Research Article

Influence Of Ion Implantation And Bombing On Solid Substances Surface And Areas Close To The Surface

R.U. Elmurodov[1],Sh.K. Niyazov[2], G.B. Samatov[3], A. Abdullaev[4]

[1,2,3]Associate professor ,I. Maripov, undergraduate A. Fayzullaev (Gulistan State University)
[4]teacher,I. Maripov, undergraduate A. Fayzullaev (Gulistan State University)
(tel. +998933273683)Email address: elmuratov55@gmail.com

Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 16 April 2021

Abstract. In this work, under vacuum conditions, ions of substances are implanted or bombarded with these ions in the surface and areas close to the surface, as well as by growing films or coatings from other metallic materials on the surface of these bases by simultaneous thermal evaporation. or the interaction of atoms of coating materials and the formation of multi-component solid alloys, which can be studied in several ways.

Keywords: implantation, ion bombardment, thermal evaporation, series collision, cascade, defect, vacancy, voltage, enforcement, cathode distribution, energy distribution, ion-beam diagnostics, electronic spectrometry,. photoelectron spectrometry, secondary ion mass spectrometry, Auger spectrometry, radiation-stimulated diffusion, migration, dislocation, microhardness, adhesion, electrical conductivity, corrosion.

1.Introduction

It determines the basic properties of solid substances and metals, their structure and composition. This suggests that many physical and chemical properties of solids or metals can be altered or controlled by simply changing their composition without breaking the basic structure, i.e. the crystal lattice. For this purpose, it is possible to artificially introduce foreign gas molecules or atoms of substances into the crystal lattices in different ways, in large quantities and at a sufficiently high velocity, i.e. the penetration of foreign mixtures into the crystal lattices.

2.Object of the research and used methods

This process can be accomplished through ion implantation or ion bombardment. In this case, the amount of mixture entering the crystal lattice depends on the energy of the ions being implanted or bombarded, the dose of ions, the ion current on electric density, the type of ions and other values [1,2].

Using these two methods, any solid can be applied to the surface and near-surface areas of substrates made of metals, ionizing atoms or molecules of other substances, in the form of mixtures, using ion implantation or ion bombardment.

It is noteworthy that gases, solids, and metal ions, which differ sharply in physical and chemical properties from each other, can be introduced into other solids or metals, i.e., to cause mixing and to form solid alloys.

In order to increase the efficiency of these methods, the surface of the base made of one metal material is used, under vacuum, from another metal material, by thermal evaporation, to grow films or coatings.

Unlike ion implantation, in the process of growing films or coatings on the surface of bases, simultaneous bombardment with ions of different substances gives more and better results in the formation of mixtures, i.e. in the formation of hard alloys [3].

In the process of growing films or coatings on the surface of metal bases, at the same time, as a result of bombardment with ions of different substances, on both sides of the boundary of the film and the substrate, a mixed film-substrate system is formed. When bombarded with ions, the collision zone of ions has a higher temperature than the other regions of the crystal lattice, which, in turn, leads to the movement and partial addition, pairing (annihilation) of point defects in the collision zone. Many physical and chemical properties of this system, i.e. solid alloy, formed as a result of mixing, differ from the purely physical and chemical properties of film and base materials, under the influence of ion bombardment, changes occur in the film-base system.

These changes include: 1) the occurrence of defects and vacancies in the crystal lattices of the base material as a result of successive collisions of the atoms of the bombarded ions and the evaporating film or coating materials with the atoms in the crystal lattices of the base material; 2) diffusion of bombarded ions and atoms of film or coating materials into these vacancies; 3) occurrence of stresses and strains in the crystal lattices of the base material due to mixtures; 4) cathodic erosion of the film or coating and base material as a result of ion bombardment; 5) due to cathode erosion, atoms of the base material, gas ions in the crystal lattices of the film or coating material and atoms of the base material in the crystal lattices of the film or coating material are mixed; 6) changes in the microrelief in the film-base system; 7) the occurrence of the mixing distribution of three different atoms in the film-base system; 8) changes in the composition of atoms in the film-base system; 9) the occurrence of structural-phase changes in the film-base system [4].

In order to identify and explain these changes, it will be necessary to study the distribution and energy states of the particles of the compounds entering the crystal lattices of the film-base system. Such studies are performed using ion-beam diagnostic methods [5].

