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Development of technology for multi-hard and super alloys based on ti, si, w and others with an ionizing radiation

Abstract. Complex researches on creation of scientific bases of receiving new and perspective firm and superfirm materials with use of bunches of particles are carried out. Bases of radiating technology of receiving multicomponent firm and superfirm alloys on the basis of Ti, by Si, W, etc., high-energy bunches of ions, electrons, thermoinfluence and the microwave oven are developed. Works on search and a choice of modes radiating and the microwave oven of processing of powders, components of polymers and agglomeration modes (temperature, pressure) are carried out. The technique of manufacturing of samples is developed.
Keywords: Ti, Si, W, multi-hard, super alloys.

Introduction

As show the literature data the ion-implanted systems are formed by the introduction of accelerated dopant ions in the surface layer [1-5]. In the interaction of ions with atoms of the material it passes the energy that is greater than the energy shift of an atom in a substance. Further, the primary knock-on atom recoil, having sufficient energy, generates a cascade of collisions resulting in the displacement of a large number of metal atoms. In this case are going the following processes: 1) the introduction of ions in the solid; 2) the generation of radiation defects, in which the lattice atoms are displaced with respect to their location; 3) radiation sputtering, in which the atoms are ejected from a solid surface material; 4) the atomic mixing. The changed physical and chemical parameters of implanted ions have a significant effect on structure and properties of the material, which are formed as a result of the relaxation processes that take place after the stage of collisions. The processes are occurring in a given metal depends on the physical and chemical properties of implanted ions and their concentration in the collision cascade. The generation of surface layers is a function of the beam parameters of the bombarding ions (type, energy and dose). When implanting by ions in small doses at the room temperature or below the cascade of collisions is practically no overlap, as interstitial atoms separated from each other at a great distance, without the possibility of migration. In this case, the dopant is distributed over the volume of the metal. Ion implantation can form metastable structures with special properties and it is accompanied by a wide range of processes that have a significant effect on the properties of the material [6-10].

As it is known the surface morphology determines many properties of solids. The radiation treatment of the surface by ion beams can change its morphology. The surface of the material upon ion implantation is heterogeneous: it is clearly defined developed relief on which the concentration traces of the ion beam and the various non-uniformity is well observed. The presence of defects on the surface in the form of pits, craters have a negative impact on the performance of the material and are stress concentrators, which reduce fatigue and lead, ultimately to corrosion [4-10].

Experiment

In this paper the complex studies to establish a scientific basis for obtaining new and advanced hard and super hard materials with particle beams were conducted. The fundamentals of radiation technology were developed for obtaining multicomponent solid and super alloys based on Ti, Si, W, etc., high-beams of ions, electrons, thermal effects and microwave. The works on the search and selection modes of radiation and microwave processing of powders, polymer components and sintering conditions (temperature, pressure) were carried out. The method of fabrication of the samples has been developed.

It was revealed that new technology of hard and super hard materials based on Ti, Si, W, and others can be used in the domestic industry. It was found that the use of radiation treatment, laser, gamma, thermal effects and microwave radiation can significantly improve the properties of materials. The consumers of these products will be plants for the production of products and materials (Gidromash, Vostokmashzavod, and plant Kirov, etc.).

The proposed radiation technologies should be used in some special cases: in the production of solid and heat-resistant materials, diamond-metal alloys, and large objects (eg, carbide rolls). In addition, it can be used in the manufacture of thin plates, discs, and other details that are jarred during sintering; making them by cold forming is difficult.

The approbation of the results (scientific publications, conference papers, etc.) was carried out.

The fundamentals of the new manufacturing techniques and advanced materials based on Ti, Si, W, etc. were developed and obtained results. They tested in the laboratory and industrial applications.

The results suggest that these properties of nano crystalline coatings as the size and orientation of the grains, their structure is highly dependent on the technological parameters of the ion bombardment, the bias potential, substrate temperature, flux density and energy, so to achieve results in each case must seek to optimize the deposition of coatings. The multifactor of considered physical process and the complex relationship between the parameters cause the difficulty of mathematical modeling.

