NGR AND THE MAGNETIC SUSCEPTIBILITY OF THE LAYERED CRYSTALS $Bi_{m+1}B_mO_{3m+3}$ (B=Ti, Fe)

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In the given paper the discussion of the results of magnetic and mossbauer investigations of the compounds $Bi_{m+1}B_mO_{3m+3}$(B=Ti, Fe) revealing in the result of the specific of crystal structure, properties, which are character for the thin magnetic films has been carried out. It was shown, that the influence of the concentration of the magnetic iron ions on the magnetic transition temperature in these compounds significantly differs from the similar influence in the three-dimensional magnetic substance.

The structure of the compound with the general formulae $B_{m+1}B_mO_{3m+3}$ (where m is number of monooctahedronic layers in the perovskite-like packet) is build by the following principle: in the direction [001] the perovskite-like layers (packets) $[Bi_{m-1}B_mO_{3m+1}]^{2-}$take turns with the bismuthooxigen layers $[Bi_2O_2]^{2+}$ (fig.1) [1]. The thickness of the perovskite-like layers is defined by the m value, including in the formulae: these layers have oxygen octahedrons, connected by their vertexes. Inside the oxygen octahedrons are B cations, where B-Ti, F. Because of the octahedron positions are as the magnetic ions of iron, so and the diamagnetic ions of Ti, so these compounds can be considered as the magnetodiluted systems. The magnetic properties of such systems, particularly, the temperature of the transition in the magnetoordered state, depend on the concentration of the magnetic ions.

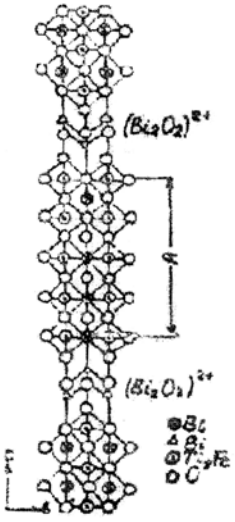

Fig.1. The cell projection of compound $Bi_{m+1}B_mC_{3m+3}$ with the layered structure (m=5) on (001).

In the refs [3-5] it is shown, that compounds $B_{m+1}B_mO_{3m+3}$ reveal the properties, which are characteristic for the thin magnetic films. The revealing of the properties, which are characteristic for the thin magnetic films, by the given crystals is caused by the following reason. In these compounds the magnetic ions of iron, situated in the one packet, are divided from the iron ions, being in the neighbour perovskite-like packets, by the layer, consisting on the diamagnetic ions Bi^{3+} and O^{2-}. That's why the magnetic properties of the investigated crystals will be defined by the interaction of the iron ions only inside the packet, i.e. each packet can be considered as the thin magnetic film. The thickness of such film will be defined by the number of the ionooctahedron layers in the one packet, i.e. by m. It is known, that the magnetic properties of the thin magnetic films are strongly differ from the thickness of the films. Firstly, the dependence of the spontaneous magnetization with Curie point (Neel), values of the internal magnetic field on the nucleus from film thickness and the revealing of its supermagnetic behaviour in the wide temperature region can be considered in these properties. All these peculiarities of the investigated crystals were revealed in the refs [3-5]. The big interest is the following question. If the compounds $B_{m+1}B_mO_{3m+3}$, in the respect of the magnetic properties, behave themselves as the magnetic films, so the influence of magnetic ion concentration on the magnetic properties (particularly on the magnetic transition temperature) will depend on the film thickness and differ from the similar influence for the massive three-dimensional magnetic substance. And with this point of view in the given paper the discussion of the results of mossbauer and magnetic investigations is carried out.

The values of concentration © of iron magnetic ions in the octahedron positions, leading to the appearing of the magnetic order, investigated compounds are defined by method [2] and given in the table1.

Table1

Compound	*C*	*M*
$Bi_6Ti_8Fe_2O_{18}$	0,4	5
$B_6Ti_2Nb_{0,5}Fe_{2,5}O_{18}$	0,5	5
$Bi_7Ti_3Fe_3O_{21}$	0,6	6
$Bi_2Ti_3Fe_5O_{27}$	0,62	8

The mossbauer measurements were carried out in the temperature interval 5-300K, but magnetic measurements - 77-950K. In the compounds $Bi_6Ti_8Fe_2O_{18}$ and $B_6Ti_2Nb_{0,5}Fe_{2,5}O_{18}$ the number of the octahedron layers in the perovskito-like packet are equal, i.e. the thicknesses of the films are equal. However, the magnetic ion concentrations in the octahedron states of these compounds are different: $Bi_6Ti_3Fe_2O_{18}$ c=0,4, and in $Bi_6Ti_2Nb_{2,5}O_{18}$ c=0,5. From the mossbauer investigations of these compounds it follows, that magnetic transition temperature in $Bi_6Ti_2Fe_3O_{18}$ is between 20-30, but in $Bi_6Ti_2Nb_{0,5}Fe_{2,5}O_{18}$ is between 150-170K. Under the magnetic transition temperature is meant the temperature, lower of which in the spectrum begin to appear the lines of the magnetic fission. It is seen, that the change of

the magnetic ion concentration in the octahedron positions on 0,1 leads to the change of the transition temperature on 130-140°C.

