OPTICAL AND MAGNETOOPTICAL PROPERTIES OF $Ni_3Fe_{1-x}Ti_x$ ALLOYS

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The dispersion dependences of $\sigma(h\nu)$ optical conductivity and Kerr $\delta(h\nu)$ equatorial effect for $Ni_3Fe_{1-x}Ti_x$ are learnt. Under the measured optical and magnetooptical characteristics have evaluated values of nondiagonal ε' components of the dielectric constant tensor. The obtained theoretical results satisfactory are compounded with experiment.

Iron-nickel alloys doped with a transition group of metals characterized by high initial and maximal dielectric constants are widely used in industry. Increasing their quality is closely connected with the study of their electronic structure. For a solution of the problems, connected with electronic structure of ferromagnetic alloys the knowledge of the complete electronic spectra of the external energetic bands is necessary. This problem is successfully solved by using optical and magnetooptical methods. Optical methods are used for revealing additional ultrastructural gaps in the electronic spectrum under ordering as well as for the investigation of the influence of doping elements on different physical properties of alloys. The determination of the positions of energetic bands with differently oriented spins by this methods gives information for a evaluation of different physical characteristics of metals and metal alloys such as an exchange spin-orbital splitting, degree of electron polarization, etc.

By observation of the changes on the optical and magnetooptical spectra under doping and ordering, one can study the influence of doping on ordering and trace electronic structure changes under order-disorder transition [1-3].

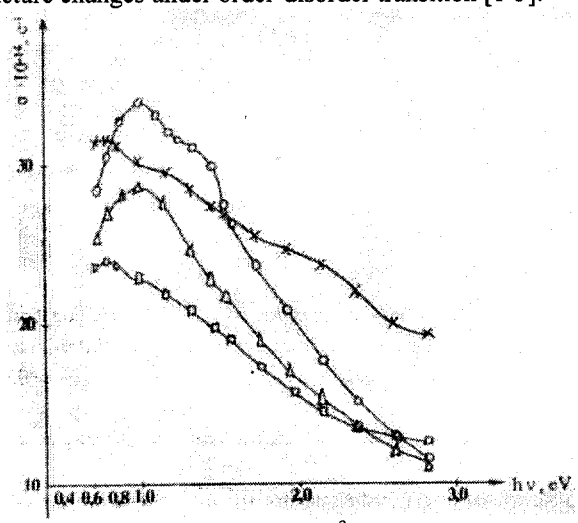

Fig.1 Optical conductivity $\sigma(h\nu)^2$ for $Ni_3Fe_{1-x}Ti_x$ alloys. o-Ni_3Fe, x-Ni_3Fe, Δ-$Ni_3Fe_{1-x}Ti_x$ (x=0,04), □- $Ni_3Fe_1.Ti_x$ (x=0,06)

The processes of ordering exert strong influence on magnetic state of alloys, and thus on magnetooptical properties. From this point of view Ni_3Fe alloy remains as ferromagnetic under order-disorder transition, but its magnetooptical spectrum exhibits strong anomalies [4-6].

In this paper results of the study of optical and magnetooptical properties in 0.7-3.0eV region for Ni_3Fe ordering alloy systems, doped by titanium are presented. Ni-Fe-Ti alloy was alloyed in vacuum high-frequency furnace. Purity of source alloy compounds was higher than 99.9 %. After the melting alloys were annealed in hydrogen furnace at 1100°C during 10 hours. The ingots obtained were forged and rolled up to 1.5mm thickness. From rolled material specimens of rectangular shape with 5x10 mm dimension were cut out which further were refined to 0.5-0.7 mm thickness and mechanically polished for obtaining a mirror surface. Specimens obtained were placed into quartz tubes (vacuum in the tube was ~10^{-4}Pa) and exposed to long time ordering annealing with slow cooling in accordance with regime offered elsewhere [6]. Non-ordered state of Ni_3Fe alloy was obtained under cooling tube in water at 1100°C.

For the measurements of the optical and magnetooptical characteristics and Kerr equatorial effect the universal automated plant, developed at "Physics of Metals and Alloys" Scientific Research Laboratory [7] on the basis of polarimetric Bytti-Cone method was used. An accuracy of our measurements was about 2-3%.

In fig.1 curves of optical conductivity $\sigma(h\nu)$ for ordered and non-ordered Ni_3Fe alloy and $Ni_3Fe_{1-x}Ti_x$ (where $0.01<x<0.08$) alloy systems are presented.

