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RESEARCH OF THE INFLUENCE OF THE ELECTRIC FIELD ON THE ICE-FORMING EFFICIENCY OF ALUMINUM OXIDE CLUSTERS

Research article

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Abstract

Laboratory experiments have been conducted to study the effect of electric field strength on the specific yield of ice-forming nuclei from aluminum oxide clusters.

A set of equipment has been developed for conducting experiments and a methodology for conducting experiments has been developed. The experiments were conducted in a large cloud chamber at subzero temperatures and 100% relative humidity. The thermal sublimation of the reagent and the production of ice crystals were carried out in the electric field of a flat capacitor.

The errors associated with the deposition of reagent particles on the capacitor plates at different field values are calculated. The total margin of error is 10%. Thus, the deposition of reagent particles on the capacitor plates does not significantly affect the values of the specific yield of the reagent.

It was found that the specific yield of ice-forming aluminum oxide clusters reaches maximum values up to 10E12 g-1 in the temperature range from -8 to -12 °C at a voltage of 300 kV/m.

There is a local increase in the electric field on aluminum oxide nanostructures, which leads to an increase in the formation of ice crystals on clusters of aluminum oxide nanostructures.

Keywords: weather modification, pyrotechnic composition, reagent, ice-forming particles, aluminum oxide, clusters, nanoparticles, electric field, specific yield.

ИССЛЕДОВАНИЕ ВЛИЯНИЯ ЭЛЕКТРИЧЕСКОГО ПОЛЯ НА ЛЬДООБРАЗУЮЩУЮ ЭФФЕКТИВНОСТЬ КЛАСТЕРОВ ОКСИДА АЛЮМИНИЯ

Научная статья

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Аннотация

Проведены лабораторные эксперименты по исследованию влияния напряженности электрического поля на удельный выход льдообразующих ядер из кластеров оксида алюминия.

Для проведения экспериментов разработан комплекс аппаратуры и выработана методика проведения экспериментов. Эксперименты проводились в большой облачной камере при отрицательных температурах и относительной влажности 100%. Термическую возгонку реагента и получение ледяных кристаллов проводили в электрическом поле плоского конденсатора.

Подсчитаны ошибки, связанные с осаждением частиц реагента на пластины конденсатора при различных значениях поля. Суммарная погрешность составляет 10%. Таким образом, оседание частиц реагента на пластины конденсатора не оказывает существенного влияния на значения удельного выхода реагента.

Получено, что удельный выход льдообразующих кластеров оксида алюминия достигает максимальных значений до 10E12 $г^{-1}$ в температурном диапазоне от -8 до -12 °C при напряженности 300 кВ/м.

Происходит локальное усиление электрического поля на наноструктурах оксида алюминия, что ведет к повышению образования кристаллов льда на кластерах из наноструктур оксида алюминия.

Ключевые слова: активные воздействия, пиротехнический состав, реагент, льдообразующие частицы, оксид алюминия, кластеры, наночастицы, электрическое поле, удельный выход.

Introduction

Scientifically based methods of influencing atmospheric processes began to develop intensively from the middle of the twentieth century. Thanks to them, currently the protection of large areas from hail, artificial increase in precipitation, fog dispersion, etc. is carried out by seeding them with ice-forming reagents using special anti-hail missiles, artillery shells, aviation and ground-based generators of crystallizing particles [1].

Most cloud seeding projects use pyrotechnic compounds containing up to 20% silver iodide (AgI), which are equipped with anti-hail projectiles, rockets and pyropatrons. It should be noted that the efficiency of using AgI in the applied formulations reaches only 5 to 9% [1].

As is known, the yield of crystallizing particles and the threshold of the crystallizing action of the generated aerosol determines the effectiveness of the effect, therefore, improving existing and creating new pyrotechnic compositions is one of the most important tasks.

In [2], the results of laboratory studies were presented, where the fundamental possibility of using aluminum oxide nanoparticles as an additive to the main pyrotechnic composition of AD-1 was noted. The interest in aluminum oxide nanoparticles is due to the fact that the transition to the nanometer range of particles in some cases is accompanied by a sharp increase in the adsorption and catalytic activity of the metal, which makes it possible to create fundamentally different materials with qualitatively new, previously unknown properties [3].

The paper presents a set of equipment, a research methodology and the results of laboratory experiments on the effect of an electric field on the ice-forming efficiency of aluminum oxide clusters.

Attention should be paid to the rate at which the reagent particles turn into cloud particles or precipitation particles. Back in 1951, it was found in [4] that high electric fields can cause the formation of large supercooled droplets due to the dielectric polarization of water. Pruppacher [5], freezing samples in a glass tube, found that the electric field affects the formation of ice at the point of contact of water with the surface of a solid.

As is known, electrical processes in the cloud affect the phase transitions of water. There is a strong electrification of the surface, both of the reagents and the resulting particles. The surface relief of the particle changes, which is caused by diffusion flows and the "leap" of ice particles from one position to another as a result of the action of electric forces [6].

