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# CONSTRUCTION OF GAS DISCHARGE FIELDS WITH SURFACES OF SPACE VEHICLES USING THE CHEMOGRAPHY METHOD

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Annotation. The results of conceptual studies of the intensity of vacuum gas evolution of materials used in spacecraft by chemography are presented. This method is based on the fact that the mass of emitted volatile substances actively condensed on the cooled surfaces of the detector plates can be accurately measured at any distance from the surface under study, which makes it possible to predict the intensity of contamination of the optical surfaces of the spacecraft in real operating conditions.

Keywords: gas evolution, chemography, volatile materials, degree of pollution, pollution fields

## 1. Introduction

Gas evolution is a natural process of mass loss by materials of spacecraft in airless conditions during long-term operation. Appropriate standards exist, for example, ECSS-S-ST-00 (ECSS - S - ST - 00-01 ECSS System - Glossary of terms; ECSS - Q - ST - 10 Space product assurance - Product assurance management; ECSS - Q - ST -10-09 Space product assurance – Nonconformance control system), [1], which regulate the norms of material mass loss, as well as the norms of the condensed phase. The importance of such studies lies in the fact that gas evolution and subsequent condensation do not occur uniformly, are determined by the presence of a particular material on the surface of the spacecraft, as well as the effect of space factors. However, the standard focuses its attention only on the properties of the material, without reference to the conditions of its use and being in a specific place in the spacecraft.

## 1. Problem analysis

**Traditionally, to control gas evolution and decide on the use of a particular material in the production of spacecraft, the method of cold deposition (condensation) of volatile substances released in a vacuum when heating samples of materials is used [2].**

**Then, determining the mass of the condensed phase, determining the intensity of mass recovery under atmospheric conditions, we conclude whether irrevocable mass loss with condensation occurred or whether the change in the mass of the samples is a result of the removal of moisture and surface contaminants from the sample material.**

**As a rule, small samples of the test material are used for testing, and the tests are carried out in a specially equipped vacuum chamber. We used the VUP-5 camera with a special working insert for this purpose, which allows heating and cooling the plates to a given temperature with an accuracy of 0.5 0C (Fig. 1). Temperature control on a cold plate is carried out using Peltier elements, which allow controlling heat fluxes by changing the potential difference on semiconductors.**

**Typically, samples are installed in special compartments with a volume of not more than 2-3 cm3 in which they are heated. Opposite the compartments, condensed chilled plates are installed at some distance. Typically, the temperature difference between hot and cold surfaces is 100 ° C, and the distance is about 25.4 mm**

Figure 1 - Vacuum post VUP-5 with a special insert for testing materials for gas evolution

Subjecting to high temperatures and vacuum, the materials partially lose their weight, so weighing the samples before and after the tests shows whether such a loss can be expected even in operating conditions.

At the same time, the indicators below are controlled:

1) Total weight loss of samples

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$$ЗВМ = \frac{m_1 - m_2}{m_1} \cdot 100\%$$

1) Recovered mass loss

$$ВВМ = \frac{m_1 - m_3}{m_1} \cdot 100\%$$

1) Mass of volatile condensed substances

$$ЛКВср = \frac{m_4 - m_3}{m_1} \cdot 100\%$$

In these formulas, $m_1$ is the initial mass of the sample, g; $m_2$ is the mass of the sample after testing; $m_3$ is the mass of the sample after 24 hours at a temperature of 180C and a humidity of 55-65%; $m_4$ is the mass of the condensation plate before testing, g; $m_5$ is the mass of the plate after testing.

To record changes in the mass of the plates and the tested materials, high-precision analytical scales are used with a mass measurement accuracy of 10-5 g. The mass of the samples is 1 ... 3 g, while the mass of the condensation plates is 15-20 g. For such conditions mass presents certain difficulties, therefore, a search is currently being made for methods and methods of fixing ultra-small masses on relatively massive objects. So, for example, in [3], the authors propose determining the mass using quartz microbalances that control surface films by changing the vibration frequency. The latter will be proportional to the mass of the film on the surface of the resonator.