It is seen that total shape of frequency dependence $\sigma(h\nu)$ for non-ordered Ni_3Fe alloys doped with titanium (x<0.1) coincides with the shape of $\sigma(h\nu)$ for pure nickel [6]. Fine electronic structure manifests itself on the $\sigma(h\nu)$ curves; that is double anomaly at 0.7-0.9 eV and bending at 1.1-1.3eV is observed.

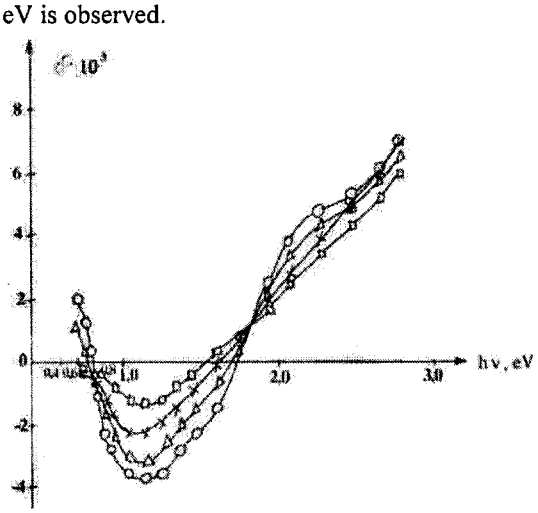

Fig.2. Kerr equatorial effect $\delta(h\nu)$ for $Ni_3Fe_{1-x}Ti_x$ alloys. o-Ni_3Fe, x - Ni_3Fe, Δ - x=0,04, □-x=0,06

It must be noted that total increasing occurs on the optical properties of alloys.

Ordering of Ni_3Fe alloys leads to change of characteristic

behaviour of the optical conductivity $\sigma(h\nu)$ curves. In near infrared region decreasing in $\sigma(h\nu)$ values is observed, which is accompanied by decreasing in energy in contrast to increasing of conductivity for non-ordered alloys. In 0.7-1.4eV energy region pronounced maximum in $\sigma(h\nu)$ is observed. Small additions of titanium leads to total increasing of $\sigma(h\nu)$. Further increase of titanium concentration results in decreasing $\sigma(h\nu)$ values as elsewhere [6].

Frequency dependences of Kerr equatorial effect (KEE) for $Ni_3Fe_{1-x}Ti_x$ alloys is shown in fig.2.

From the data of frequency dependence of the KEE and optical constants with using well-known formulas [8] we have evaluated values of non-diagonal ε'_1 and ε'_2 components of the dielectric constant tensor. $\varepsilon'_1(h\nu)^2$ and $\varepsilon'_2(h\nu)^2$ dependences for $Ni_3Fe_{1-x}Ti_x$ alloys are presented in fig.3(a, b). The obtained optical and magnetooptical spectra can be qualitatively understood on the basis of existing representations on electron structure changes of Ni_3Fe alloy under ordering. The main peculiarity in the behaviour of density of states $n(E)$ of Ni_3Fe ultra-structure is the appearance of the region with low values of $n(E)$ in Fermi level region [9]. Such a condition in density of states arises under the formation of ultra-structure at the expense of dividing of $d\downarrow$-bands on two groups and formation of the energy gap. The density of states far from the gap and in other spin sub-band, which as in the case of Ni is assumed fully to be fully filled, changes slightly. Carrying out the comparison of $\varepsilon'_2(h\nu)^2$ curves proportional to interband density of states [8] for NisFe in ordered and disordered states one can see that the main peculiarity of considered curves is sharply decreasing ε'_1 $\sigma(h\nu)$ value in 0.7-1.2 eV region under ordering. Assuming that in alloys main peculiarities of optical spectra can be explained on the basis of non-direct interband transition model [3, 10] one can to modelling the shape of occurred energetic gap in $\downarrow$ spin sub-band starting from the peculiarities of experimental cures in 0.7-1.5 eV region. Optical curve $\sigma(h\nu)$ is proportional to the sum of $\uparrow$ and $\downarrow$ sub-bands contributions and must have maximum at the energy equal to a distance between peaks in $n(E)$ $h\nu_{max}=E_{12}$ and magnetooptical curve $\varepsilon'_2(h\nu)^2$ is proportional to the difference of this contributions and must have maximum at $h\nu_{min}=E_{12}-2\Delta E$ and maximum at $h\nu_{max}=E_{12}$. From the Berglund-Spicer formula [11] intra-band density of states $N(h\nu)$ is estimated for each of spin sub-band which are in a good agreement with the shape of experimental $\varepsilon'_2(h\nu)^2$ and $\sigma(h\nu)^2$ curves. Thus one can say that experimental results on optical and magnetooptical properties of ordered and non-ordered $Ni_3Fe_{1-x}Ti_x$ alloys are in qualitative agreement with energetic structure in the Fermi level region.

