«Sound» Experiment

DEVELOPMENT OF A NEW METHOD OF PRODUCING THE MATERIALS UNDER MICROGRAVITY USING ULTRASONIC FIELD

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Modern industry requires materials with advanced properties, namely high magnetic characteristics, high heat resistance, wear resistance, etc. Such materials can be obtained from aggregates that do not dissolve in each other, namely from a disperse system. The specific mechanical and electrical properties can be achieved, when particles with the diameter of 0.1 micron are used and the distance between the particles is 1 micron, that corresponds to the order of volumetric content of dispersed component of 10 %. Such systems can be illustrated by the following examples: 1) systems where disperse particles considerably raise the durability (especially at high temperatures for turbine blades); 2) systems, where the self-lubricating bearings — disperse particles of graphite, tin, lead are applied in the Al matrix; 3) materials for electrical contacts with high wear resistance represented by aggregates based on dispersions of solid particles (*W* or oxides) in a metal matrix with a good conductivity, low hardness and yield stress. The alloy for constant In-Al magnets, where the high values of coercive force were obtained, is also a disperse system. Usually, however, it is impossible to obtain high-quality disperse alloys under the regular conditions, because of sedimentation and fast stratification of liquid components.

The research under microgravity provides new possibilities to study these systems. Under microgravity the velocity of coalescence and sedimentation is considerably lower, allowing metastable disperse phases to be produced, that is practically impossible under the normal conditions. Emulsions are 10 times more stable under microgravity and velocity of coalescence is 10^{-6} lower, than under the usual conditions [1]. At the same time, in spite of the fact that during space experiments the acceleration was practically absent, attempts to obtain homogeneous composite alloys with small size particles (micron) have not been successful. Instead, rough dispersions and alloys with coarse inclusions of one component surrounded with the other component, were obtained. In some experiments a complete separation of phases caused by the low mutual wettability of components was observed. Among the basic requirements to disperse compositions are small sizes of disperse particles and their uniform distribution, as well as wettability of disperse particles with the molten alloy.

We anticipate that the combination of microgravity and ultrasound will enable slowing down the processes of coagulation and sedimentation of insoluble components in disperse systems. Cavitation in a molten alloy caused by intensive ultrasound increases the wettability of insoluble components of the alloy [2], while intensive dispersion takes place, which in combination with slowed down diffusion and lack of stratification under microgravity yields finely dispersed homogeneous composite materials with new physical properties.

Wettability plays a special role. When dipped into the matrix molten alloy, disperse particles do not exhibit any tendency to separation until they are wetted with liquid matrix [3]. It has been pointed out [4, 5] that inhomogeneous distribution of disperse particles changes to a homogeneous one in the case if they are first metallized with the molten alloy, i. e., if disperse particles are initially wetted. Ultrasound increases the wettability of disperse particles as a result of a local raise of temperature and pressure on the boundary between disperse particles and molten alloy mainly due to cavitational bubble shocks. In addition, the impact of powerful ultrasound on a molten alloy with disperse particles or liquid drops causes intensive dispersion of these particles and drops. Acoustic mixing of Zn-Pb system under microgravity conditions was used in [6]. Coalescing drops in the molten alloy were dispersed by ultrasound, and well-dispersed structures were obtained; however, these experiments were carried out only at small concentration of Pb and at low ultrasound intensity.

The intent is to carry out these experiments at disperse components concentration of more than 10 %, i. e., at such a concentration, when the processes of coagulation of dispersions predominate under the usual conditions. Such zero gravity experiments on model systems with the low melting point of the matrix will allow us to develop methods of obtaining especially fine dispersions, and they will also help to clarify the mechanism of crystallization of disperse systems with application of ultrasound.

The knowledge obtained during the project will provide a physical background for development of the technology of producing new composite materials for aerospace and electronic engineering.

The developed ultrasonic equipment will be also used in the experiments of an independent biological project of the Institute of Biochemistry of the NAS of Ukraine. This project is devoted to the study of functional abilities of diaphragms under the conditions of microgravity to obtain suspensions of onemolar liposomes, which is achieved by destruction of large multilayer vesicules with ultrasound.

The Institute of Metal Physics is planning to make a flight unit for obtaining the composite materials using an ultrasonic field under microgravity onboard the Ukrainian Research Module of the ISS. The unit is designed for performance of the above-mentioned and other research.

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ELECTRON BEAM ZONE MELTING OF Ni-BASE EUTECTIC

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One of the promising methods of obtaining the modern composite materials is the unidirectional solidification (DS) of the eutectic alloys by means of electron beam zone melting. The characteristic property of this method is gradual solidification of the sample by moving the melt zone. Under these conditions, a perfect structure designed and oriented in the specific crystallographic direction is formed in the sample. Existence of such a structure leads to the unique physical-mechanical properties of a sample. The advantages of this method of obtaining the composite materials are the one-stage processes controlling the morphology of the phases and perfection of the material structure. The number of investigations concerning the influence of microgravity, in particular, on the process of solidification, has considerably increased, as they offer outstanding possibilities of the material structure control.

Among the composite materials currently obtained by electron beam zone melting, the most promising are Ni-base eutectic alloys reinforced by refractory metal carbides, in particular, the alloys of Ni-Nb-C system. It was this system which formed the base for development of the currently used alloys for the turbine blades. Alloys proposed for this experiment are being currently manufactured. They have a relatively low melting temperature (full power for maintaining the liquid zone during electron beam zone melting is 200 W). The authors have carried out calculations and ground-based experiments with alloys of this simple system. The basic mechanism of formation of a perfect oriented composite structure has been worked out [1, 2]. At present the eutectic composites are being improved by making them more complex. To this end, variation in the number and concentration of the alloying elements is accompanied by changing the temperature-concentration parameters of the eutectic transformation and by decreasing the DS velocity. In order to design advanced superalloys, it is necessary to know how the DS parameters (DS velocity, temperature gradient on the crystallisation front) and characteristic proper-