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SECTION 3. Nanotechnology. Physics.

STRUCTURAL CHARACTERISTICS OF COPPER-NICKEL ALLOY THAT WERE IRRADIATED BY ELECTRONS

Abstract: Measurements of experimental spectra of angular distribution annigilation photons having swum systems Ni - Cu, containing are executed 7,0; 9,0; 14,0; 21,0; 30,0 and 40,0 am. % Cu. Alloys had initial отожженное and irradiated of elektrons with energy 2,5МэВ conditions at fluens 1019см-2. The structurally-sensitive parametres connected with distribution free and the connected electronen, co-operating with positrons are defined. Are established the law radiathion-stimuliren changes annigilations parametres depending on structure of alloys. Observable experimental dependence has nonmonotonic character. It, possibly, is connected with radiatsionno-stimulirovannym change of a near order in spheres of education of radiating defects.

Key words: nickel, copper, alloys, radiation, structure, positron electron annihilation.

Language: English

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Introduction

It is well known that radiation treatment leads to a significant changes in the physical and mechanical properties of metals and alloys [1]. Thus the greatest disorder occur in the micro-regions of metallic systems, the structure and local electronic properties of which influences the kinetics of changing of the properties of the material as a whole during subsequent thermal and mechanical impacts [2]. For example, in experiments on the effects of gamma-quantum with $E = 1,2МэВ$ of a $1500P/\sec$ intensity on an ordered alloy $Fe - 12$ $am.\%Al$ the decrease of the activation energy of low-order up to~ 10% was found [3]. Changing of the degree of short-range order in wrought alloys Fe-Al after irradiation with gamma-rays and neutrons observed in researches [4, 5]. A similar effect was also observed in the cold-deformed alloys Al-8,75 $am.\%Zn$ under electron irradiation [6]. In these circumstances it is interesting to study the effects of electron irradiation on metallic systems which, according to the state diagram, forms a continuous series of solid solutions. In these systems, at a specific concentration range of the second component, at a relatively low temperature a low-order clusters may appear. Such systems include binary alloys Ni-Cu with FCC lattice (γ-phase). At the concentration range of ~5,0-7,0ат.% Cu and below $448^0 C$, a bundle solution into two phases γ_1 and γ_2, also with FCC lattice, occurs. Alloys of this system below $448^0 C$ show an ordered state [7]. In addition, while studying the Hall effect in these alloys a non-monotonic change of the Hall constant R_H, depending on the concentration of the second component, was found [8-11]. A minimum of changes in R_H was detected at a concentration of 32 ат.% Cu, and the position of the maximum corresponds to the content of 17,5 ат.% Cu (pic.2a).

Since the Hall constant is inversely proportional to the electron density $R_H = 1/ne$, where e - electronic charge, therefore, there is reason to believe that the alloy 17,5 ат.% Cu has a minimum average electron density and the alloy with 32,4 ат.% Cu – the maximum one. Nonmonotonic variation of the electronic density in the investigated alloys of system Ni-Cu, probably is due to the difference in the structural conditions caused by a bundle of alloys or by the formation of clusters, depending on the degree

of short-range order. It is expected that in such a system, the effect of electron irradiation of high-energy will have a radiation stimulating effect, the extent of which is probably determined by the clusternest and bundle of the structure of the material, which is of fundamental importance.

Methods of the experiment. To solve this problem a nickel of a 99,99 purity and a copper of a 99,999 purity were double-melted in argon-arc furnace into alloys containing *7,0; 9,0; 14,0; 21,0; 30, and 40,0 am.%* Cu. From cold-rolled alloys by spark machining the samples of 15 mm diameter and 1 mm thick were cut. After electrolytic polishing of the surface surface the samples were annealed in a vacuum $10^{-7} Topp$ for 1 hour in $T = 0,4 T_{ni}$. The study of the structure of alloys was made by measuring the angular distribution of annihilation photons (ADAP) on the spectrometer with a linear-slit geometry with an angular resolution of 0.5 mrad. Irradiation of samples was carried out by electrons with an energy of E=2,5 МэВ on the accelerator at a temperature no higher than 70ºC and beam current density - 1,5 мкА/см².

It should be noted that the method of electron-positron annihilation (EPA) is a highly sensitive means to various violations of the crystal structure [12]. Form of ADAP spectrum that was resulted from the annihilation of positrons with electrons of the material changes significantly in the case of localization of positrons in the crystal lattice near the defects, as well as the atomic environment of the defective areas. Slow positrons also react to changes in the order of the structure [13]. Therefore, positron probe is an ideal tool for the study of electron states of local microdomains of metallic materials.

