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THEORETICAL AND EXPERIMENTAL INVESTIGATIONS OF ICE CRYSTALS FORMING ON ZINC OXIDE NANOSTRUCTURES IN A WATER VAPOR MEDIUM

Аннотация. At present, by creating additional crystals in supercooled clouds, it is possible, depending on their number and place of introduction, to control the development of clouds. One of the most widely used reagents in active treatments is silver iodide AgI. At the same time, the effectiveness of this reagent decreases when interacting with a supercooled cloudy environment at a temperature of minus 60C and above. Therefore, research related to the creation of new reagents and improving the efficiency of existing ice-forming reagents are still relevant. A promising direction in this area is the use of various chemical additives.

Ключевые слова: Active influences, reagent, nanoparticles, ice-forming nuclei.

The development of technologies for active influence on cloud processes sets the goal for researchers to increase the efficiency of reagents, usually characterized by the following parameters: the yield of active ice-forming nuclei from 1 gram of the composition; threshold of crystallizing action; speed, estimated by the number of active ice-forming nuclei within 2 minutes after sublimation of the reagent; ecological purity of the reagent [1,2]. To achieve these goals, work is underway to improve existing pyrotechnic compositions and develop new ones [3,4]. A special place here is occupied by an increase in the efficiency of reagents with additives based on nanostructures [5, 6, 7].

As a result of theoretical and laboratory studies, a set of equipment was developed and a methodology for studying the processes of formation of ice crystals formed on zinc oxide nanostructures was developed. The equipment complex includes: a large cloud chamber, an ultrasonic steam generator, a reagent sublimation device, an electronic balance, an optical microscope, and a personal computer.

The reagent sublimation device is located in the lower central part of the large cloud chamber. Thermostated substrates are installed at the bottom of the chamber to collect ice particles. The methodology for performing experimental studies is presented in the previous works of the authors [5-10]. During the sublimation of zinc, zinc oxide nanostructures of various configurations and sizes are formed, mainly these are nanotubes and nanoclusters. Laboratory studies have shown that ice crystals of various shapes are formed on zinc oxide nanostructures (Fig. 1).

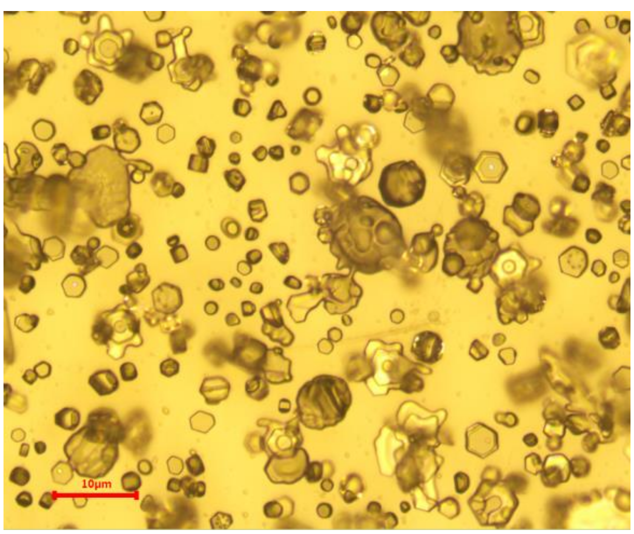
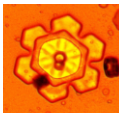
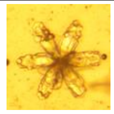
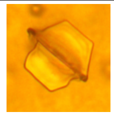
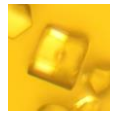
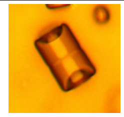
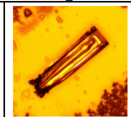
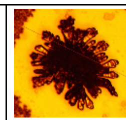
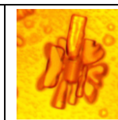


Figure 1. Ice crystals formed on zinc oxide nanostructures

Based on experimental data, it is possible to conclude that the ratio between different crystal forms varies with temperature. The results obtained are presented in table 1 and figure 2.

Table 1

Ratio (%) of different crystal forms at different temperatures

$n_{кр}/n$,% / t, °C								
-11…-12	35,6	15,9	8,3	10,0	3,0	5,1	8,0	14,3
-9…-10	35,4	0,0	9,9	1,6	26,1	2,6	9,0	15,4
-7…-8	29,1	0,0	17,1	16,6	5,0	16,4	0,9	14,9
-5…-6	0,0	0,0	2,3	0,0	15,0	13,4	32,1	37,3
-3…-4	0,0	0,0	0,0	0,0	26,9	19,6	15,8	37,8

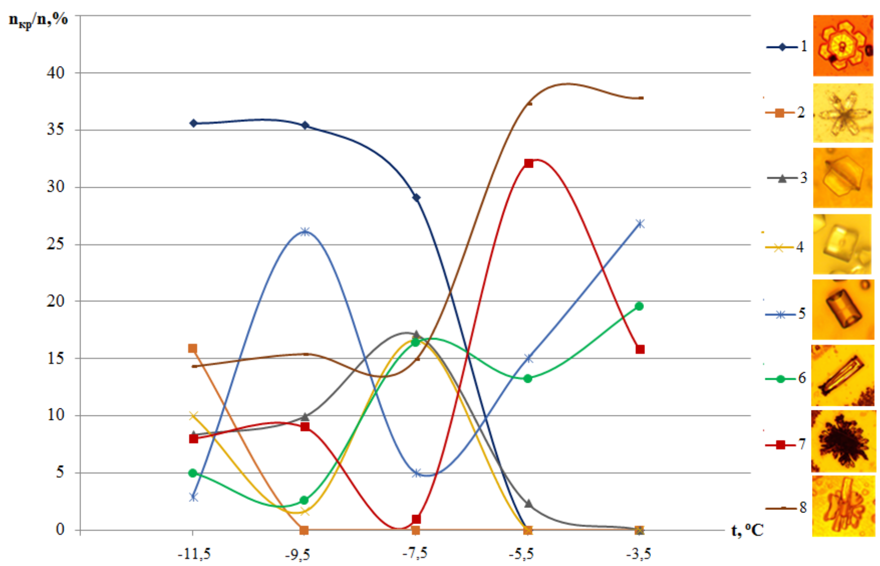


Figure 2. Ratio of different crystal shapes in temperature dependent

As can be seen from the table and graphs, crystals having shape 1 and 2 are formed at low temperatures ranging from -7.5 to -11.5 ° C. Crystals are formed on separate dense accumulations of zinc oxide nanostructures. The proportion of crystals in the form of columns increases to the highest values at a temperature of -9.5°C. At temperatures of -11.5°C and -7.5°C, less than 5% of such crystals are observed. The proportion of crystals in the form of needles gradually increases with increasing temperature, while some fluctuations in their number are observed. As the temperature rises from -5.5°C and above, the proportion of columnar and acicular crystals steadily increases. This form of ice crystals is formed on zinc oxide particles in the form of nanotubes. With an increase in temperature above minus 7.5 ° C, the proportion of irregularly shaped ice crystals increases. They are formed on nanoclusters of zinc oxide. Thus, experimental studies on the study of zinc oxide nanoparticles, carried out in laboratory conditions, confirm the effectiveness of using ZnO nanoparticles to increase the efficiency of pyrotechnic compositions based on AD-1. At present, the implementation of this kind of research seems to be relevant and practically significant.

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