installation intend to grow crystals of model transparent substances by directional crystallization with video recording of the morphology of solid-liquid interface during the entire growing process under microgravity conditions.

The experiment runs in the automatic mode. Operator interference is assumed in the stages of preflight preparation and on completion of the flight.

The installation design provides a possibility to realize preliminary ground-based experiments with working samples at the vertical position of the sample axis (heater from above, cooler from below) for minimizing the convective flows in the liquid phase.

A separate ground variant of the installation with the vertical arrangement of the elements similar to those mounted in the flight unit will be created.

References

1. Jackson K. Main concepts of crystal growth // Problems of crystal growth. — M.: Mir, 1968.—P. 13—26.
2. Glicksman M. E., Schaefer R. J., Ayers J. D. Dendritic growth — a test of theory // Met. Trans. A.—1976.—7, N 11.—P. 1747—1759.
3. Huang S. C., Glicksman M. E. Fundamentals of dendritic solidification. II // Acta met.—1981.—29, N 5.—P. 717—734.
4. Trivedi R., Tiller W. A. Interface morphology during crystallisation. I. Single filament unconstrained growth from a pure melt // Acta met.—1978.—26, N 5.—P. 671—679.
5. Borisov A. G., Fedorov O. P., Maslov V. V. Features of dendritic and cellular morphology of the front in crystals growing in different crystallographic orientations // Crystallography.—1991.—36, N 5.—P. 1267—1274.
6. Fedorov O. P. Cellular pattern during directional growth of a single crystal in a quasi-two-dimensional system // J. Crystal Growth.—1995.—156.—P. 473—479.
7. Fedorov O. P. Interaction between growing crystals and inclusions in the melt // J. Crystal Growth.—1990.—102.—P. 857—861.
8. Flemings M. Solidification processes. — M., 1977.—423 p.
9. Fedorov O. P. Interaction of crystals growing from the melt with inclusions and concentrational inhomogeneity // Crystal growth. — M.: Nauka, 1990.—18.—P. 197—214.
10. Fedorov O. P., Ovsienko D. E., Krivoshei M. B. On the mechanism of transformation of dendrite branches of a binary alloy under isothermal conditions // Metallofizika.—1987.—9, N 2.—P. 68—75.