In the direction of ion-beam diagnostics of the study of the distribution of molecules, atoms and ions penetrated into the film-base system by thickness, were studied through the methods of Auger-electron spectrometry, X-ray

photoelectronic spectrometry, secondary electron emission, secondary ion mass spectrometry, thermodesorption, etc. [6].

Each film-base system is studied in these methods, at least in three ways. The results obtained are compared with each other. On this basis, conclusions are drawn from the results obtained.

3.Results and their analysis

One of such studies was performed on a base made of molybdenum, under vacuum conditions, simultaneously bombarded with inert gas-argon ions, in a rare metal-silver film, by the method of mass spectrometry of secondary ions [7].

The prepared silver-argon-molybdenum sample (system) is mounted on a secondary ion mass spectrometry (SIMS) device. This device creates a high vacuum [7]. Then, this system (sample) is bombarded with high-energy (E=5-6 keV) primary O_2^+-oxygen ions at a certain angle, causing cathode decay [8,9]. In cathode decay, the primary ions strike the ionized atoms — secondary ions — in the film-base system. These secondary ions fly out at a precise angle and are focused by a magnetic field, i.e., these ions move in the form of a thin-diameter stream, moving towards the recording device of the mass spectrometer. During motion, in electric and magnetic fields that are mutually perpendicular, ions are serrated in relation to the charges/masses e/m, i.e., separated. The reconstituted ions fall on the recording detector. The detector converts these ions into electrical signals and transmits them to a recording potentiometer. The potentiometer draws spectral graphs corresponding to changes in electrical signals [10].

Cathode destruction lasts from the film-base system, the film material, to a certain thickness of the base material. This makes it possible to determine the distribution of mixed particles in the film-base system at a certain thickness from the surface of the system [11].

The results obtained are illustrated in Figure 1.1. This figure shows a graph of the dependence of the intensity of secondary ions knocked out of the film-base system on the cathode destruction by oxygen ions, the cathode destruction time, and the decay depth. As can be seen from the graph, the thickness distribution of argon gas in the silver film is slightly more at the film-base boundary, uniform in the remaining thicknesses, and a rapid decrease with transition to the base is observed in the curve. Similarly, the intensity of the silver atoms decreases with the thickness of the molybdenum base. At the transition boundary of the film-base system, on both sides, the transition of the mixtures to each other is observed. This form of distribution of the mixtures entering the film-base system is consistent with the results obtained by calculation [12]. These results show that the simultaneous bombardment with argon gas ions into silver films grown on molybdenum substrates results in the transition of molybdenum substrate atoms to the film material as a result of cathode destruction, as well as their location and distribution in the film material. However, under the influence of ionic bombardment, the molybdenum shows the penetration, location, and distribution of the atoms of the film material into the defects and vacancies that occur in the crystal lattice of the substrate as a result of diffusion.

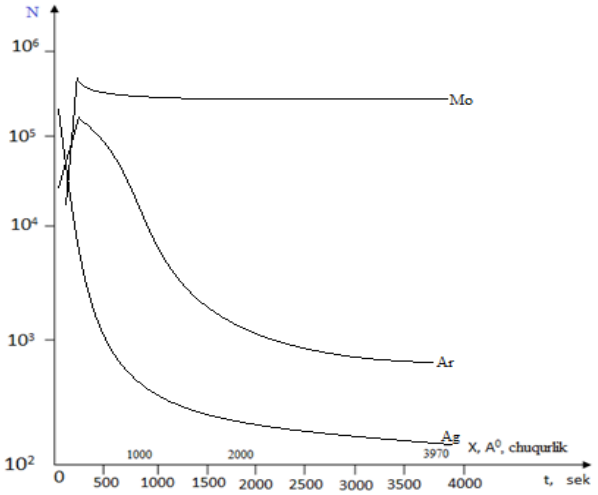

Figure 1.1. Secondary ions of silver, molybdenum and argon gas with oxygen ions graph of dependence on lactation time. Intensity of N-secondary ions; t-absorption time; x-absorption depth

Thus, under the influence of ionic bombardment, solid alloys are formed as a result of the mixing of the film and the base material in the crystal lattice [13].

Solid alloy samples consisting of a prefabricated film-base system were also studied by Auger-electron spectroscopy.

