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Effective renormalization of g - factors anisotropic ferromagnetic narrow-band f –d -metal

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Conducting anisotropic narrow-band ferromagnetic connections on the basis of f - d - elements attract enhanceable interest, as systems tightly-coupled between electronic, magnon and latticed by subsystems [1-3]. Magnetic resonance is the effective instrument of research of their power spectrum, however the mechanisms of forming of g - factors of magnetic moments in such substances are studied not enough. Methods of theoretical researches of the resonant phenomena, developed for ferromagnetics described within the framework of charts with Heisenberg intersite by an exchange, as in dielectric [4], so in wide-band conducting systems [5], inapplicable for direct description of the connections examined here. In the real work we investigated the spectrums of magnetic excitations in a narrow-band ferromagnetic explorer containing local (f) and quasilocal (d) magnetic moments [6]. These spectrums are formed by the spin correlations generated jointly by interatomic co-operations of d electrons (by an exchange with the electrons of shells and Hubbard pushing away), and them intersite hops, taking into account the spatial chaotization of g - factors d - and f - subsystems [6].
Keywords: magnon; Green function; narrow-band ferromagnetics; g - factors.

Исследованы спектры магнитных возбуждений в узкозонном ферромагнитном проводнике, содержащем локальные (f) и квазилокальные (d) магнитные моменты [6]. Эти спектры формируются спиновыми корреляциями, порождаемыми совместно внутриатомными взаимодействиями d электронов (обменом с электронами f оболочек и хаббардовским отталкиванием), и их межузельными перескоками, с учетом пространственной хаотизации g-факторов d- и f- подсистем [6] и анизотропии параметров «внутриатомного» обмена между локальными и квазилокальными электронами. Полученные выражения для эффективных g-факторов взаимодействующих f - и d – магнитных подсистем в узкозонном ферромагнетике содержат как изотропные поправки к g-факторам невзаимодействующих f - и d - подсистем, так и поправки, зависящие от отношения x,y - и z - компонент тензора локальных обменных параметров, причем знак поправок для f - и d – подсистем различен.
Ключевые слова: магнон; функция Грина; узкозонные ферромагнетики; g-фактор.

Досліджені спектри магнітних збуджень у вузькозонному феромагнітному провіднику, що містить локальні (f) і квазілокальні (d) магнітні моменти [6]. Ці спектри формуються спіновими кореляціями, що породжуються спільно внутрішньоатомними взаємодіями d електронів (обміном з електронами f оболонок і хаббардовским відштовхуванням), і їх міжвузельними перескоками, з урахуванням просторової хаотизації g -факторів d - і f - підсистем [6] і анізотропії параметрів «внутрішньоатомного» обміну між локальними і квазілокальними електронами. Отримані вирази для ефективних g -факторів взаємодіючих f - і d - магнітних підсистем у вузькозонному феромагнетику містять як ізотропні поправки до g -факторів невзаємодіючих f - і d - підсистем, так і поправки, залежні від відношення x, y - і z - компонент тензора локальних обмінних параметрів, причому знак поправок для f - і d - підсистем різний.
Ключові слова: магнон; функція Гріна; вузькозонний феромагнетик; g-фактор.

Model and method

The charts of electronic power spectrum (Fig. 1) and spectrum of elementary excitations (Fig. 2) of the investigated system used in-process are analogical to used in [6].

Electronic descriptions of the investigational system were analogical to considered in [6], except for the parameters of "interatomic" exchange between local and quasilocal electrons, which in this case was anisotropic, -

$$H_{ex} = -2\left[J_{\perp}\left(S^X s^X + S^Y s^Y \right) + J S^Z s^Z \right].$$

Here S and s are backs local *f* - shells and quasilocal *d* -электрона, accordingly, S>>1; $J_{\perp}$ and J is interatomic exchange constants, $0< J_{\perp} \leq J$.

