# Comparison of the Calculated and Experimental Results on the Research of Interaction of the Particle Beams with a Surface in Technologies to Nuclear Power[1]

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**Abstract – The research of interaction processes of various kinds of radiations with constructional materials remains an actual problem. First of all it is concerned to increase the operation characteristics of details of machines and the mechanisms working in conditions of radiating loadings.**

**Frequently such interactions possess a combine influence of ionizing and toxicological factors that demands development of theoretical approaches and methods of modelling in this important practical area.**

**In this work are resulted the calculated and experimental data concerning the change of structure and properties of iron surface and its alloys under impact of ionic beams of metals IVB-VIB groups with a low energy. The general regularities in behaviour of calculated and experimental results are found out and its variance is estimated.**

**Now the development of methods of modelling of influence of fission neutrons resulting to change the properties of the modified surface of iron are carried out.**

### 1.1. The research methods and experimental results

The process of interaction of ionic beams with a surface of the constructional materials, resulting to change their structure is the most delicate management processes of the surface properties [1,2].

For the solution of such specific target the carrying out of some preliminary researches is usually required. But these researches are difficult carried out for materials possessing a number of dangerous properties including a radioactivity. In this case the usage of forecasting methods and the development of stochastic approaches are most actual and safe. The legality of its usage can be established by comparison of the obtained theoretical and practical results with a simultaneous estimation of the reasons of an available variance.

Iron and its alloys are the most widespread kind of constructional materials; therefore the researches have been started from this element and its compounds.

The thickness of the zone of modified surface and its phase structure are the basic characteristics to change the material properties, therefore they were primarily investigated.

These parameters were determined with the help of theoretical methods as well as set of modern methods of physical and chemical analyses.

At the first stage of research the thickness of the modified structure of iron layer was determined with the help of simple calculations of a particle free path at its stopping in the matter [3]. The calculations have shown that for ions of metals IVB-VIB groups this path does not exceed few microns and increases with energy growth. For example, titanium penetration depth of ions of beams of multicharge plasma at various energies is resulted in Table 1.

Table 1. The Calculated Values of the Penetration Depth (nanometers) of Titanium Ions into Iron

| Charge | Energy of ions, eV | | |
|---|---|---|---|
| | 500 | 1000 | 2000 |
| +1 | 0,8 | 3,4 | 9,2 |
| +2 | 1,6 | 8,1 | 27,0 |
| +3 | 8,3 | 17,1 | 43,2 |

Also this problem was solved by the Monte Carlo method with to obtain more information. It was used the program for modelling of ion interactions with the matter by directly on a normal to a surface at the binary impacts. The calculated results are demonstrated on Fig. 1.

These data confirm the results received earlier concerning depth of penetration of ions in iron which size does not exceed 30–60 nanometers. Also it has been established, that the maximal depth of penetration into iron corresponds to easier ions of the titan, and minimal to heavy ions of tungsten. Besides in all cases ions of easy elements tend to be distributed in regular more intervals in superficial layers of iron in comparison with heavy metals.

The modern methods of physical and chemical analyses were used for comparison of the theoretical and experimental data of the penetration depth of ions of metals IVB-VIB groups into iron.

Ionic beams formed with usage of the ionic-plasma technology. The metal cathodes evaporated in vacuum with the arc discharge and directed ionic beams to an iron surface with energy of 500–2,000 eV.

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The results of the local X-ray spectral analyses have confirmed that the light metals will penetrate into iron on the large depth in comparison with heavy elements. However the zone size of the modified structure into iron was within 2–9 microns that considerably exceeds its calculated value (Fig. 2).

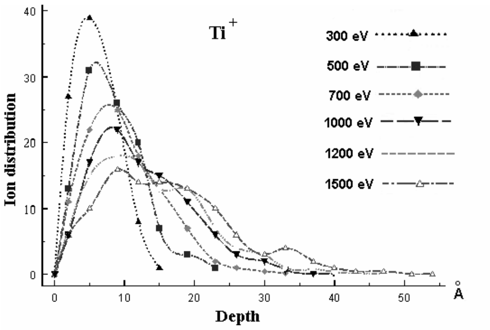


Fig. 1. The implantation structures of titanium ions into iron depending on initial energy