At the same time the individual questions can be studied in detail and the physically-based regularities can be defined for them. These results may include the consideration of the processes associated with the formation of the structure of binary and ternary systems of transition refractory metals. In particular it was established a fact of a significant increase in macro stress state of compression and hardness forming a substitutional solid solution of transition metals with different metal radii, compared with the condensates of the corresponding binary alloys. This is explained by the additional lattice distortions due to the formation of substitutional solid solutions of metals with different radii of the action, characteristic for the method of ion bombardment, which allows you to create high super saturation. The increasing in hardness of ternary systems compared with the binary systems is also due to the increase of the energy barrier to dislocation motion through crystallites as a result of the mechanism of deformation of the crystal lattice.

With increasing temperature the depositions become more stable to subsequent temperature effects on the structure and phase composition and properties of the formed materials that can be explained by the equilibrium conditions of film formation with increasing temperature of their formation. The physical and chemical properties of the test samples, depending on the physical factors (particle beams, mechanical stress) and the concentration of components were studied.

Within the framework of the cascade-probabilistic method the computer modeling of radiation processes was conducted.

It is shown that the interaction of ions with matter is a Markov process and is described by the probabilities $\psi_0(h', h, \alpha_0)$, $\psi_1(h', h, \alpha_0)$,..., $\psi_n(h', h, \alpha_0)$, since all the probabilistic characteristics in the future depends on only in what state this process is at the present time and do not depend on the way in which this process took place in the past.

The Markov chain is a type of Markov process in which the future depends on the past through the present.

The physical characteristics of the interaction of particles (including ions) with the substance, including solid are described as a Markov chain, since the conditional probabilities occurrence of each event in this study are uniquely determined by the result of the previous state.

The Markov chain is completely described by giving all possible probabilities. In general, the Markov chain is not uniform, since the transition probabilities ψ_k, $k = 0, 1, \dots n$ vary at each step k, intensity of the flow is independent of the depth of penetration, ie all flows that take the system S from one state to another, is a simple, stationary Poisson. This Markov chain has a stationary regime, because it has an ergodic property.

In some cases, the interaction of charged particles with solids in the consideration of multi-process must take into account, in particular, the total energy losses for ionization and excitation in the generation process of primary knocked-out atoms.

For ions, forming primary knocked-out atoms, the approximation function of energy was calculated, which in turn is a function of penetration depth. In this case, the intensity of flow depends on the depth of penetration; therefore, the system transitions of S from state to state are caused by the non-stationary Poisson process.

The ions most of their energy are lost for ionization and excitation of the atoms of the medium (99%) and only 1% goes to the formation of the atomic structure of defects. In the interaction of charged particles with the material can be formed the point defects, Frenkel pairs, large concentrations of vacancy and interstitial atoms.

The calculation of the concentration of radiation-induced defects (Cascading areas) under ion irradiation is performed using the formula:

$$C_k(E_0,h) = \int_{E_c}^{E_{2\max}} W(E_0,E_2,h)dE_2 \,, \qquad (1)$$

$$E_{2\max} = \frac{4m_1c^2 m_2c^2}{(m_1c^2 + m_2c^2)^2} E_1 \,;$$

m_1c^2 - is the rest energy of the ion. Ck(E0,h) is determined by taking into account the fact that the energy of a particle at a depth h is E1 (h). Since E1 (h) =E0-DE (h), then setting the energy loss due to ionization and excitation DE, we obtain the corresponding depth observations h of the Bethe-Bloch formula. The spectrum of primary knocked-out atoms defined by the following relation:

$$W(E_0,E_2,h) = \sum_{n=n_0}^{n_1} \int_{h-k\lambda_2}^{h} \psi_n(h')\exp\left(-\frac{h-h'}{\lambda_2}\right)\frac{w(E_1,E_2,h')dh'}{\lambda_1(h')\lambda_2}, \qquad (2)$$

where n0, n1 – is the initial and final value of the number of interactions in the domain of the cascade-probability function.

Results and Discussion

Let us note some of regularities that arise when finding the real domain of the results, depending on the depth of penetration. (at irradiation of titanium, silicon and tungsten charged ions in particular nitrogen, carbon, etc.):

1. The calculations show that at low atomic weight of the incoming particle and shallow result area of CPF depending on h is close to h, which corresponds to h/l. With increasing depth of the observation area, the result is shifted to the right and is narrowed.

2. With decreasing the initial energy of the particles (the incoming particle is the same) at the same depth of the observation area, the result is shifted to the right and is narrowed.

3. With increasing depth of the observation for any of the incoming particle the area result is shifted to the right and the percentage of the inner region is reduced. The shift percentage of the left border region decreases, sometimes at the end of run slightly slower. The right border region varies, at the end of run is reduced, but the percentage of the interior of the result always decreases.