Model Hamiltonian

Hamiltonian of the system in the external magnetic field of H, directed along the co-ordinate axis of Z, looks like

$$H = H_e + H_m ,$$

where

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$$H_e = -\frac{W}{2z}\sum_{\lambda,\eta,\sigma} c^{+}_{\lambda+\eta,\sigma} c_{\lambda,\sigma} + \frac{U}{2}\sum_{\lambda,\sigma}\hat{n}_{\lambda,\sigma}\hat{n}_{\lambda,-\sigma} - 2\sum_{\substack{\alpha,\beta\\ \lambda,\sigma,\sigma'}} J^{\alpha,\beta}\left(S^{\alpha}_{\lambda} s^{\beta}\right)_{\sigma,\sigma'} c^{+}_{\lambda,\sigma} c_{\lambda,\sigma'}$$

- electronic Hamiltonian in presentation of numbers of filling, qualificatory energies of both one-particle and collective states, in particular is a magnon spectrum [6]. Element

$$H_m = -\mu_B \mathrm{H} \cdot \sum_{\lambda}\left(g_f S^z_{\lambda} + g_d s^z_{\lambda}\right)$$

describes co-operating of spin subsystem with the external magnetic field of H; $c^{+}_{\lambda,\sigma}$, $c_{\lambda,\sigma}$ are electronic Fermi operators; λ is a sites of grate, μ_B is the Bohr magneton; $n_{\lambda,\sigma} = c^{+}_{\lambda,\sigma} c_{\lambda,\sigma}$ are electronic numbers of filling; σ is the spin index (the values of this index are represented by the symbols ↑(↓) or +(–)); $s^z_{\lambda} = \frac{1}{2}\left(c^{+}_{\lambda\uparrow}c_{\lambda\uparrow} - c^{+}_{\lambda\downarrow}c_{\lambda\downarrow}\right)$ are operators of electronic spins; *J* is an interatomic (*d* - *f* -) exchange integral, *U* is the Hubbard interaction constant; *W* is a width of electronic zone; g_d (g_f) - is the crystal averaged value of the *g* factor for the *d* and *f* electrons; inequalities of *W*<<4*zJS* are used, *U/2JS*<<1, 0<*W*≤2*zJ*, *U*>*J*, where z is a co-ordinating number of crystalline grate.

There is a calculation of magnon spectrum in the region of small values of the magnon quasimomenta.

The site magnetic moment of the crystal looks like

$$\mathbf{M}_{\lambda} = \mu_B\left(g_{f\lambda}\mathbf{S}_{\lambda} + g_{d\lambda}\mathbf{s}_{\lambda}\right);$$

his transversal components in circular coordinates are equal

$$\mathrm{M}^{\pm}_{\lambda} = \mathrm{M}^{x}_{\lambda} \pm i\mathrm{M}^{y}_{\lambda}.$$

Transversal dynamic magnetic susceptibility of the system

$$\chi^{+-}\left(\mathbf{Q},\mathbf{Q}',\gamma\right) = \frac{1}{N}\sum_{\lambda,\lambda'}\left\langle \chi^{+-}_{\lambda,\lambda'}\left(\tilde{\gamma}\right)\right\rangle_{c} \cdot e^{-i(\mathbf{Q}\lambda+\mathbf{Q}'\lambda')}$$

can be expressed through Fourier transforms of twotemporal late temperature of the Green's function

