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The Influence of Annealing Time of a Ferromagnetic on the Value of Effective Mangetic Field B(Hf)

Wpływ czasu wygrzewania ferromagnetyka na wartość efektywnego pola magnetycznego $B(Hf)_{Fe}$

Влияние времени отжига ферромагнетика на величину эффективного магнитного поля $B(Hf)_{Fe}$

The series of papers published in the least years [1,2] indicate that the values of effective magnetic fields acting on the nuclei impurity atoms implanted into ferromagnetic targets depends on the of implantation as well as target processing. The factors which may influence on the measured values of magnetic fields, are:

1) the concentration and the location of impurity atoms in the cristal lattice,

2) the radiation damages, and

3) the migration of impurity atoms in the annealing process.

In the paper [3] the authors suggest the possibility of internal oxidation of impurities by oxygen led into the deep layers of the sample in the implantation process.

It is the purpose of this paper to investigate the influence of annealing time of a ferromagnetic on the value of effective magnetic field.

The integral perturbed angular correlation (IPAC) method has been used to study this problem.

EXPERIMENTAL

In the investigations described the ^{177}Lu isotope, decaying to excited states of ^{177}Hf, $T_{1/2}$=6,2 days, has been applied.

The radioactive isotope ^{177}Lu in the form of liquid lutetium chloride in water solution was obtained as a result of chemical treatment of lutetium oxide enriched in ^{176}Lu of irradiated in nuclear reactor INR in Świerk. Subsequently, using the electrolitical method, the lutetium was carried on a thin rhenium ribbon and put to a thermoemission ion source of a mass-separator of the Department of Nuclear Physics, Institute of Physics, UMCS. The ^{177}Lu ions were accelerated to 50 keV and implanted in 0,0012 cm thick ferromagnetic foils (99,85 % Fe). Before the implantation, the ferromagnetic foils were put into an acetone bath and after that in distilled water to remove the protective coats of acrylic resin and $NaNO_2$.

The radioactive source prepared in this form was placed in homogeneous magnetic field produced by an electromagnet. The electromagnet is fixed in a special centre system which permits it to move in two mutually perpendicular directions in the plane of two NaJ(Tl) detectors. In order to minimize the effect of the magnetic field on the amplification of the photomultipliers, both scientillators are shielded by two iron tubes and one permalloy tube. In the front, the scintillators led collimatic shields to prevent registration of scattered gamma rays.

The coincidence system used in this experiment is a fast-slow type, the resolving time of which was 32 us. The coincidence gamma spectra for the selected positions of the movable gamma detector and the two opposite directions of the magnetic field are registred in the memory of a 1024-channel analyser type NTA-512B. The measurement was completely automatized by using an automatic unit and the timer of the multichanuel analyser.

RESULTS AND DISCUSSION

The measurements of effective magnetic fields acting on the nuclei ^{177}Hf in policristalic Fe for the annealing probes were carried out on the cascade 113 keV-208 keV.

The mean lifetimes (τ) of the level 113 keV, is $(0.736\pm0{,}014)$ ns [4,5]. The fragment of levels scheme of ^{177}Hf is presented in Fig. 1.

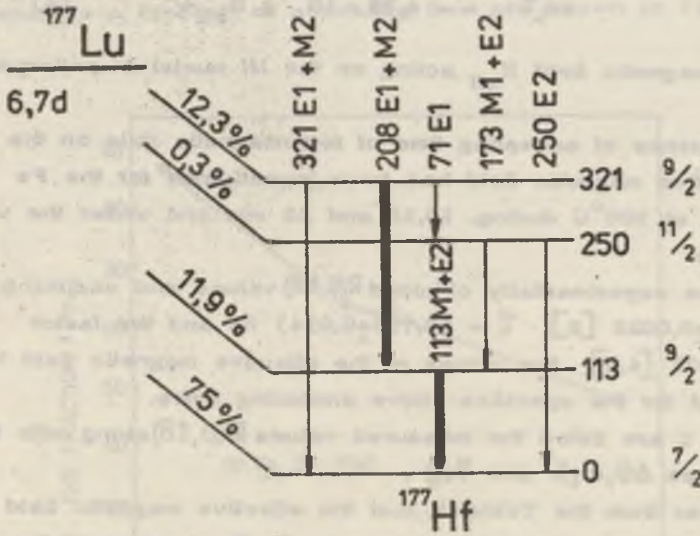

Fig. 1. The fragment of levels scheme of ^{177}Hf

The IPAC method to determine the parameter

$$R(\Theta, \pm B) = 2\,\frac{N(\Theta,+B)-N(\Theta,-B)}{N(\Theta,+B)+N(\Theta,-B)}\,, \qquad (1)$$

where $N(\Theta \pm B)$ is a number of coincidence counts at the selected angle Θ and direction of external magnetic field B, has been used. The coincidence spectra were collected for two angles between the scintillators (135° and 225°) and two opposite directions of the external magnetic field polarizing the probe.

Assuming that $A_4 = 0$, the parameter $R(\Theta, \pm B)$ can be expressed in the following form

$$R(\Theta, \pm B) = \frac{3A_2}{4+A_2}\,\sin 4\,\Delta\Theta\,, \qquad (2)$$

where

$$\Delta\Theta = \frac{1}{2}\,\mathrm{arc\,tg}\,(2\omega_L \tau). \qquad (3)$$

The above expressions (2,3) permit to obtain the precession frequence ω_L, and subseqently from the formula

$$\omega_L\tau = - 4{,}79 \cdot 10^3 \; g \; B_{eff}\tau \qquad (4)$$

the effective magnetic field B_{eff} acting on the Hf nuclei in policrystalic Fe.