There are other, no less complicated methods for determining the mass of condensed substances. In any case, such control is aimed at providing the most rational layout decisions of the spacecraft that prevent the deposition of volatile substances on its optical optical systems [4].

The purpose of the research is to develop a more effective method for establishing ultra-low concentrations of a substance deposited on control (condensation) plates at distances greater than 25 mm.

1. Research results

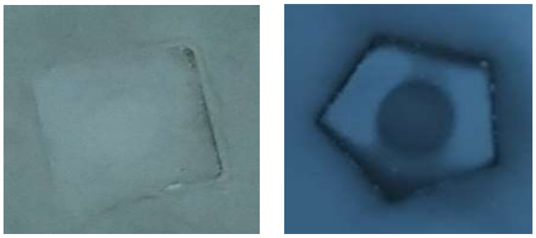
We have previously shown that the method of chemography can be successfully applied in various studies related to the establishment of changes in surface activity, including due to the formation of various substances on this surface of polymolecular films.

According to [5], the method of chemography is based on the use of phenomena of activation and fixation of chemical heterogeneous processes of extremely low concentrations of substances (including aqueous solutions) that occur in places of excess surface activity of the body under study. To fix these reactions, the authors of [6] propose using photographic film (X-ray type RT-1 or AGFAD7 NIF).

The researchers studied the indicated effect using metals as an example, the oxidation of which occurred in the presence of moisture with an intermediate product in the form of atomic hydrogen H +, the ingress of which on the surface of the film in the dark leads to the formation of atomic silver Ag + in it, just as it does on contact with emulsion of light rays.

Due to chemical reactions in the film, a latent reflection of this interaction is formed. If the surface of a solid body, being oxidized during chemographic exposure - the contact time through a thin water gap of the oxidizing surface and the film - is spatially inhomogeneous to emit atomic hydrogen into the aqueous medium, the nature of the heterogeneity of such a process is recreated in a latent picture of the film, which is converted into a visible one by a usual manifestation.

Despite the fact that reactions are fixed by the contact method (that is, by placing the film directly on the object under study), the heterogeneity of the latent image may include a certain portion of the surface of the film. In this case, there are various factors leading to the activation of the process of formation of a chemographic image. It was found that the surfaces themselves (even practically inert to chemical interactions) due to certain features can give a chemographic effect. In one case, this effect manifests itself as a result of the functioning of peculiar microvoltaic pairs (for example, in aluminum alloys), in others - as a result of defects in the crystal lattice or its deformation under the action of previously applied loads (Fig. 2).



a) б)

Figure 2 - Chemographic images: a) the surface of the ceramic instrumental plate; b) the surface of the carbide element

An important point of the method for fixing reactions of ultra-low concentrations is its resolution. Despite the fact that atomic hydrogen H + practically affects Ag +, causing silver to manifest in Ag2O during the manifestation of silver, the resolution will theoretically be determined by the size of silver particles (its grain); in practice, it will establish close contact with the test surface with a layer of H + OH- liquids practically quite difficult.

To solve the issue of resolution, a microcracked specimen was examined, which was established by the chemographic method. In accordance with Fig. 3, atomic hydrogen, moving from the surface to the film, covers a certain funnel of its final positions, forming a certain chemical range on the film.