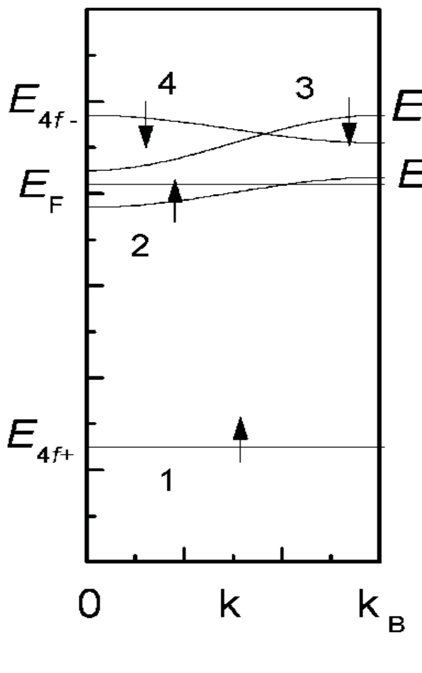

Fig. 1. Scheme of the electron energy spectrum of the model: 1 – partially filled magnetically active 4 *f* level (E_{4f+}), 2 – partially filled 5*d* band, 3 – band of unfilled 5*d* states, 4 – band of unfilled 4 *f* states, E_F – the Fermi energy, E_{d+} , E_{d-} , and E_{4f-} – maximum energies in the corresponding bands, k_B is the Brillouin quasimomentum; the arrows represent the spin indices of the electron states.

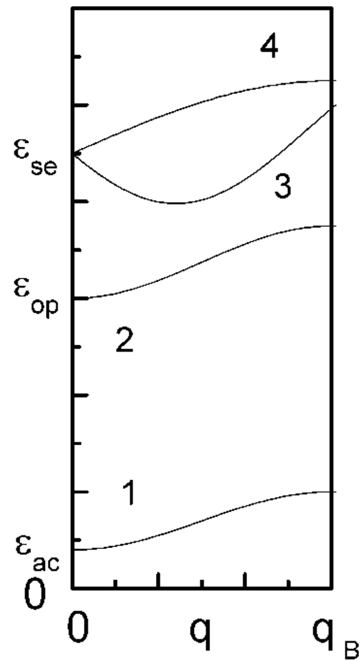

Fig. 2. Scheme of the spectra of the elementary excitations in the model used: 1 – acoustic magnon spectrum, 2 – optical magnon spectrum, 3,4 – lower and upper boundaries of the continuum of single-particle (Stoner) electronic excitations with a spin flip (the figure corresponds to the one-dimensional case with $k_F = 0.4k_B$), ε_{ac} and ε_{op} are the energies at the corresponding zone centers (q=0), ε_{se} is the energy of the Stoner excitations at zero quasimomentum transfer (all three bands are shifted upward by an applied external magnetic field).

$$÷^{+-}_{ë,ë'}(\tilde{ã}) = -\frac{1}{v_a}\left\langle\left\langle M^{+}_{ë}\middle| M^{-}_{ë'}\right\rangle\right\rangle_{\tilde{ã}},$$

where $\varepsilon = \varepsilon + i\alpha,\ \alpha \to 0,\ \varepsilon = \omega,$ ω is frequency of the trial field, v_a is an atomic volume.

Resonant frequencies correspond to the poles of the Green’s function $|_{\varepsilon}$, which can be defined from equalization of motion for her.

Calculation of transversal dynamic magnetic susceptibility, conducted by the method of twotemporal late of the Green’s function within the framework of the approach developed in [6], resulted in two resonant frequencies of homogeneous precession of constrained *d* - and *f* - the magnetic moments of the system, related to *acoustic* and *optical* to the magnon branches.

Linearizing on the field of H=(0, 0, H^Z) of the got expressions for resonant frequencies of homogeneous precession allowed to define effective *g* - factors, corresponding acoustic and optical to the magnon branches which in linear for 1/S approaching, have a next kind:

$$g^{*}_{ac} = g_f\left[1 - \frac{\langle s^Z\rangle}{\langle S^Z\rangle}\left(1 - \frac{g_d}{g_f}\right)\left(\frac{J_\perp}{J}\right)^2\right],$$

$$g^{*}_{op} = g_d\left[1 - \frac{\langle s^Z\rangle}{\langle S^Z\rangle}\left(1 - \frac{g_f}{g_d}\right)\left(\frac{J_\perp}{J}\right)^2\right].$$

Conclusions

Got expressions for effective g - factors interactive f - and d - magnetic subsystems in narrow-band ferromagnetic contain both izotropic amendments to g - factors uninteractive f - and d - subsystems and amendments depending on the relation of x, y - and z is a component of tensor of local exchange parameters, thus sign of amendments for f - and d - subsystems different.

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