Cathode destruction occurs when the film-base system, placed inside a high-vacuum-generated device [14], is bombarded with primary electrons at a precise angle. Based on the cathode decay, secondary electrons are knocked out of the film-base system.

The flow of the secondary electrons struck is focused by a magnetic field generated by special devices so that it is not scattered, and the spectrometer's analyzer is directed to the input hole. In the analyzer, secondary electrons are serrated, i.e., separated by their energies. These separated electrons fall on the detector and are converted into electrical signals. These electrical signals are transmitted to the recording potentiometer itself. The potentiometer draws spectral graphs corresponding to changes in electrical signals [15]. The spectral graphs obtained by Auger-electron spectroscopy are shown in Figure 1.2. It describes Auger-spectra confirming the mixing processes that occur in arrays of copper (Su) material, bombarded with argon gas ions with energy E = 600eV, in rare earth metals, in films of yttrium (Yb) material, and in copper bases In this spectral graph, the "peaks" of shifts in the energy of the secondary electrons that fly out and the changes in the intensities of these "peaks" are observed. In this case, the spectrum emitted by electrons emitted from atoms belonging to the copper base differs from the energy and intensities given by the spectra emitted by electrons emitted from the atoms belonging to ytterbium.

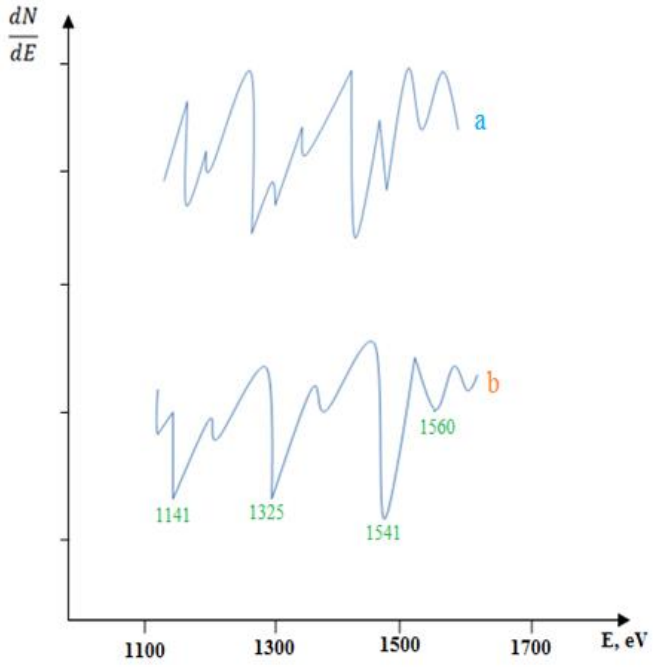

Figure 1.2. Auger-spectral graph obtained from yttrium film and copper base grown by simultaneous bombardment with argon gas ions on copper bases.

Electrons belonging to copper atoms were found to fly out of the film thickness. Electrons belonging to the yttrium atoms were found to fly out of the copper base. Hence, under the influence of ionic bombardment, the atoms of the yttrium film material penetrate and mix with the crystal lattices of the copper base material due to radiation-stimulated processes, as well as the resulting defects and vacancies. The atoms of the copper base material, on the other hand, fly out due to cathode destruction and settle on the crystal lattices of the yttrium film material.

In experiments performed by X-ray photoelectron spectroscopy, spectra of excited secondary electrons were also recorded. Using these spectra, the intensity, energy, and relative composition of the secondary electrons emitted from the film-base system were studied. Experiments have shown that under the influence of ion bombardment, in the film-base system, atoms of the film material penetrate the substrate, and conversely, atoms of the substrate material pass into the film material. This method also confirmed the interaction of atoms of two different materials in the film-base system under the influence of ion bombardment.

By thermo desorption spectrometry, bases made of tantalum (Ta), molybdenum (Mo) and tungsten (W) are separated from the silver film, which is bombarded simultaneously with argon gas ions. The spectral graph of the temperature dependence is shown in Figure 1.3.

As you can see from the graph, the release temperature of argon gas from the silver film grown on the bases of tantalum material is very close to the release temperature of argon gas from the pure silver film. In bases made of molybdenum and tungsten materials, the temperature of release of argon gas corresponds to the temperature of release of argon gas from pure molybdenum and tungsten bases when thermally heated silver films grown simultaneously with argon gas ions. Hence, when the above-mentioned metal alloys are thermally heated, the release temperature of argon gas from some of them changes [16].

