«Diffusion-mono» Experiment

MICROSCOPIC MECHANISMS OF DIFFUSION IN MELTS UNDER MICROGRAVITY

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The purpose of the experiment is to solve one of the principal problems of materials science. Does the distribution of dissolved elements in a fluid matrix obtained by melting of a monocrystal without modification of its outward form have the microscopically ordered character? In case of a positive answer to this question, the new effect of existence of the anisotropy of diffusion in metal melts will be discovered. Use of this effect will result in modification of practically all the space technologies of crystal growing and directional solidification, as well as production of glasses, alloys, composite materials and metastable phases in metal systems.

Similar experiments have been already conducted at «Salyut» and «Skylab» OSS.

Let us describe this effect. The crystal instability of Ga, In, Sn, Cu, Ag, Au, Pb, Zn was studied *in situ* at heating, melting and overheating of a melt by electron beams. The generated results on the structure of a melt at the atomic-lattice and cluster levels did not confirm a well-known notion of a fluid as the statistically non-ordered system with some near-range ordering. That is, microcrystals have been found to fragmentize spontaneously in the form of strip contrasts as soon as the Debay temperature was increased (Fig. 1). This spontaneous fragmentary structure was named the dissipative structure (DS). In our opinion, the melting of a metal monocrystal may be represented as the formation of a steady DS, which fragments a crystal into the sub-microscopic polydomain dynamical system. Being the unit of coherent dispersion, the minimal domain has the size of 2.5 — 10 nm [1]. This structure of a fluid was named the domain-dissipative structure [2]. The self-ordered structure of fluctuating waves of the localised anomalous displacements of plane atomic orderings arises in heating. Being a DS, such a structure is considered a new degree of freedom. The DS orientation is due to the symmetry of a crystal. Melting of a polycrystalline sample results in formation of the quasi-eutectic (colloidal) structure of a fluid. The colloidal structure is connected with different relative orientation of grains-monocrystals. It is supposed that the main arteries of inter-penetration of components in a fluid are the vacancy flows generated by the DS in colloids and inter-colloidal zones (Fig. 2). Study of self-diffusion of zinc at thermal gradient («Skylab» OSS, M558 experiment by A. Ukenva) has demonstrated that during 3600 seconds, penetration of ^{65}Zn isotope was equal to 1-2 cm. Such a value of penetration leads to overestimation of the coefficient of self-diffusion and can be connected with the looseness and thermal activity of inter-colloidal zones. To perform a more precise experiment in space, it is necessary to exclude not only the convective mass-transfer connected with the gravitation influence on a melt, but also the influence of inter-colloidal boundaries.

The purpose of the experiment is to study the microscopic mechanism of diffusion (self-diffusion) in heated crystals and melts under microgravity.

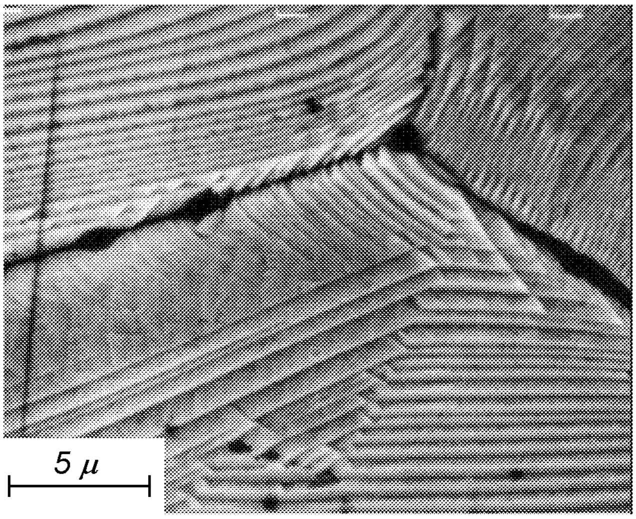
We have the following objectives:

— to define the preferential directions and planes of diffusion mass-transfer in solids and liquid metals;

— to work out methods of mass-transfer control for producing new materials and crystals with the given distribution of donor and acceptor additives, as well as for crystal growing and electrophoretic separation of substances.

It is suggested to produce a melt by melting a zinc monocrystal of two orientations (cylinder axis parallel and perpendicular to C axis). Melting will be conducted in the sealed-in ampoule having the form of sample and ^{65}Zn diffusant. The melt will be soaked in the thermal gradient field (similar to M558 experiment by A. Ukenva, «Skylab» OSS). Such conditions are necessary to validate the crystal-like mechanism of diffusion mass-transfer to large distances in liquid metals, and to define the level of macro-volume conservation of the translation motive of a fluid structure in the large molten monocrystal.

The resistive thermogradient unit with automatic sample-ampoule feed (Low Gradient Furnace) will



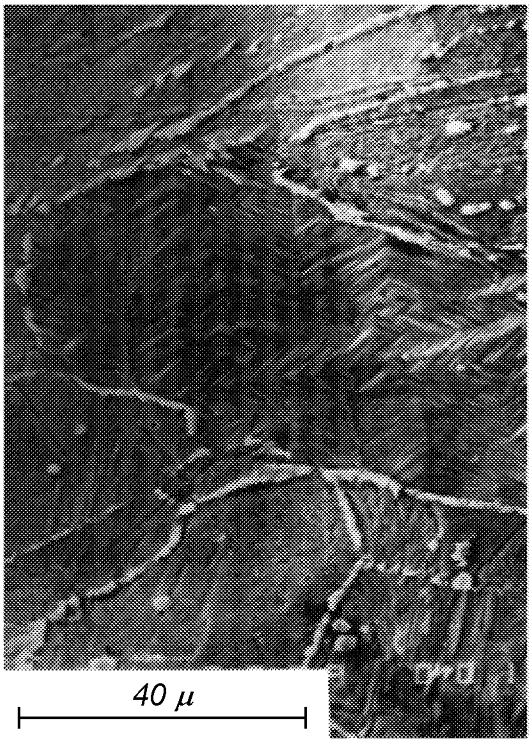


Fig. 1. Spontaneous fragmentation of microcrystals of copper at the temperature of 1065°C.

Fig. 2. Frozen structure of a boiling zinc melt.

be used for conducting this experiment onboard the ISS. The process of thermodiffusion will be studied at the temperature T = 450 ... 550°C. The volumetric distribution of the diffusant will be defined by the radiographic method.

The obtained results will be important for physics of monopropellant and multicomponent fluids, as well as for physics of complex fluids (colloids, jellies, foam) and processes of boiling. The worked out concept of the domain-dissipative structure of colloids and macrocolloids of overheated fluids will be useful for study of the formation of gaseous bubbles inside a volume and their behaviour during the thermo-temporal variations of a system. The obtained results can be also applied for the effective transfer of heat and energy flows, for the systems of cooling and energy conversion, and for the life-support control systems of fluids.

References

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