The influence of annealing time of ferromagnetic foils on the value of effective magnetic field has been investigated for the Fe foils annealed at 300°C during. 10,15 and 25 min and under the vacuum of 2.10^{-5} Torr.

Using the experimentally obtained $R(\theta,\pm B)$ values and assuming $A_2 = -0{,}1311 \pm 0{,}0025$ [6], $\tau = (0{,}736 \pm 0{,}014)$ ns and the factor $q = 0{,}232 \pm 0{,}002$ [4,5] the values of the effective magnetic field has been estimated for the specifics above annealing times.

In table 1 are listed the measured values $R(\theta,\pm B)$ along with the estimated values $\Delta\theta, \omega_L\tau$ and B_{eff}.

It is clear from the Table 1, that the effective magnetic field acting on the impurity nuclei is weakened with the increas of the annealing time. This effect can be partially explained by the implantation model [7], the basic assumption of which is that the implanted. atoms occupy two different positions: (1) so called substitutional sites, where the nuclei feel the full internal magnetic field, and (2) unsubstitutional sites, where the nuclei do not feel any magnetic interaction at all.

In terms of this model, the measured function $\overline{W(\theta,B)}$ is a superposition of perturbed function $W(\theta,B)$ and unperturbed function $W(\theta)$, so it can be expressed by the following formula:

$$\overline{W(\theta,B)} = fW(\theta,B) + (1-f)\; W(\theta), \qquad (5)$$

where f is a fraction of the number of the nuclei feeling the full internal magnetic field.

The fraction f can be calculated using the following expressions

$$(\omega_L\tau)_{obs} = \frac{f\omega_L\tau}{1+(1-f)(2\omega_L\tau)^2} \qquad (6)$$

and

$$\frac{\bar{b}_2}{b_2} = (1-f)^2 + \frac{f\;(2-f)}{1+(2\omega_L\tau)^2} \qquad (7)$$

where $\omega_L \tau$ is precession angle of the nuclei feeling the full internal magnetic field while $\left(\frac{\bar{G}_2}{G_2}\right)$ is the ratio of the observed to the unperturbed angular correlation coefficients. The calculated values of this parameter as a function of annealing time are shown in Fig. 2.

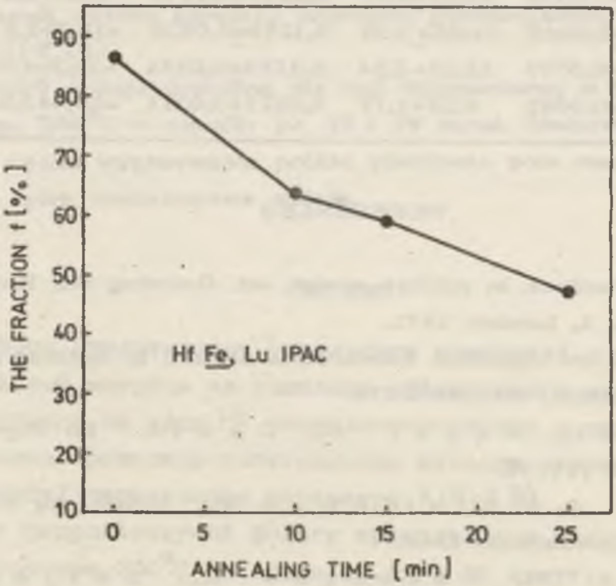

Fig. 2. The dependence of the fraction f out the number of nuclei vs annealing time of the sample at 300°C.

The observed decrease of the effective magnetic field with increase of the annealing time can be partially explained by surface oxidation of the foil during annealing. The mean range of the impurity atoms implanted, the initial energy of which was 70 keV, is 150 Å. As a result of the annealing process, the depth of the surface oxide layer can reach as much as 40 Å, which reduces the nuclei number feeling the internal magnetic field.

Table 1. The results of the measurements of B_{eff} as a function of annealing time

Annealing time of the foil [min]	$R(\theta, \pm B)$	$\overline{2\Delta\theta^{\circ}}$	$\overline{\omega_L \tau}$	B_{eff} [Ts]
0	0,0785±0,0078	25,26±2,55	0,2359±0,0445	-28,8±5,5
10	0,0495±0,0045	14,56±1,35	0,1299±0,0236	-15,9±2,9
15	0,0451±0,0073	13,16±2,14	0,1169±0,0374	-14,3±4,6
25	0,0325±0,0062	9,32±1,79	0,0821±0,0311	-10,0±3,8

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STRESZCZENIE

W pracy przedstawiono wyniki badań wpływu czasu wygrzewania ferromagnetyka na wartość efektywnego pola magnetycznego działającego na jądra Hf implantowane do folii Fe. W badaniach zastosowano całkową metodę korelacji kątowych gamma-gamma, wyznaczając parametr $R(\Theta,\pm B)$.

Pomiary przeprowadzono dla folii wygrzewanej w próżni 2.10^{-5}mm Hg w temp. 300^{o}C w czasie: 10, 15 i 25 minut. Stwierdzono, że ze wzrostem czasu wygrzewania próbki efektywne pole magnetyczne działające na jądra domieszkowe maleje.

РЕЗЮМЕ

В работе представлены результаты измерений влияния отжига ферромагнитной матрицы на значение эффективного магнитного поля действующего на ядра Hf заимплантированные в железную фольгу. Измерения проведены интегральным методом угловых гамма-гамма корреляций определения параметра $R(\Theta,\pm B)$.

Отжиг ферромагнитной фольги проводился в вакууме 2.10^{-5}мм Hg в температуре 300^{o}C во время 10,15 и 25 минут.

Определено, что эффективное магнитное поле уменьшается при возрастании времени отжига матрицы.

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