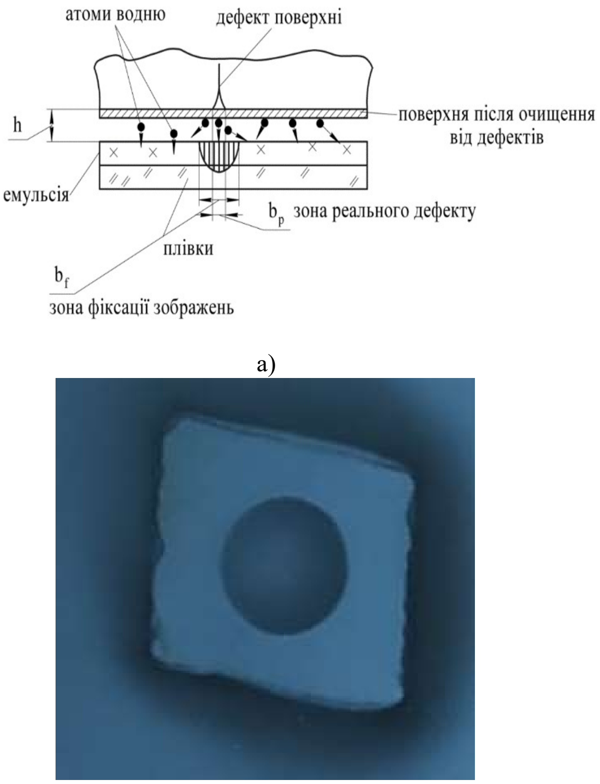


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Figure 3 - The movement of hydrogen atoms from defects to the photographic plate (a) and the image of the exposed sample with surface defects (b)

A chemographic effect occurs during the oxidation of many metals and semiconductors. Obviously, it can be assumed that oxidative phenomena also appear for studies of carbon materials. Moreover, the rate of carbon oxidation also increases significantly in the presence of a small amount of moisture, that is, the presence of H + OH- on the surface of dissociated water.

In [5], the authors note that the metal surface freed from oxides in the initial stages is very sensitive to various factors: moisture, temperature, ion etching, deposition (adsorption) of atoms or molecules other than the elemental composition of the substrate, deformation, etc. Therefore, such a surface exhibits high chemical activity, a variable depending on the active factor. If the action of these factors is local, they will locally affect the rate of further oxidation of the investigated surface even during chemographic exposure and thus visualize themselves. At the same time, the manifestations of film are intensified by the formation of a latent image in 106-107 times. This allows you to use the chemographic method to visualize heterogeneous processes of ultra-low intensity and successfully apply it to study a wide class of phenomena: metal corrosion, the structure of chemically or mechanically processed surfaces, electrode processes, metabolism in biological tissues, etc.

Previously, the authors expressed the opinion that one of the best materials, which has a high chemographic activity, is silicon (Si), which is often used to study the external effects on the kinetics of the oxidation reaction on its surface. Silicon has no more than one foreign atom per 106-107 Si atoms. Therefore, silicon thin elements can act as plates for deposition, which are preliminarily purified in vacuum for 12 h [7].

The vacuum level in the working chamber was established on the basis of considerations of the possibility of free entry onto condensation plates.

Assuming (Fig. 4) that the molecules of the substance, leaving the surface of the material, move to the collector plates (and further, if deposition does not occur), the probability of their collision is determined as follows

$$N_1 = \sqrt{2} n_1 \pi \frac{(D+d)^2}{4} L$$

Thus, a large concentration of molecules emitted from the surface can be fixed at a greater distance. In this case, the residual pressure in the chamber

$$p < \frac{4kT}{\sqrt{2}\pi L d^2((\alpha+1)^2 + 4\beta\alpha^2)}$$

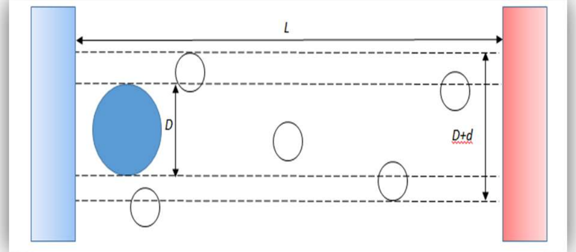

Figure 4 - Scheme of the movement of molecules between two plates

For the conditions of fixation of volatile substances at a distance of 250 mm, the vacuum should be no worse than 10-4 Pa.

