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ӘУЕ КӨЛІГІ ЖӘНЕ ТЕХНОЛОГИЯЛАР
ВОЗДУШНЫЙ ТРАНСПОРТ И ТЕХНОЛОГИИ
AIR TRANSPORT AND TECHNOLOGY

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IRSTI 15.31.31
https://doi.org/10.53364/24138614_2024_34_3_1

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ANALYSIS OF MODERN TECHNICAL SOLUTIONS FOR VACUUM COATING FORMATION TECHNOLOGIES USED IN THE AVIATION FIELD

Abstract. *Modern requirements for technologies and mechanical engineering products necessitate the creation of new technological methods for processing materials and the development of appropriate technical means. Promising are environmentally friendly vacuum, ion, beam and photonic processes for obtaining materials, applying various coatings, and creating multilayer structures. An urgent scientific and technical problem is the creation of devices and methods for processing materials, vacuum devices for producing composite materials and forming coatings.*

It is known that significant parameters of materials are determined by the properties of their surface layers, therefore surface treatment technology, including the application of coatings and the creation of complex structures based on them, is of great importance. Vacuum-thermal and plasma surface treatment processes are promising in this regard.

Key words: *vacuum coatings, deposition, evaporation, condensation, magnetron sputtering.*

Introduction. A relevant and popular direction in the development of technology and technology at the present stage is the use of vacuum coatings, in particular functional coatings for the automotive industry.

The practical interest is the development of devices for applying vacuum coatings, the study of coating deposition and their parameters in combination with plasma treatment on the composition, structure and properties of various materials. The study of these processes and determination of the practical possibilities of using coatings, including nanocoatings and nanostructures, is an independent urgent problem in science and technology.

Main part. The deposition of various coatings, including decorative, conductive, reflective metal coatings, is a whole group of methods in which the coating and its connection with the base (the substrate being processed) is created by the deposition (adsorption, sorption, chemisorption) of particles at the atomic-molecular level, as a result whereby a layer of material of a given thickness is formed on the substrate. To create coatings on products of the automotive industry, it is technically possible to use galvanic (electrochemical) processes and the use of other similar coating deposition methods. However, these technologies require a conductive substrate, are energy intensive, and are environmentally incompatible with environmental conditions.

One of the most promising methods for deposition of some materials onto others is vacuum deposition. Under certain vacuum conditions, atoms of a substance experience virtually no collisions or interaction with the environment when moving, which allows them to be transferred to objects being processed (substrates). Deposition of materials under conditions of low pressure (vacuum) forms a fairly large group of coating methods [1], in which a functional coating of a given thickness and composition is formed by sorption at the atomic-molecular level from material vapors (flow of atoms A onto base B).

The diagram of mass transfer during evaporation and condensation (deposition) of materials is shown in Figure 1.1. Of the total number of evaporated atoms of material, A (NA), part of the flow reaches the front surface of the substrate B. In this case, the atoms A are partially condensed and remain on the substrate (NO flow) and are partially reflected (evaporated) - NR flow. The thickness and nature of the coating being formed depend on the speed of these flows (and other deposition modes). The deposited flow of NO on a relatively cold substrate usually forms a coating with a fairly clearly defined boundary between material A and B. At high temperatures, evaporation of atoms and mutual diffusion of atoms of the coating and substrate are possible.

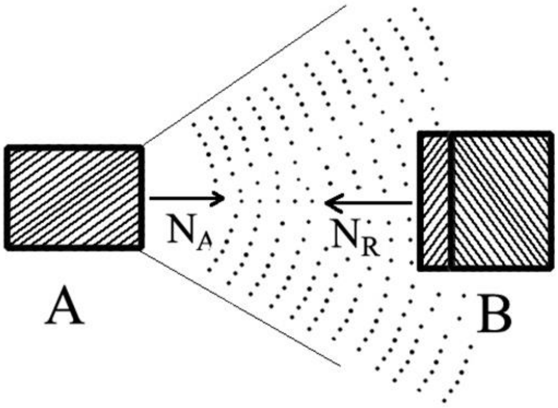

Figure 1. Scheme of evaporation and condensation of atoms of materials on a substrate

Methods and devices for obtaining high vacuum in working chambers are well known and are used in various fields [2]. Technologies for surface treatment of various materials at reduced pressure (in vacuum) currently represent a fairly developed field of science and technology. Methods and technical means associated with the formation of coatings and modified areas on the surface of materials are successfully used in practice [3].