As the source of the positron the isotope ^{22}Na with the activity of 10 microns is used. Measurement of ADAP spectrum allows to determine the relative contribution to the annihilation of positrons with electrons of the conductivity and the ion core. For this the intensity of the annihilation gamma radiation is experimentally measured, as the dependence of counting rate of pulses coincident in time 2-photon that were recorded by opposing detectors on the angle of the movable detector θ. ADAP spectrum measured for different states of the material were normalized to a single space. It is not difficult to establish that the spectrum for the defective material has a higher intensity at the maximum and a narrow width at half maximum (pic. 1).
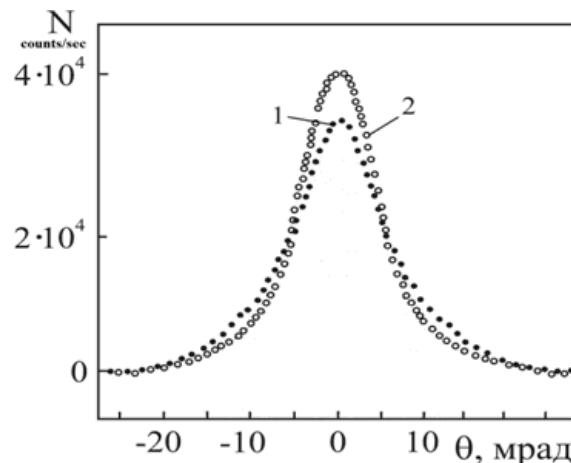

Figure 1 - The experimental spectra of the angular distributions of annihilation photons in alloys Cu-Ni: a - for the original; b- irradiated by electrons.

To interpret the results of studies the following structure-sensitive annihilation parameters were used: *F* - redistribution of positron annihilation probability between the conduction electrons and bound electrons and its corresponding increment Δ*F* relative to the values for the initial state that are recovered by processing the spectrum of the angular correlation of annihilation radiation [14].

The discussion of the results. In accordance with experimental ADAP spectra for annealed of Ni₁₋ₓ-Cuₓ the concentration dependence of the parameters F and ΔF were obtained out of their copper content in alloy, they presented on the picture 2 b, c. As can be seen, the annihilation parameters change depending on the composition correlates well

with the change of the Hall constant $R_{H1}(x)$, obtained from the data from [8-11].

Picture 3 shows the radiation - stimulated changes in the same parameters F_i and ΔF$_i$ for electron-irradiated materials. It can be seen that the annihilation parameters undergo complex change in the investigated concentration range of the second component of the alloy. If the dependence F_i has one maximum in the area of 10 ат.% Cu and a minimum in 30 ат.% Cu, then as the parameter ΔFi undergoes two maxima, so at 10 ат.% Cu and 30 ат. % Cu, and minimum at 21 ат. % Cu. The least impact the electron irradiation has on a clean Ni.

Moreover, the parameters F_i and ΔFi after irradiation did not change synchronously in concentration range 21 ат.% - 40 ат.%Cu. Probably, this process is associated with both the formation of radiation-induced defects and with radiation-stimulated reconfiguration of the boundaries of the clusters of

γ_1 γ_2 phases or clusters of short-range order. Obviously, the essence of the problem is in following.
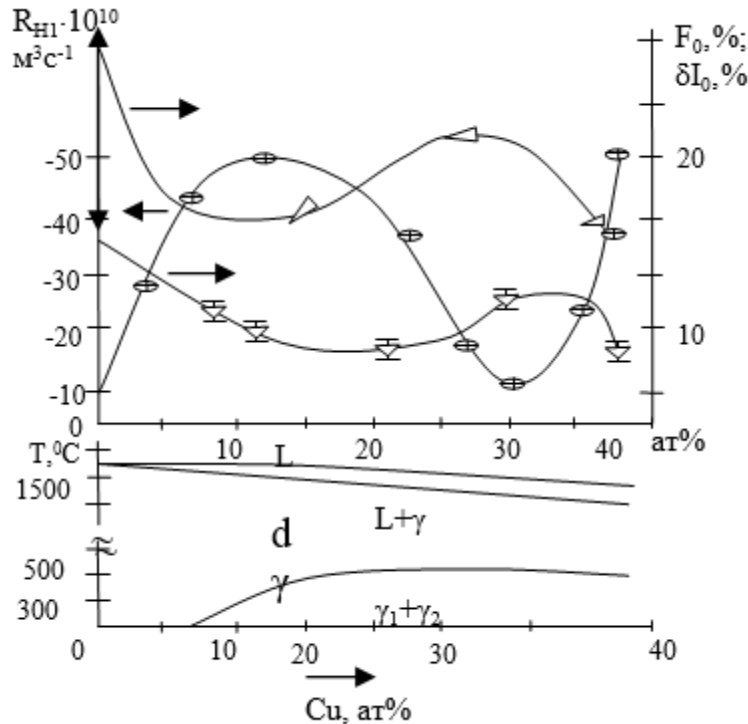