The tests were carried out according to the standard method, installing the test materials in the appropriate bars (Fig. 5). However, the location of the heated and cooled bar was changed, tracking the deposition rate of volatile substances depending on the distance to the object under study along the unit vector.

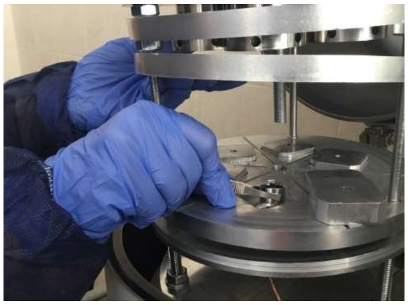

Figure 5 - Samples installed in bars

Then, volatiles were deposited on silicon wafers and control aluminum, chrome plated, 0.14 mm thick (Fig. 6). After the experiments, the plates were weighed and the mass of the deposited material was calculated..

а) б)

Figure 6 - The studied material (a) and the plate with the deposited volatile phase (b)

Plates with deposited volatiles are exposed in an appropriate bath in complete darkness in accordance with the recommendations [8]. To this end, distilled water is poured into a specially prepared clean cuvette. Then, in the dark, the prepared sheet of film is opened and a sheet of film is placed with the emulsion up on a flat bottom.

The studied samples with a chemographically active surface are placed on the film, maintaining the recommended interval [5] between the surface of the sample and the film emulsion at a level of 0.08-0.1 mm.

The film is maintained during a chemographic exposure, which is 5.00 ... 6.00 min. At the end of the exposure time, the samples are removed from the film, the water is drained, and the developer is poured into the bath and the film is developed and the resulting image is fixed, guided by the rules for processing film. Next, the film sheet clings vertically and is dried at room temperature.

The finished prints were scanned, correcting the actual image size and the image obtained on the computer raster, as well as evaluating the amount of illumination of the deposition surface relative to a clean surface. Comparison of the characteristic areas of the image and the calculation of the intensity of the chemographic effect in black gradations over a 100-point scale were performed using original computer programs.

To estimate the mass, we proceeded from the linear dependence of the density of the chemographic image of the plate with the mass of the deposited substance. Moreover, it was revealed that with increasing distance, the mass of condensed substances decreased significantly, Fig. 7. This made it possible for the studied sidewall surface of the satellite to construct the gas emission fields shown in Fig. 6, b.

Since chemography captures the oxidative reactions of ultra-low concentrations, and the surface of the wafer - Si - is not prone to active oxidation under normal conditions (at T = 20 ° C), we additionally studied the maximum possible resolution of the method, which allows predicting the depth of damage to the layer by based on a number of scribes made on the surface of the samples and measured from SEM microelectronic photos.