To obtain reflective, electrically conductive, shielding and other coatings in a vacuum, methods of thermal evaporation of materials, cathode (ion) sputtering of targets and pyrolysis of compounds under reduced pressure are widely used. The most common method is vacuum deposition of coatings by thermal evaporation of various materials, in particular pure metals, at pressures of $10^{-1} \div 10^{-7}$ Pa. The process of coating formation includes creating the required degree of vacuum, heating the evaporated working material until steam is formed in the heating zone with a pressure of about 1 Pa, transfer and deposition of vapor on the treated base (substrate) in the selected mode. Temperatures at which effective evaporation of most metals occurs are usually 1000÷1700°C.

The thermal evaporation method can be used to obtain coatings of many non-degradable materials, but significant difficulties are caused by the evaporation of refractory materials, alloys and compounds, the composition of which changes when heated, as well as interaction with the evaporator [4,5]. It should be noted that the energy of atoms in a vapor flow during thermal evaporation usually does not exceed $5 \cdot 10^{-20}$ J (about 0.1-0.3 eV/atom). Application rates during thermal evaporation are usually 1÷100 nm/s.

To heat and evaporate materials in a vacuum, the heat generated in resistive evaporators made of refractory materials (W, Mo, Ta, C) and boats of various shapes is most often used. In directly heated evaporators, filament currents reach hundreds of amperes. Refractory ceramic crucibles are also used, in which evaporation can be carried out due to induction heating of the material by eddy currents. A variation of the thermal evaporation method is the application of coatings by heating refractory crucibles using electron bombardment, for which electron flows accelerated to energies of 2÷4 keV are used.

When forming coatings, the method of electron beam evaporation of materials with a focused beam with an energy of 5÷50 keV of various powers is also used. The electron flow is easily focused and controlled using magnetic coils and additional electrodes. The specific power of the electron flow reaches 107 W/cm^2, which allows you to evaporate any materials from the surface heated zone. In this case, the interaction of the evaporated molten material with the walls of the crucible is eliminated, which ensures the purity of the applied coating. The coating deposition rate during electron beam evaporation of materials is usually 5÷100 nm/s.

Figure 1.2 shows one of the diagrams of a device for electron beam evaporation of materials from copper crucibles.

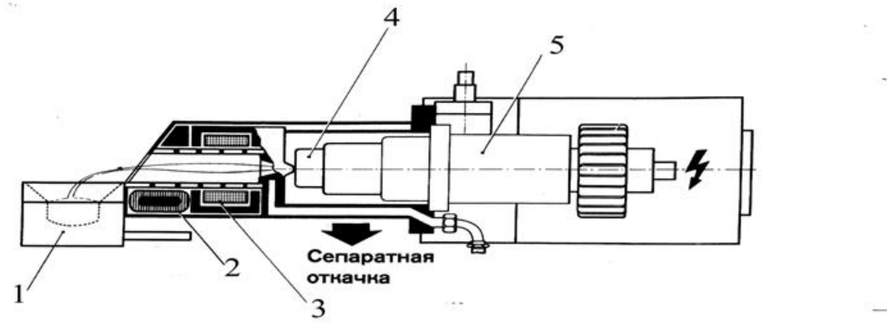

Figure 2. Diagram of the electron beam evaporation device: 1 - cooled crucible, 2 - electromagnetic coil, 3 - focusing coil, 4 - filament cathode, 5 - high voltage insulator

Another large group of vacuum coating methods is based on the well-known phenomena of cathode sputtering, in which the transfer of target material is observed due to the transfer of energy from bombarding ions [6-8]. Spraying methods have advantages such as the ability to apply refractory materials and alloys. The simplest is the conventional diode system for cathode sputtering of materials in a glow discharge at working gas pressures of about 10 Pa and cathode voltages of up to 3÷4 kW (the system provides a deposition rate of no more than 1÷2 nm/s). There are complex cathode sputtering systems for carrying out processes at pressures of about 10^{-1} Pa, using additional electrodes, incandescent cathodes and magnetic fields, but the deposition rate of coatings is low.