Figure 2 - Dependence of the Hall constant R_{H_1} **(a) and parameters of the ADAP spectrum of F (в) and ΔFi**

(c) alloys $Ni_{1-x}Cu_x$ **from the content of** Cu **. /** d **/ - part of the diagram on the condition of alloys** $Ni_{1-x}Cu_x$ **.**

The positrons while penetrating the metal material are slowed down to thermal velocities (thermalizes) and are captured by certain centers inside the crystal with subsequent annihilation of electrons in the vicinity of the trapping centers. The effective traps of the positrons are those microregions that create a local electric field gradients causing movement aimed to places of annihilation of positrons with electrons, and through that creating an excess charge. These field gradients occur in the vicinity of vacancies, dislocations, dislocation loops, stacking faults, borders of microclusters of short-range order [2].

In the case of microclusters of low-order the electric field gradient may be created by the excess atoms of one of the components of the alloy. The alloys of the Ni-Cu system the probability of

annihilation of positrons with electrons of the conductivity will be higher to that extent of how high is the excess of Cu atoms in the vicinity of the trap positrons. As these may serve the boundaries of clusters of short-range order, which may be formed as a result of exposure to low temperatures $\prec 400^0 C$ and also under electron irradiation of the alloy at ~ 70⁰C. The lifetime of the positron in pure copper is usually $\tau = 122 - 132$ ps. It is much less than the lifetime of the positron in Ni, which reaches 180 ps. Since the probability of annihilation of positrons with electrons of the conductivity $\sim \tau^{-1} \sim n$, then the average in terms of the electron density n will depend on the excess of any other component in the capture of positrons.
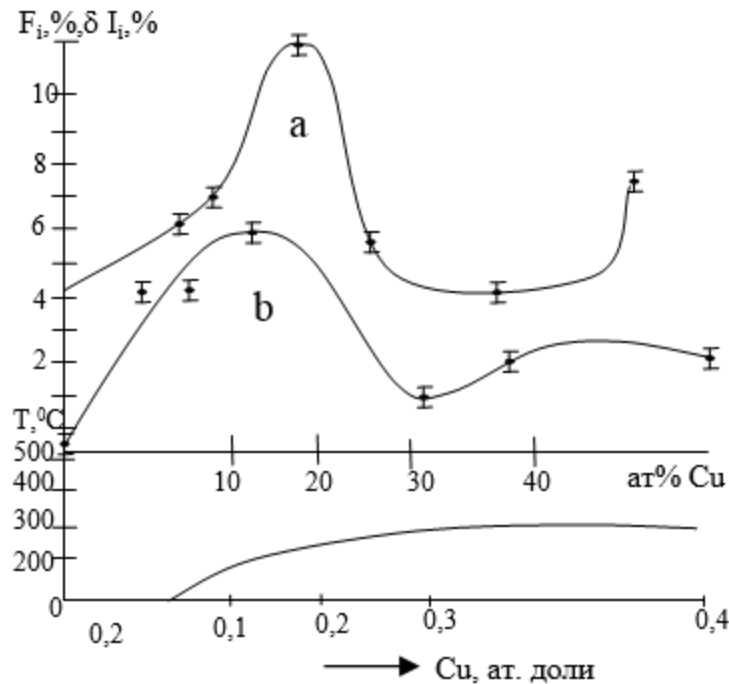
Figure 3 - Relative change of the parameters F_i (a) и ΔFi (в), caused by irradiation of the alloys $Ni_{1-x}Cu_x$, depending on the content of Cu . / c / - part of the diagram on the condition of alloys $Ni_{1-x}Cu_x$.