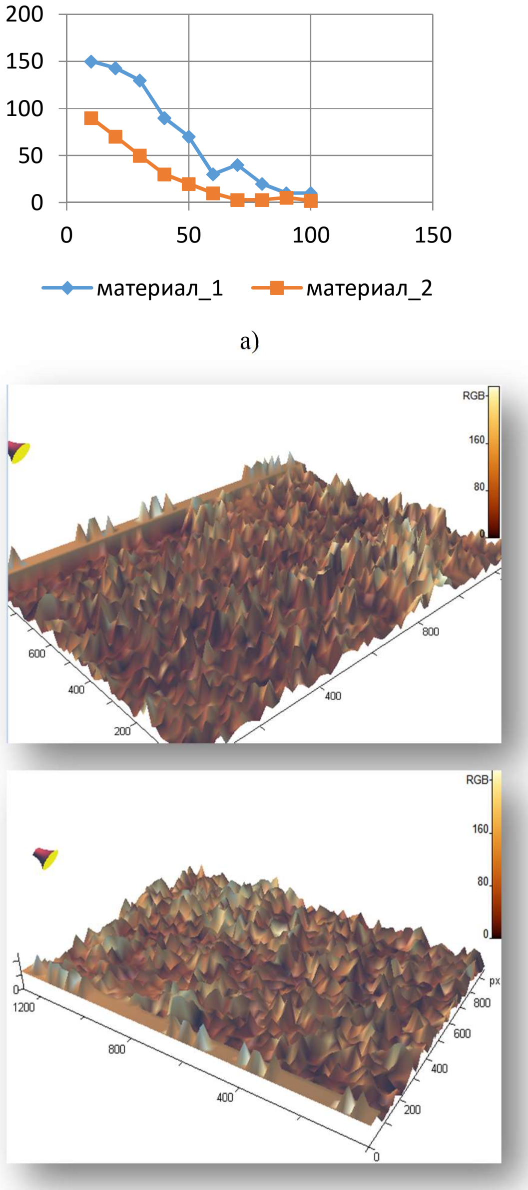

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Figure 7 - Change in the intensity of deposition of the volatile component of the investigated materials No. 1 and No. 2 (a) and the constructed gas emission fields of the surface of the spacecraft (b)

Main conclusions

The proposed system for predicting the level of gas evolution and obtaining a condensable phase based on the construction of a point model of the spacecraft's body, for each point of which the gas evolution is determined along the unit vector to the surface based on standard techniques, as well as an improved chemography technique that allows one to record multimolecular oxidative interactions, allows quite accurate to predict the intensity of deposition of volatile substances on various optical elements of spacecraft c - solar panels, scanners, optical and navigation systems, etc.

Unlike well-known techniques, chemography makes it possible to accurately determine the mass fraction of volatile substances on condensed surfaces; therefore, it makes it possible to predict the installation sites of optical equipment using the available calculated data and also to verify the suitability of technical solutions in terms of the reliability of operation of the spacecraft.

The application of the equipment and methods presented significantly clarifies the level of prediction of gas evolution and condensation, and also allows for direct modeling of these phenomena for various circuit designs and materials used.

## References

1. ECSS–Q-70-05A. Detection of organic contamination of surfaces by infrared spectroscopy
2. AIR POLLUTION MEASUREMENTS FROM SATELLITES by C. B. Ludwig, M. Griggs, W. Malkmus, and E. JR. Bartle Prepared by CONVAIR AEROSPACE DIVISION GENERAL DYNAMICS CORPORATION San Diego, Calif. For Langley Research Center NATIONAL AERONAUTICS AND SPACE ADMINISTRATION - WASHINGTON, D. C. - NOVEMBER 1973
3. Mikhnev M.M., Evkin I.V., Kolchanov I.P., Delkov A.V. Technological opportunities to reduce critical gas loads at the stage of thermal vacuum mining of a spacecraft and its components. - Zheleznogorsk, Krasnoyarsk Territory, Russia. - Siberian State Aerospace University. Acad. M.F. Reshetneva, Krasnoyarsk, Russia
4. Tumanov, A.V. T83 Basics of the layout of spacecraft onboard equipment: a training manual / A.V. Tumanov, V.V. Zelentsov, G.A. Shcheglov. - 2nd ed., Revised. and add. - Moscow: Publishing house of MGTU im. N.E. Bauman, 2017. - 572, [4] p. : ill.
5. Ulizarov O.I., Sukachov O.V., Kuts V.M. - About the effect of interchangeable photosensitive // UV. 1996, t. 41, No. 4, p. 455-457.
6. Elizarov AI, Sukachov AV - New Method for Visualizing Heterogeneous Reactions // Vacuum.-1999.-№54.-P.233-237.
7. Yelizarov MA - Visualization of early stages of corrosion processes by a chemography method // Surface and Interface Analysis. – 2006. – T. 38. – C. 263–266.
8. Elizarov MO - Application of a film for visualization of heterogeneous reactions of low intensity // Physics and chemistry of a solid body. - 2007. - Vol. 8, №3. - pp. 597–600.