In the compound $Bi_9Ti_3Fe_5O_{27}$ the number of the monooctahedron layers in the perovskito-like packet is equal to 8. The iron magnetic ion concentration in the octahedron positions is equal to 0,62. The lines of the superthin magnetic structure in the mossbauer spectrums of this compound disappear between 260 and 280K, i.e. the magnetic transition temperature is in this region.

The lines of the magnetic fission in the mossbauer spectrums of $Bi_7Ti_3Fe_3O_{21}$ compound, in which the number of the monooctahedron layers and magnetic ion concentration in the octahedron positions are equal to 6 and 0,5 accordingly, and disappear between 200 and 220K. The temperature difference of the magnetic transition, defined from the mossbauer measurements in the compounds $Bi_9Ti_3Fe_5O_{27}$ and $Bi_7Ti_3Fe_3O_{21}$ is ~60°C. The more high value of the magnetic transition temperature in $Bi_9Ti_3Fe_5O_{27}$ with the comparison of the transition temperature in $Bi_7Ti_3Fe_3O_{21}$ is caused by two reasons. The first reason is the number of layers (thickness on the film) in is $Bi_9Ti_3Fe_5O_{27}$ more, than in $Bi_9Ti_3Fe_5O_{27}$ is also more, than in $Bi_7Ti_3Fe_3O_{21}$. It is followed, that it can be proposed that in these compounds the temperature difference, caused by the only increase of the concentration of magnetic ions, will be less than 60°.

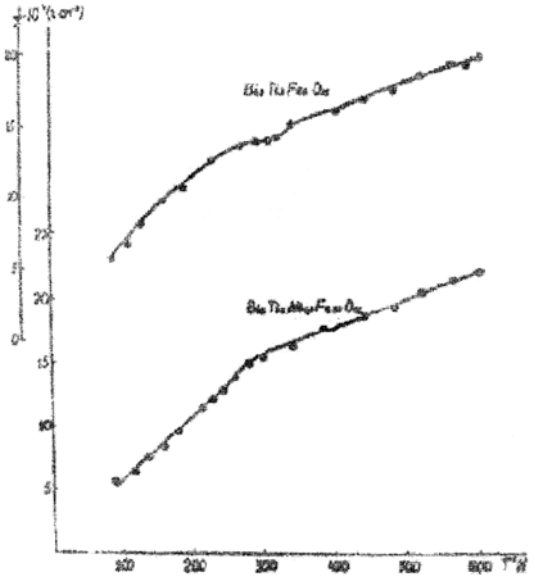

Fig.2. The temperature dependences of the reversible specific magnetic susceptibility of compounds $Bi_7Ti_3Fe_3O_{21}$ and $Bi_6Ti_2Nb_{0,5}Fe_{2,5}O_{18}$.

Later let's consider the results of the magnetic measurements. On the figures 2 and 3 the temperature dependencies of the inverse specific magnetic susceptibility are given. For all compounds at the high temperatures the Weiss-Curie law $\chi = \frac{C}{T + \theta}$ is carried out. The effective magnetic moment, on the each iron ion, defined from these curves, well agrees with the theoretical value 5,92μ for the trivalent iron. About the trivalent state of the iron ions the values of the isomer shifts, defined from the mossbauer spectrums of the investigated compounds at the room temperature is also evidence.

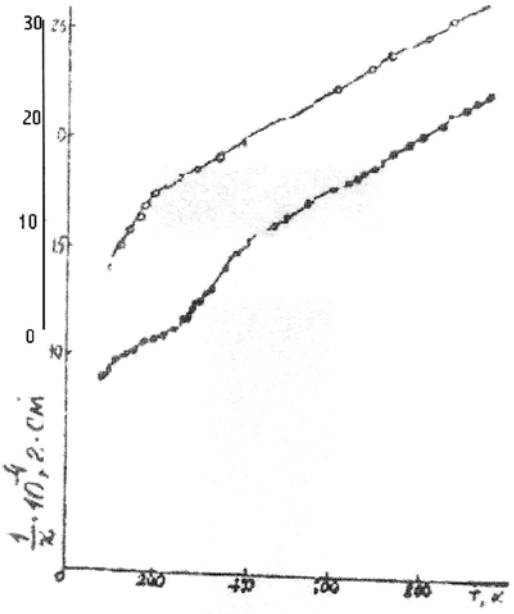

Fig.3. The temperature dependences of the reversible specific magnetic susceptibility of compounds $Bi_6Ti_3Fe_2O_{18}$ and $Bi_9Ti_3Fe_5O_{21}$ (low curve).

The negative values of the paramagnetic Curie O temperatures, given in the table 2, show on the antiferromagnetic interactions between iron ions in the compounds $Bi_{m+1}B_mO_{3m+3}$ in the magnetoordered phase.

Table2.