The position of minimum on curves $F_0(xCu)$ and $\Delta F_0(xCu)$ corresponds to the maximum in the change of the Hall constant $R_{H_1}(xCu)$(pic.2a). So, the results of this study confirm the data from [8-11]. Therefore, the electronic structure of these alloys is undergoes not monotone changes with the composition of the alloy. In this case, there is a reason to believe that the microstructure of these alloys is not identical in different areas of concentration. These data reflects the annealed alloy with a minimum of defects in the crystal structure that corresponds to the equilibrium concentration of vacancies. Then the assertion that the annihilation of positrons in this case occurs at the boundaries of the blocks-phase and clusters of short-range order is justified.

It is well known that the radiation impact changes the short-range order, as well as the configuration of segregation at grain boundaries, blocks and clusters [2]. The obtained experimental dependence and $Fi(xCu)$ и $\Delta F_i(xCu)$ for irradiated materials is due to the radiation-stimulatory redistribution of Ni and Cu in the short-range order cluster boundaries and γ_1 and γ_2 phases boundaries. Simultaneously, the influence of formed under the action of electron irradiation of point defects is not excluded, mainly vacancy, since interstitial atoms are going to the drains quick enough so, probably, they segregate at boundaries of clusters and γ_1 and γ_2

phases. The minimum value of the annihilation parameters after electron irradiation occurs in pure nickel. Subsequently, the parameters Fi and ΔF_i Fi synchronously increased to a concentration of 17,5at.% Cu, after which there is a decrease. Considering that the concentration of radiation vacancies (as positron trapping centers) in all irradiated alloys is about the same, then change of the parameters F_i and ΔF_i occurs due to a corresponding change in the number of centers of capture of positrons, or their efficiency, are determined not only by the changes of the composition of the configuration of the atoms in the local positron traps, but also the local concentration of free electrons in the vicinity of these traps.

Higher concentration of 21 ат.% Cu alloy in the annihilation parameters F_i and ΔF_i change asynchronously, which is probably due to the development of clusters of short-range order. In this configuration of the atoms in the short-range order cluster's boundaries is so that the local electronic states are changing. At the same time there is a change in the nature of the interaction of positrons with electrons in the vicinity of the traps. The increase of the parameter ΔF_0 while reducing Fi is associated with a change in the probability and the annihilation of positrons with electrons of the ionic core.

Thus, the radiation-induced segregation of atoms Ni and Cu in these alloys as well as the formation and development of clusters of short-range

order occurs due to the formation of an excessive amount of vacancies that were created as a result of electron irradiation, and by processes of radiation-stimulated diffusion in the alloy structure leading to a decrease in the energy of activation processes moving atoms.

References:

1. Diens GI (1958) The effects of radiation on materials. New – York. Chapman Hall. LTO. London. 1958.
2. Shalaev AM (1988) Radiacionno – stimulirovannye processy v metallah. – Moscow: Jenergoatomizdat. -1988. – 176 p.
3. Chyrko LL, Chyrko VJ, Chyrko EU, et al. (2000) J. Nucl. Mater. - 2000. -279, pp.162.
4. Konov JI, Astrahancev SM, Lifshic BG (1966) Fiz.met.i metallovedenie. – 1966.-26.-pp.66.
5. Danilenko BA, Krulikovskaja MP, Petrenko PV, et al. (1978) Ukrainskij fizicheskij zhurnal. -1978.-23.-pp.397.
6. Bystrov LN, Platov JM (1969) Dokl. AN SSSR. -1969.-185, №2. –pp.30.
7. Barabash OM, Koval' JN (1986) Struktura i svojstva metallov i splavov. Kristallicheskaja struktura metallov i splavov. – Kiev: Naukova dumka. -1986. 598 p.
8. Smith J (1955) Physica. -1955. -21. pp.877.
9. Allison FE, Pugh EM (1956) Phys. Rev. -1956. -120. –pp.1281.
10. Foner S (1956) Phys. Rev. -1956. -101. -pp.1648.
11. Dutta SK, Subarahnnagam AV (1969) Phys. Rev. -1969. -117. –pp.1133.
12. Dekhtyar IJ (1974) Pys. Let. C.-1974. –pp.243.
13. (1987) Amorfnye metallicheskie splavy. Pozitrony i jelektrony v amorfnyh splavah //Nemoshkalenko V.V., Romanova A.V., Il'inskij A.G. i dr. – Kiev: Naukova dumka. 1987. -248 p.
14. Mukashev KM (2011) Fizika medlennyh pozitronov i pozitronnaja spektroskopija. – Almaty. 2011. 508 p.