More advanced and promising systems are magnetron devices, which are distinguished by the presence of perpendicular electric and magnetic fields in the cathode region. The devices operate effectively at working (inert) gas pressures of about 10^{-1} Pa, voltages up to 1000 V and discharge currents of 1÷50 A. Cooled cathodes usually have a long service life and provide a coating deposition rate of 1÷10 nm/s.

Conclusion. An urgent technical problem in the industrial production of various products is the development of environmentally friendly methods for processing materials and industrial products, in particular parts of the automotive industry, the creation of vacuum import-substituting devices and methods for producing functional coatings from composite materials with specified properties, in particular reflective and protective coatings.

Р.Х. Сайдахмедов, Г.Р.Саидахмедова

АВИАЦИЯ САЛАСЫНДА ҚОЛДАНЫЛАТЫН ВАКУУМДЫ ЖАБЫНДЫ ҚАЛЫПТАСТЫРУ ТЕХНОЛОГИЯЛАРЫНЫҢ ЗАМАНАУИ ТЕХНИКАЛЫҚ ШЕШІМДЕРІН ТАЛДАУ

Аңдатпа. *Технологиялар мен машина жасау өнімдеріне қойылатын* *заманауи талаптар материалдарды өңдеудің жаңа технологиялық әдістерін жасауды және тиісті техникалық құралдарды жасауды қажет етеді. Материалдарды алу, әртүрлі жабындарды қолдану, көп қабатты құрылымдарды құру үшін экологиялық таза вакуумдық, иондық, сәулелік және фотондық процестер перспективалы болып табылады. Материалдарды өңдеуге арналған құрылғылар мен әдістерді, композициялық материалдарды өндіруге және жабындарды қалыптастыруға арналған вакуумдық құрылғыларды жасау өзекті ғылыми-техникалық мәселе болып табылады. Материалдардың маңызды параметрлері олардың беткі қабаттарының қасиеттерімен анықталатыны белгілі, сондықтан жабындарды жағуды және олардың негізінде күрделі құрылымдарды жасауды қоса алғанда, бетті өңдеу технологиясының маңызы зор. Осыған байланысты бетті вакуумдық-термиялық және плазмалық өңдеу процестерінің болашағы зор.*

***Түйін сөздер**: вакуумдық жабындар, тұндыру, булану, конденсация, магнетрондардың шашырауы.*

Р.Х. Сайдахмедов, Г.Р. Саидахмедова

АНАЛИЗ СОВРЕМЕННЫХ ТЕХНИЧЕСКИХ РЕШЕНИЙ ВАКУУМНЫХ ТЕХНОЛОГИЙ ФОРМИРОВАНИЯ ПОКРЫТИЙ, ПРИМЕНЯЕМЫХ В АВИАЦИОННОЙ ОБЛАСТИ

***Аннотация.** Современные требования к технологиям и изделиям машиностроения, обуславливают необходимость создания новых технологических методов обработки материалов и разработки соответствующих технических средств. Перспективными являются экологически чистые вакуумные, ионные, лучевые и фотонные процессы получения материалов, нанесение различных покрытий, создание многослойных структур. Актуальной научно-технической проблемой является создание устройств и методов обработки материалов, вакуумных устройств получения композиционных материалов и формирования покрытий.*

Известно, что значимые параметры материалов определяются свойствами их поверхностных слоев, поэтому технология обработки поверхности, в том числе нанесение покрытий и создание сложных структур на их основе имеет большое значение. Перспективными в этом отношении являются вакуумно-термические и плазменные процессы обработки поверхности.

***Ключевые слова:** вакуумные покрытия, осаждение, испарение, конденсация, магнетронное распыление.*

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