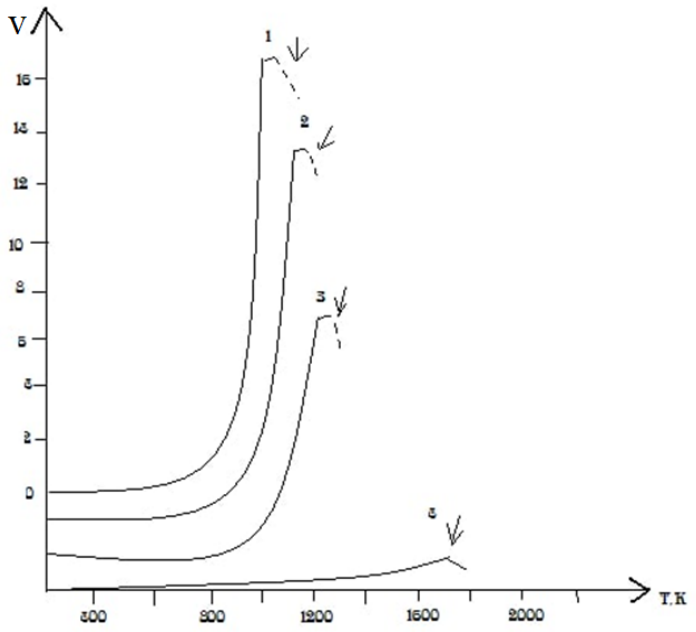

Figure 1.3. Spectral graph of the temperature dependence of the emission of argon gas from the film-base system as a result of thermal heating of the molybdenum, tantalum and tungsten materials from the silver film, which is bombarded simultaneously with argon gas ions. 1-Argon gas released from pure silver film; 2-Argon gas released from the silver-tantalum system; 3-Argon gas released from the silver-molybdenum system; 4-Argon gas released from the silver-tungsten system; - heating rate of the film-base system; T-heating temperature.

This is because when ionic bombardment of base materials, ions are subjected to a series, cascading collision with atoms located in the bottom crystal lattice, in areas close to the base surface. As a result of the mixing of atoms or molecules of other substances in the crystal lattice of the base material occur many, different types of defects, radiation-stimulated diffusion, vacancies, migrations (movements), dislocations. In these collisions, because the ions transfer their energy to the atoms, they settle in the areas close to the base surface, in the vacancies at the nodes of the crystal lattices, or in the spaces (defects) between the lattices, stopping and settling in the crystal lattices. This results in the mixing of atoms of two different foreign substances in the crystal lattices of the base materials. The energy given off by ions in collisions increases the vibration motion energy of the atoms in the crystal lattice, and the atoms radiate this energy in the form of heat. This heat radiation increases the temperature of the crystal lattice. As the temperature of the crystal lattice increases, the binding energies of the atoms in the crystal lattice change. An increase in the energy of the temperature-dependent oscillations of the atoms in the crystal lattice reduces the energy of the interaction between the atoms [17].

Inside the crystal lattice, in areas where the energy of the interconnections is reduced, the atoms can move out of their positions or inside the crystal lattice, they can migrate to a part of the lattice [17]. This, in its turn, causes many defects in the crystal lattices of the film-base system. These defects lead to disruption of the relatively orderly energy bonds in the crystal lattices of the film-base system. As a result, a certain portion of the atoms in the crystal lattice move or migrate. These processes occur in the boundary areas of the film-base system in contact with each other, from the film material, towards the inside of the film, or towards the film material growing from the surface and areas close to the base [18]. In addition, ions of argon gas are also involved in these processes. This results in the mixing of three different atoms in the crystal lattice of the film-base system [19].

The result is this that a solid mixture of film-base materials, i.e. a mixed alloy of solids appears. The formation processes of solid alloys depend on the quantities that characterize the physical and chemical properties of the film and base materials. Such quantities include the surface binding energy of the atoms of the film base material, the binding energy of the atoms in the crystal lattices, and the vacancies in the crystal lattices

of each material, migration speed, vacancy activation energy, vacancy concentration, exchange defect concentration, boundary displacement energy of atoms, maximum energy transmitted in collisions, cathode decay coefficients, strength (hardness) coefficients, depth of defects in crystal lattices, etc. [20]. As for metals, these quantities have been identified in theoretical calculations and confirmed in experiments [21].