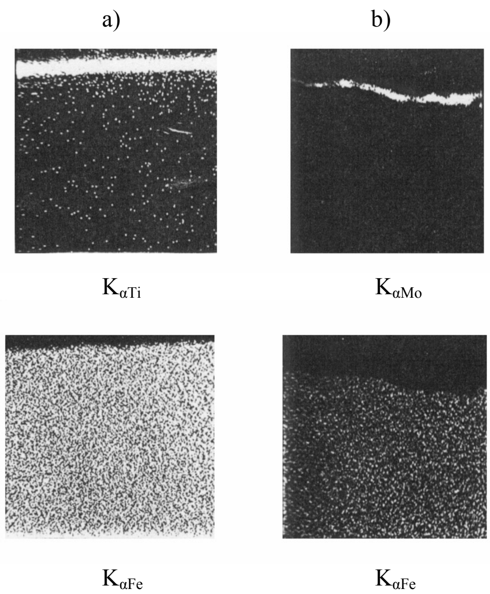


Fig. 2. The distributions of titanium (a) and molybdenum (b) into the surface layers of iron, ×1000

The size of penetration depth of ions of metals IVB-VIB groups into iron largely, apparently, is concerned to properties of a target and metal of ion. The self-activation energy of its diffusion in iron has most importance. Besides the proceeding physical and chemical and radiation-dynamic processes have the substantial contribution. The penetration depth is less concerned to energy of ionic beam in this case.

It is established by the methods of X-ray phase and electroscopic analyses that during an irradiation of iron by ionic beams of metals IV–VI groups in a zone of the modified structure there is a formation of alpha – firm solutions of iron and metal of ionic beam as well as intermetallic compounds like Laves-phases (Table 2).

Thus, a character proceeding in an interaction zone of reactions between metal of ionic beam and iron is individual for each kind of ions.

These tendencies are observed for more complex systems of iron, including for carbonic and alloyed steels which are carried out now.

At the same time the programs of modelling of neutrons interaction with the iron modified surfaces are developed. The primary calculations of thermal emission for fission neutrons by the Monte Carlo method are resulted in Table 3. The results are given on the depth of zones synthesized during interaction of ionic beams of metals IVB-VIB groups and iron.

Table 2. The results of phase structure of an iron surface after irradiation by ions of metals IVB-VIB groups

| Metal of ionic beam | Phase structure of interaction zone |
|---|---|
| Titanium | A solid solution of alpha-iron and Laves-phase $TiFe_2$ |
| Niobium | A solid solution of alpha-iron and Laves-phase $NbFe_2$ |
| Molybdenum | A solid solution of alpha-iron and Laves-phase $MoFe_2$ |
| Tungsten | A solid solution and Laves-phase $WFe_2$ |

Table 3. The specific thermal emission distribution, MeV/g

| Depth, cm | Ti | Zr | Fe | W |
|---|---|---|---|---|
| 0,1 | 0,0092 | 0,0074 | 0,0087 | 0,0106 |
| 0,5 | 0,0105 | 0,0091 | 0,0101 | 0,0114 |
| 1,0 | 0,0119 | 0,0106 | 0,0115 | 0,0130 |
| 2,0 | 0,0132 | 0,0121 | 0,0127 | 0,0143 |
| 2,5 | 0,0134 | 0,0127 | 0,0127 | 0,0153 |
| 3,0 | 0,0181 | 0,0142 | 0,0127 | 0,0085 |
| 4,0 | 0,0177 | 0,0143 | 0,0125 | 0,0085 |
| 5,0 | 0,0169 | 0,0137 | 0,0119 | 0,0081 |
| 10,0 | 0,0116 | 0,0094 | 0,0080 | 0,0054 |
| 15,0 | 0,0063 | 0,0051 | 0,0043 | 0,0029 |
| 20,0 | 0,0026 | 0,0021 | 0,0018 | 0,0012 |

The first zone of a composition which was irradiated by neutrons has consisted of metal thickness of 0.1 cm, then an alloy of iron with the given metal (equal weight parts) has thickness of 2.4 cm, and the third layer of iron has thickness of 17.5 cm. In the left column of the table the boundaries of zones are bolded. The minimal thermal emission is observed in the zones formed in iron by zirconium ions. The maximum in distributions is near to boundary of layers of an alloy and iron.

Development of these researches is especially important from the point of view of use expansion of alloys on the basis of iron and its usage in new nuclear power technology.

The combined usage of theoretical approaches and of experimental results gives most complete picture at the solution of these problems.

**References**

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