It is currently known that nanoscale aluminum oxide particles, depending on their shape, can amplify the electric field thousands of times near their surface, which can lead to a significant increase in the temperature threshold for the formation of an ice phase on reagent particles. Also, the presence of an electric field in clouds and a charge on reagent particles can affect the specific yield of ice-forming nuclei during work on active effects on cloud processes [7], [8], [9], [10].

In this regard, studies related to the study of the effect of the electric field on the ice-forming efficiency of the reagent seem relevant.

Research methods and principles

To carry out the full cycle of the experiment, the following were used: a large cloud chamber, a small cloud chamber, a reagent sublimation device, an ultrasonic fog generator, electronic scales, flat capacitor plates, a high-voltage rectifier, electronic scales, an optical microscope, thermostatic substrates (Fig.1).

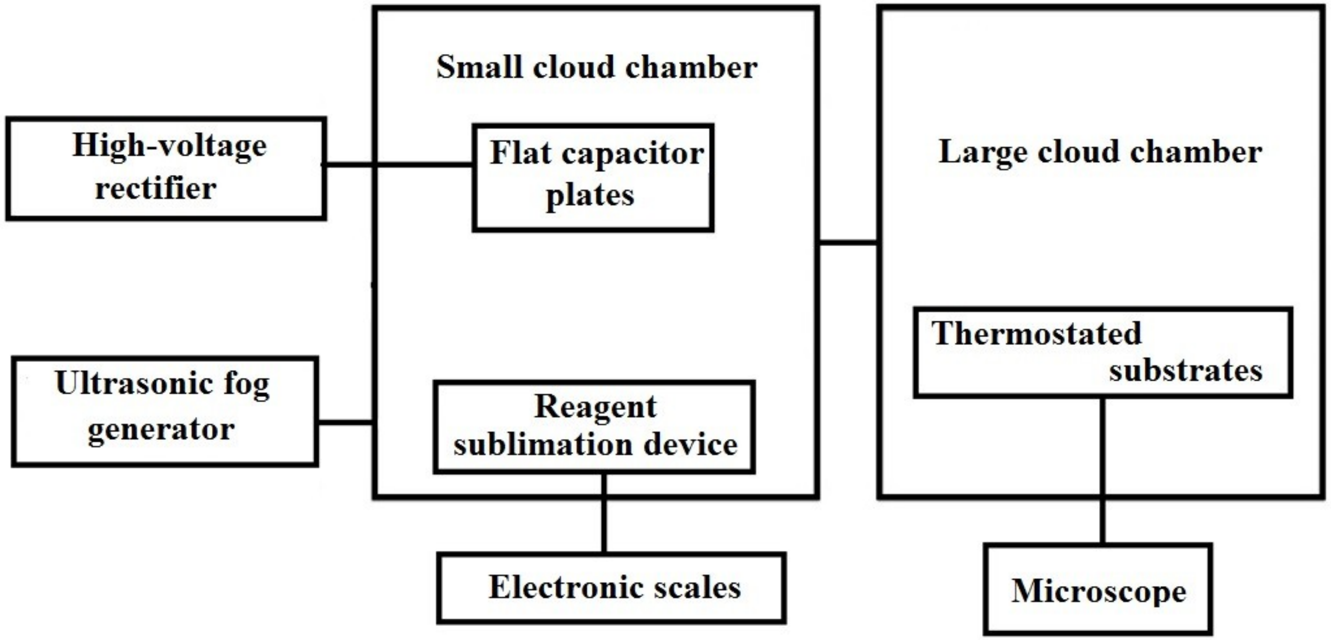

Figure 1 - The scheme of a typical installation
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A small cloud camera is connected to a large cloud camera. This approach avoids heating the vapor-reagent mixture in a large cloud chamber, which may affect the formation of ice crystals. The device for sublimating the reagent is installed in a small cloud chamber, plates of a flat capacitor are fixed above it, which are connected to a high-voltage rectifier. Thermostatic substrates covered with lids are installed at the bottom of the chamber.

A certain amount of aluminum powder is weighed on an electronic scale and loaded onto a graphite substrate. An artificial cloud environment is created in a small chamber. A large cloud chamber is cooled at negative temperatures. A current is supplied to the reagent sublimation device. At a graphite substrate temperature of about 2500ºC, the aluminum evaporation process begins with simultaneous oxidation. Clusters of aluminum oxide nanoparticles are formed.

After sublimation, the mixture of the products of sublimation and water vapor is transferred to a large cloud chamber. With the appearance of ice crystals in the field of view, the substrates are opened. Each crystal substrate is removed from the chamber and examined under an optical microscope.

Then, the specific yield of ice-forming nuclei from clusters of aluminum oxide nanotubes is determined.

The calculation of the specific yield of ice-forming nuclei is carried out according to the formula:

$$A = 2.96 * 10E14 * n_c/s_c,$$

where n_c is the number of crystals in the frame; s_c is the area of the frame.