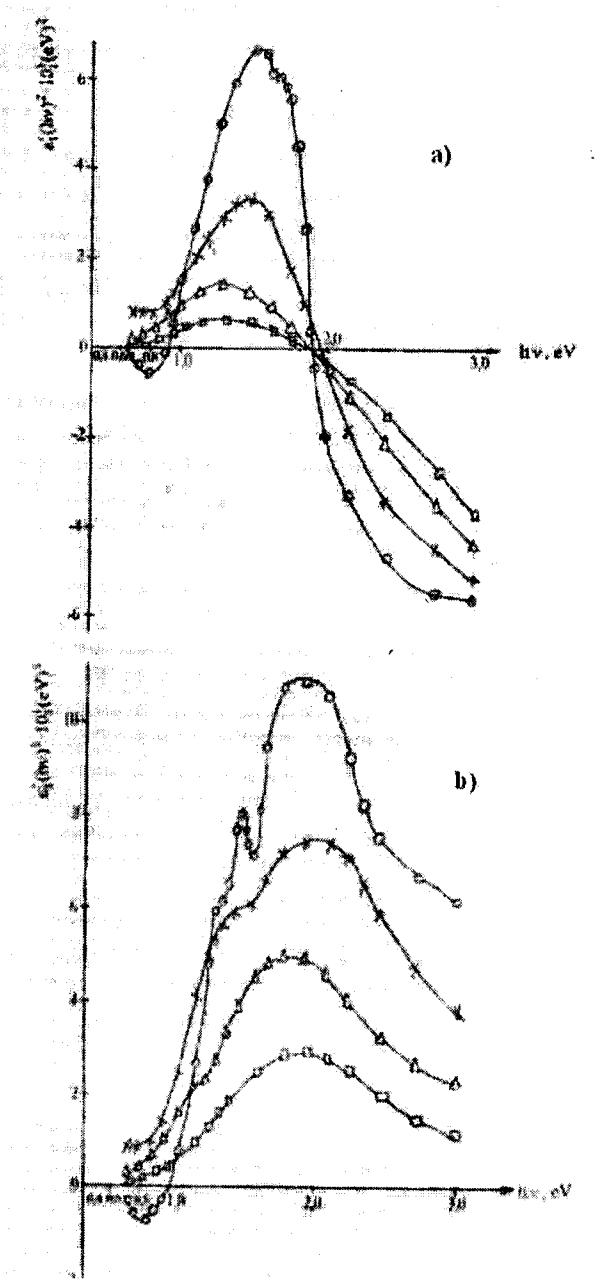

Fig.3 (a,b). Non-diagonal components of dielectric constant tensor $\varepsilon'_1(h\nu)^2$ and $\varepsilon'_2(h\nu)^2$ for $Ni_3Fe_{1-x}Ti_x$ alloys. o -Ni_3Fe, x - Ni_3Fe, Δ - x=0,04, □ - x=0,06

For complete quantitative estimation of the experimental data and the theory for the whole of spectra, detailed calculations of energetic structure of this alloys are needed.

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$Ni_3Fe_{1-x}Ti_x$ ƏRİNTİLƏRİN OPTİK VƏ MAGNİTOOPTİK XASSƏLƏRİ

$Ni_3Fe_{1-x}Ti_x$ ərintiləri üçün optik keçiricinin və ekvatorial Kerr effektinin dispersiya asılılıqları öyrənilmişdir. Ölçülmüş optik və maqnitooptik xarakteristikalarına görə dielektrik nüfuzluğu tenzorunun qeyri-diaqonal komponentlərin qiymətləri hesablanmışdır. Alınan təcrübi nəticələrin mövcud nəzəriyyə ilə uyğunluğu qənaətbəxşdir.

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ОПТИЧЕСКИЕ И МАГНИТООПТИЧЕСКИЕ СВОЙСТВА СПЛАВОВ $Ni_3Fe_{1-x}Ti_x$

Изучены дисперсионные зависимости оптической проводимости $\sigma(h\nu)$ и экваториального эффекта Керра $\delta(h\nu)$ для сплавов $Ni_3Fe_{1-x}Ti_x$. По измеренным оптическим и магнитооптическим характеристикам рассчитаны значения недиагональных компонент тензора диэлектрической проницаемости ε'. Полученные теоретические результаты удовлетворительно согласуются с экспериментом.

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