«HERUBIM» Experiment

SPACE-BORNE CRYOGENIC FACILITY TO STUDY THE LIQUID HELIUM PHENOMENA UNDER MICROGRAVITY AND THE RELEVANT EXPERIMENTAL PROGRAM

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A cryogenic liquid helium facility has been developed to study the basic problems related to the liquid helium phenomena under microgravity (MG). This facility will provide acceleration within $(1—10^{-4})$ micro-g acceleration range (g is gravity acceleration of the Earth) with the pre-assigned vector values and directions. It will also provide visualisation of this physical experiment and measurement of such main parameters as acceleration, pressure, and temperature.

Experimental and theoretical research in the field of liquids-boiling physics within mass-force fields of various intensity (i. e. phenomenon of liquid helium boiling) has been carried out in the Special Research and Development Bureau for Cryogenic Technologies, ILTPE of the NAS of Ukraine since 1960s. The heat transfer theory developed in this Bureau has been proven by numerous experiments in intensive fields of centrifugal forces and by various techniques for microgravity (MG) simulation within 2.700 g to 10.000 micro-g acceleration range.

The experiments implemented by H. Merte, USA, and J. Straub, Germany, aboard the Shuttle spacecraft in 10...100 micro-g acceleration range, have shown that boiling of non-cryogenic liquids under MG conditions reveals a series of novel effects, being outside the philosophy of the existing theories. As we may surmise, these effects are not related to the impact of MG proper, but to these tests failing to satisfy certain requirements. In particular, these requirements concern the constancy of a ratio of linear dimensions of a test-cell and experiment duration versus internal linear and time scales of the boiling process, as the scales of the boiling process are significantly increased under MG conditions.

Helium should be used as the working fluid to correctly verify the theoretical concepts of the MG influence on boiling physics, and to identify ever-new phenomena related to the MG effect as such. Our estimations have shown that the optimal MG level for this kind of experiment is 100 micro-g, and that the acceleration vector should be constant both in its magnitude and in direction relative to the boiling surface. Developing our helium cryogenic facility for installation onboard the space station, this latter requirement has been taken into account. The facility is a cryostat (filled with liquid helium) being spinned at 0.3 r.p.m. velocity during the entire experiment course. It is intended to mount this 100-litter helium cryostat on a rotating platform on the external side of the URM aboard the ISS. The recorders and measuring instruments will be installed in the manned compartment of the ISS. It will be possible to monitor this experiment by video cameras through the optical windows on the cryostat body.

The goal of HERUBIM (Helium Rotating Unit-Boiling In Microgravity) experiment is to study the MG influence on the vapour phase dynamics in boiling and barbotage, the main heat transfer parameters, stability of boiling regimes against local disturbances, and the dynamics of critical transitions in going from the nucleate boiling to the film boiling regime.

The experiment will result in radically new data on the influence of the acceleration vector controlled by magnitude and direction, on the parameters of helium boiling over a comparatively wide (relative to the scale of the internal boiling process) solid surface. These data will allow a conclusion to be made about the feasibility of extrapolation of the boiling theory to the yet unstudied range of accelerations, as well as identifying novel physical effects. In addition, the MG influence on the phenomena of stability and on dynamics of critical transitions in boiling will be studied for the first time.

The expected results will be not only of theoretical 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

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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 experi-