4. The depending on the atomic number of the incident particle with the same values of the depth h the area result is shifted to the right and the percentage of the inner region is reduced.

5. For large values of the atomic number of the incident particle the area result is shifted to the right relative h, corresponding to h/l even at shallow depths.

As an example, the dependences of the concentration of radiation-induced defects (Cascading areas) on the depth of bedding under irradiation of titanium and other nitrogen ions were calculated. As follows from the calculations, the depth of the ions is less than one micron. The concentration of the cascade region has a pronounced maximum. To obtain a uniform distribution it is necessary to produce the thermal or radiation annealing (for example, by the high-energy electrons or gamma rays).

Conclusion

The conducted works on the modeling of the radiation processes have allowed a deeper understanding of the processes, in particular to determine the depth of bedding of the ions and their distributions, the generation of high-strength joints, depending on the energy of the incident particle, the atomic number of the target, that has allowed more qualitatively carry out the works on technology development.

Next were calculated the distributions of implanted silicon with the energies of 10, 20 and 30 keV in tungsten ions in depth (figures 1-3).

As follows from the figures the distribution of silicon is given by Gaussian and shifted to the right, its concentration decreases at small depths and increases at large. The distribution of the energy loss is also a Gaussian form. However, with increasing particle energy the maximum losses grow and shift to the right.