4.CONCLUSIONS

With the help of ion bombardment, it is possible to create qualitatively new materials by simply changing the composition of the metal base materials without breaking the crystal lattice. The physical and microhardness, abrasion resistance, adhesion, electrical conductivity and chemical and corrosion resistance properties of these new composite materials are improved

List of used literature:

1. Komarov F.F.,Komarov A.F., Ïukowski P., Karwat Cz., Sielanko J., Kozak Cz.M., Kiszczak K. Ion beam assisted deposition of metal layers using a novel one beam system//Vacuum. – 2003. – Vol. 70. – P. 215-220.
2. 2.Y. Takeda, V. T. Gritsyna, N. Umeda, C. G. Lee and N. Kishimoto, "Linear and Nonlinear Optical Properties of Cu Nanoparticles Fabricated by High-Current Cu Implantation in Silica Glass", *Nucl. Instrum.& Methods Phys. Res.*, vol. B148, pp. 1029-1033, 1999.
3. Bojko E., Karwat Cz., Kiszczak K., Kolasik M., Koltunowicz T., Komarov F.F., Komarov A.F., Kozak Cz., Wdowiak A., Ïukowski P. Deposition of monoatomic and compound metal layers by the dynamic ion mixing//Vacuum. – 2005. – Vol. 78. – P. 241-245
4. Pout J.M., Foti G., Jacobson D. Modification and alloying of surface with laser, ionic and electron beams. Moscow, 1998, 424 p.
5. Feldman L., Mayer D. The basis of the analysis of surface and thin films. Moscow, 2001, 342 p.
6. Briggs D., Sikh M. Analysis of surface through methods of Auger- and X-ray photoelectron spectroscopy. Moscow, 1987, 597 p.
7. Cherepin V., Vasilev M. Secondary ionic emission of metals and alloys. Kiev, 1995, 239 p.
8. 8.Pleshintsev N., Kathode sputtering. Moscow, 2009, 363 p.
9. Berish R. Sputtering of solids by ion bombardment. Moscow, 2004, 336 p.
10. Tulyev V. Composition and distribution of components in depth, formed by the method of ionic mixing. Moscow, Physics and Chemistry of Materials Processing, 2009, pp. 55-65.
11. Pogrebnyak A.D., Chistyakov S.A. Modification of the properties of metals and coatings under the action of ion beams. Moscow, 2011, 214 p.
12. Rajabov T.D., Iskanderova Z.A. Calculation of the distribution of gas impurities introduced by ion bombardment into growing films and layers with allowance for diffusion. JTF, 1998, Vol. 48, Issue 9., Pp. 1257-1264.
13. 13.“Simulator for Dynamic Ion Beam Mixing” Government Industrial Research Institute Osaka, Midarigaoka 1–8–31, Ikeda,Osaka 563 Published online by Cambridge University Press: 25, February 2011.
14. Rozanov L.N. Vacuum technology. Moscow, 2011, 197 p.
15. Rick G. Mass spectrometers. Moscow, 2012, 380 p.
16. Pisarev A.A., Telkovsky V.G. Capture and release of helium when bombarding niobium with helium ions. Moscow, Atomic Energy, 1975, V. 38. no. 3. pp. 152-155.
17. Burenkov A., Komarov F., Kumakhov M. Spatial distributions of energy released in a cascade of atomic collisions in solids. Moscow, Energoatomizdat, 2005, 246 p.
18. Orlov A.N., Trushin Yu.V. Energy of point defects in metals. Moscow, Energoizdat, 2019, 81 p.
19. *Elmuradov R., Samatov G., Abdullayev A., Maripov I., Cho'liyev T.,Savronov D.* Penetraion of impurities into the crystal lattice of solid bodies with the help of ion implantation and bombardment. JOURNAL of CRITICAL REVIEWS, ISSN-2394-5125 vol.7, ISSUE 15, 2020 y, 1685-1689 pp.
20. Shalaev A. Radiation-stimulated processes in metals. Moscow, Energoizdat, 2008, 175 p.
21. Tables of parameters of the spatial distribution of ion-implanted impurities. Spravochnik. Moscow, 2017, 350 p.