Compound	m	θ,K	$T_{Nmag.}$	$T_{Nmoss.}$
$Bi_6Ti_3Fe_2O_{18}$	5	-390	120	20-30
$B_6Ti_2Nb_{0,5}Fe_{2,5}O_{18}$	5	-550	260	150-170
$Bi_7Ti_3Fe_3O_{21}$	6	-560	330	200-220
$Bi_9Ti_3Fe_5O_{27}$	8	-780	400	260-280

At the decrease of the temperature, the change of inclination of the curve of temperature dependence of the inverse magnetic susceptibility takes place. The temperatures, at which the change of inclination of curve $\chi(T)$ takes place, for the different compounds are different. They are given in the table2 ($T_{N\,mag}$).

As it is seen from the figures 2 and 3, the behaviour of the magnetic susceptibility of the compounds $Bi_{m+1}B_mO_{3m+3}$ lower, than T_N, differs from the behaviour of the massive three-dimensional samples lower the temperature of antiferromagnetic order. In the difference from the massive three-dimensional samples, the increase of the magnetic susceptibility value of the compounds $Bi_{m+1}B_mO_{3m+3}$ is lower than the temperature of antiferromagnetic order can be explained, if these compounds are lower than T_N, defined from the magnetic measurements, transfer in the supermagnetic state, i.e. the state with the antiferromagnetic order with spin fluctuation.

Firstly, the theoretical propositions of the essential increase of the magnetic susceptibility of antiferromagnetic substance, being in the supermagnetic state, were given by Neel (see example 6). These propositions were proved in the refs [7,8].

It is noted, that lines of the magnetic fission, showing on the magnetic order, in the mossbauer spectrums of the compounds $Bi_{m+1}B_mO_{3m+3}$ appear at the more low

temperatures (these temperatures are also given in the table2), than T_N, defined from the magnetic measurements, are the transition temperatures of the compounds $Bi_{m+1}B_mO_{3m+3}$ in the superparamagnetic state. Indeed, vice versa, if Tn, defined from the magnetic measurements, would be the transition temperatures in the stable (without spin fluctuation) antiferromagnetic state, so the lines of the magnetic fission in the mossbauer spectrums should be appear , lower than Tn at once.

The absence of the lines of the magnetic fission in the spectrums in the temperature region from mag. till mes. connects with that in this temperature region the fluctuation frequency of spins (ω_{ii}) is more, than the frequency of Larmor precession (ω_i) [9]. At the decrease of the temperature, as ω_{ii} becomes the ω_i degree, so in the spectrum began to appear the lines of magnetic fission.

Now we carry out the comparison of the results of mossbauer and magnetic measurements for two couples of compounds. The first couple $Bi_6Ti_3Fe_2O_{18}$ and $Bi_6Ti_2Nb_{2,5}O_{18}$, in which the magnetic ion concentrations differ on 0,1. The second couple are compounds $Bi_9Ti_3Fe_{0,5}O_{27}$ and $Bi_7Ti_3Fe_3O_{27}$. The concentrations of iron ions in these compounds differ on 0,125, i.e. not the more, than for the first couple of compounds.

From mossbauer investigations of first couple of compounds it follows, that temperature difference of the magnetic transition is 130-140°C. Such difference of the transition from the paramagnetic state in the supermagnetic state takes place for this couple from the magnetic measurements. For the second couple of compounds the considering differences are ~60-70°C.

It is noted, that dependence of magnetic transition temperature in the massive three-dimensional magnetodiluted systems on the magnetic ion concentrations were studied in refs [10, 11].

Thus, from the obtained results we can do the conclusion, that in the compounds with the less number of monooctahedron layers in the perovskito-like packet (in more thin film), the change of the magnetic transition temperature, than in the compounds with big number of the monooctahedron layers in the perovskito-like packet (in more thick film).

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$Bi_{m+1}B_mO_{3m+3}$ (B=Ti, Fe) LAYLI KRİSTALLARDA NQR VƏ MAQNİT QAVRAYICILIĞI

Bu işdə laylı quruluşa malik $Bi_{m+1}B_mO_{3m+3}$ (B=Ti, Fe) birləşmələrinin maqnit və messbauer tədqiqatlarının nəticələri müzakirə edilmişdir. Müəyyən edilmişdir ki, dəmir ionlarının konsentrasiyasının maqnit keçidi temperaturuna təsiri, üçolçülü maqnetiklərdəkindən kəskin fərqlənir.

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ЯГР И МАГНИТНАЯ ВОСПРИИМЧИВОСТЬ СЛОИСТЫХ КРИСТАЛЛОВ $Bi_{m+1}B_mO_{3m+3}$ (B=Ti, Fe)

В настоящей работе проведено обсуждение результатов магнитных и мессбауровских исследований соединений $Bi_{m+1}B_mO_{3m+3}$ (B=Ti, Fe), прявляющих вследствии специфичности кристаллической структуры свойства, характерные для тонких магнитных пленок. Показано, что влияние концентрации магнитных ионов железа на температуру магнитного перехода в этих соединениях существенно отличается от подобного влияния в трехмерных магнетиках.

Received: 20.04.04