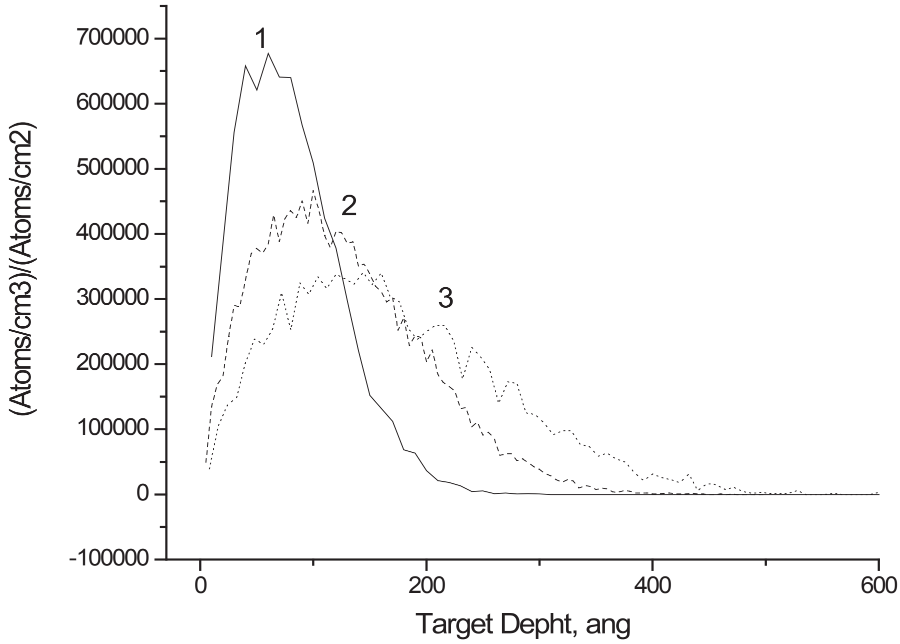

Figure 1 – The distribution of implanted silicon ions in depth of W

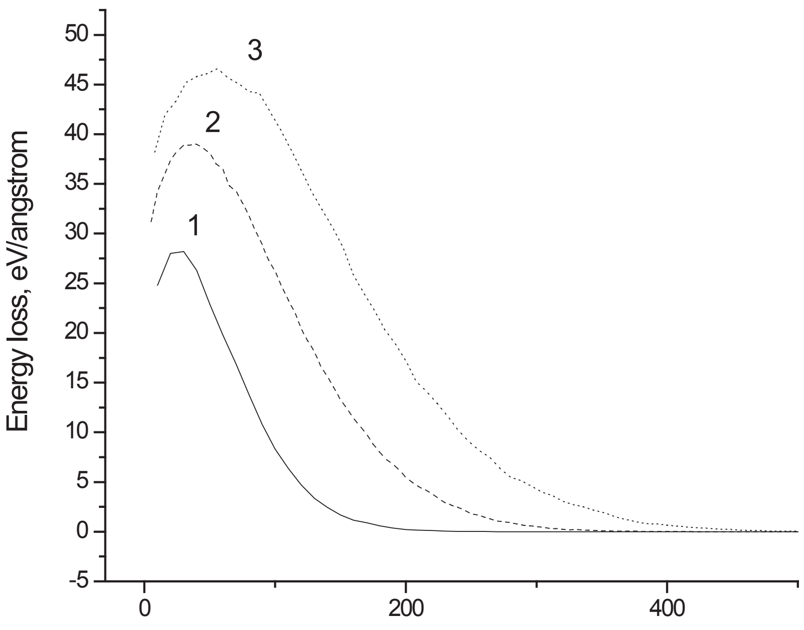

Figure 2 – The distribution of energy loss by ionization of irradiated W by the flow of silicon ions of different energies

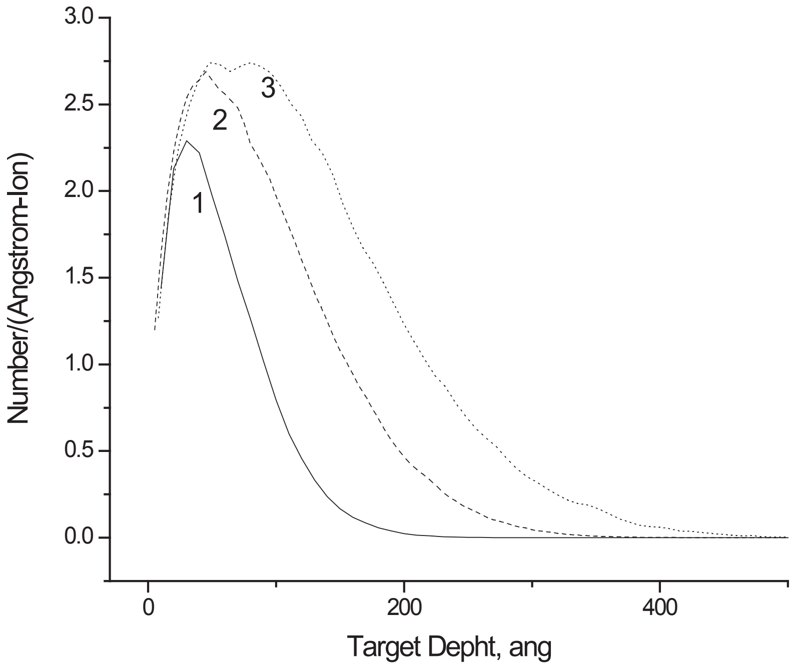

Figure 3 – The distribution of sputtered atoms of W in the depth of the target when irradiated with ion flux ofsilicon

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Қатты көп компонентті және өте жоғары қатты балқымалардың технологиялық өңделуі титан, кремни, вольфрам, т.б. негізінде иондалған сәулелердің көмегімен алынады

Кешенді зертте- ша жаңа және перспективалы қатты және сверхтвердых материалдың ал- ғылыми негізінің жаралғанына мен игерушілік бөлшектің шоқшаларының өткіздір-өткізу. Многокомпонентных қатты және сверх-твердых құйындының ал- радиациялық технологиясының негіздері бас негіз Ti әзірле-, Si, және др. W, высоко-энергетикалық шоқшалардың ионның, электрондердің, термовоздействия және СВЧ. Жұмыстар ша ізденіс және режимнің талғамының радиациялық өткіздір-өткізу және СВЧ ұнтақтың, полимердің және спекания (қызу, қысым) режимінің компонентінің өңдеулері. Үлгінің изготовления әдістемесі әзірле-.

Түйін сөздер: Ti, Si, W, супертвердые құйындылар.

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Разработка технологии получения многокомпонентных твердых и сверхтвердых сплавов на основе Ti, Si, W и др. с помощью ионизирующего излучения

Проведены комплексные исследования по созданию научных основ получения новых и перспективных твердых и сверхтвердых материалов с использованием пучков частиц. Разработаны основы радиационной технологии получения многокомпонентных твердых и сверхтвердых сплавов на основе Ti, Si, W и др., высокоэнергетических пучков ионов, электронов, термовоздействия и СВЧ. Проведены работы по поиску и выбору режимов радиационной и СВЧ обработки порошков, компонентов полимеров и режимов спекания (температура, давление). Разработана методика изготовления образцов.

Ключевые слова: Ti, Si, W, супертвердые сплавы.