The coefficient 2.96·10E14 is obtained as the ratio of the base area of a large cloud chamber to the mass of the burned reagent.

Main results

Table 1 and Figure 2 show the results of the conducted studies.

Table 1 - Dependence of the specific yield of ice-forming aluminum oxide particles on the electric field strength at different temperatures

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E, kV/m	Specific yield, $\times 10^{11}$ g^{-1}			
	-3…-4°C	-5…-7°C	-8…-10°C	-11…-12°C
0	2.35	3.11	3.77	4.6
75	1.9	2.78	3.4	4.53
150	1.42	2.87	4.78	6.66
225	1.83	3.21	6.42	11.59
300	1.45	3.03	6.21	10.36

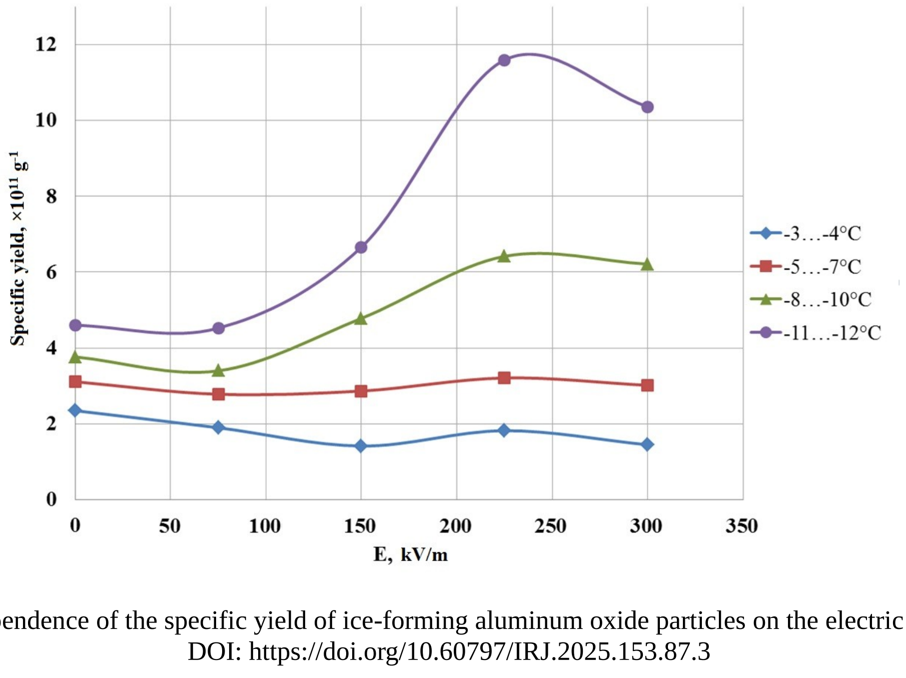

Figure 2 - Dependence of the specific yield of ice-forming aluminum oxide particles on the electric field strength

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At an electric field strength from 0 to 300 kV/m in the temperature range from -3 to -7 ° C, the specific yield of ice-forming nuclei of aluminum oxide clusters varies slightly. With an increase in the electric field strength, the specific yield of aluminum oxide particles increases and reaches maximum values of 1012 g-1 in the temperature range from -8 to -12 °C.

At the initial stage of interaction, aluminum oxide clusters enter an environment with a relative humidity of 100%. Water vapor is attracted by aluminum oxide nanoparticles, which form a dense polymolecular film on the surface of the nanoparticles. The adsorption of water leads to an equilibrium state within a few seconds. The growth of adsorption activity is determined by the size and structure of aluminum oxide nanoparticles [11].

The electric field contributes to the formation of large supercooled droplets due to the dielectric polarization of water. In this regard, the probability of ice crystals forming on clusters of aluminum oxide nanostructures increases dramatically.

Conclusion

The effect of an electric field on the ice-forming properties of clusters of aluminum oxide nanoparticles has been studied. Clusters of aluminum oxide were obtained in a cloud environment using a developed and proven experimental technique.

Experiments have shown that the specific yield of ice-forming aluminum oxide nuclei reaches maximum values of 1012 g-1 at a voltage of 300 kV/m in the temperature range from -8 to -12 °C.

During intensive phase transitions, a local increase in the electric field on aluminum oxide nanoparticles occurs, which leads to a sharp increase in the formation of ice crystals on nanoparticles.

Studies of reagent activity in laboratory conditions do not provide a complete picture of the processes occurring in clouds. However, such reagent tests are indicative in identifying the advantages of new reagents over existing ones.

Конфликт интересов

Не указан.

Рецензия

Все статьи проходят рецензирование. Но рецензент или автор статьи предпочли не публиковать рецензию к этой статье в открытом доступе. Рецензия может быть предоставлена компетентным органам по запросу.

Conflict of Interest

None declared.

Review

All articles are peer-reviewed. But the reviewer or the author of the article chose not to publish a review of this article in the public domain. The review can be provided to the competent authorities upon request.

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