ANALYSIS OF MODERN TECHNICAL SOLUTIONS IN THE FIELD OF VACUUM DEPOSITION TECHNOLOGIES

[1]Saidakhmedova G.R., [2]Saydakhmedov R.Kh.
[1]Turin Polytechnic University in Tashkent, Doctorate
[2]Tashkent State Transport University, DSc, Professor, Aviation Engineering Department
https://doi.org/10.5281/zenodo.12190561

Abstract. *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.*
Keywords*: magnetron sputtering, vacuum deposition, coating, evaporation.*

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 [1-4], 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. 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.

Methods and devices for obtaining high vacuum in working chambers are well known and are used in various fields. 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 [5-8].

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 $10^{-1}\div10^{-7}$ 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 base being processed (substrate) in the selected mode. Temperatures at which effective evaporation of most metals occurs are usually 1000÷1700°C.

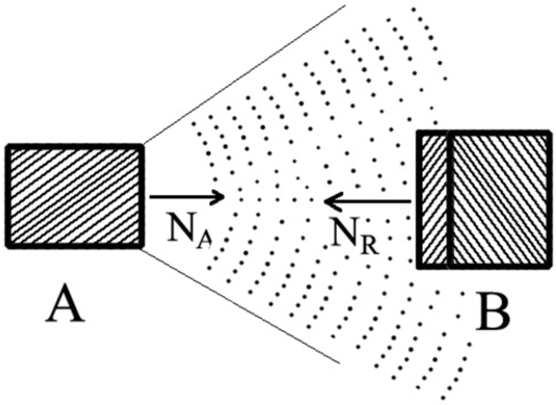

Figure 1 - Scheme of evaporation and condensation of atoms of materials on a substrate

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. 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 by 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.

As a result of the analysis of vacuum methods for deposition of metal conductive coatings for screens, magnetron sputtering methods were selected as the most promising for implementation, providing low-temperature deposition of coatings from metals and alloys [9-12].

The principle of magnetron deposition of coatings is based on sputtering of the target material (cathode) for the magnetron, when it is bombarded by working gas ions formed in the glow discharge plasma. The main elements of a magnetron sputtering system: cathode, anode and magnetic system for localizing plasma at the cathode surface. The magnetic system located under the cathode consists (optionally) of central and peripheral permanent magnets located on a base made of soft magnetic material. The cathode is usually supplied with a constant voltage (on the order of hundreds of volts) from a power source.

The main advantages of the magnetron sputtering method, when using a target for a magnetron: relatively low process temperatures (due to the cold cathode), the ability to sputter cathodes from any non-magnetic materials and alloys, a fairly high sputtering speed and accuracy of reproducing the composition of the sputtered material.

Vacuum installations equipped with simple magnetron sputtering devices make it possible to obtain coatings from almost any metal without disturbing the stoichiometric composition. Depending on the composition of the working atmosphere (proportions of oxygen, nitrogen, carbon dioxide, sulfur gaseous compounds), coatings of various compositions can be obtained. As a rule, pure technical argon is used as the working gas for sputtering. The condensation rate during magnetron sputtering depends on the discharge current or power.

Photographs of industrial technological vacuum installations using magnetron sputtering sources are shown in Figure 2.

Figure 2. - Industrial vacuum installations

To solve problems of coating materials and products used in the automotive industry, it is advisable to use simple magnetron sputtering devices with targets (cathodes) made of conductive metals.

One of the design options for coating deposition devices developed earlier is the use of sputtering materials in crossed electric and magnetic fields. To increase the productivity of the process, a magnetic field is applied to the cathode discharge area, which concentrates the plasma on the cathode target. The trajectories of electron motion are located between the entry and exit points of the magnetic field lines; it is in these places that intense plasma formation and sputtering are localized.

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.

REFERENCES

1. I. Serdiuk., V. Stolbovyi., A. Dolomanov., V.M. Domnich. Modernization of Vacuum-Arc Deposition Technology of Multilayer Nanostructured Coatings. Metallofizika i noveishie tekhnologii. 2022. pp 547-563.

2. Saydakhmedov R.Kh., Kadirbekova K.K., Kamardin A.I. Vakuumnyye funktsional'nyye pokrytiya i ionno-stimulirovannyye protsessy v mashinostroyenii i priborostroyenii. Fan. 2008, 369 p.
3. S. Sharko., A. Serokurova., N. N. Novitskii., V. A. Ketsko., M. N. Smirnova., A.H. Almuqrin., M. I. Sayyed., S. Trukhanov., A. V. Trukhanov. A New Approach to the Formation of Nanosized Gold and Beryllium Films by Ion-Beam Sputtering Deposition. Nanomaterials 12(3):470. 2022.
4. R. Garg., A. Anjum. Sustainable Approach to Protective Nanocoatings. 2024. 443 p.
5. J. Jaiswal., A. Kumar., K. Tsuchiya., R. Mulik. Coating Materials. Computational Aspects, Applications and Challenges. Textbook. 2023. 421 p.
6. Avdeyev N.V. Tekhnologiya i vybor materialopokrytiya. Tashkent, Mekhnat, 1990. 272 s.
7. Minaychev V.Ye. Naneseniye plenok v vakuume. -M., V.SH., 1989, 106 s.
8. Grigor'yev S. N., Volosova M. A. Naneseniye pokrytiy na instrument M.: Izdatel'stvo «ITO», 2007. 68 s.
9. Kuz'michev A. Magnetronnyye raspylitel'nyye sistemy Book 1. Vvedeniyev fiziku i tekhniku magnetronnogo raspyleniya. M.:Avers, 2008. 244 s.
10. P.J. Kelly, R.D. Arnell, Magnetron sputtering: a review of recent developments and applications. - Vacuumv.56 (2000), p 159-172.
11. A. Sagalovych, V. Popov, V. Sagalovych, S. Dudnik. Development of vacuum plasma strengthening hard and ultra hard 3d avinit coatings. Nanotechnology. 2024.