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Magnetoelastic communication and attenuation collective excitations in model of half metal

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It is viewed signal attenuation collective excitations in model of half metal and the effect of qualitative calculation of decay time and threshold quasimomentums of magnons is presented. Emission by magnons of phonons at zero temperature is provided at the expense of take off by a magnetic subsystem of energy from a radiant of an exterior electromagnetic field. In the field of poles of the mass functional the spin-lattice interaction main effect is signal attenuation of magnons, as should be reflected, mainly, in spectrums of magnetic uptake. The effect from a renormalization magnon energies in this spectroscopic field becomes less significant for the shape of a curve of magnetic uptake.
Keywords: phonon, magnon, spin-lattice interaction, signal attenuation of magnons, the mass functional.

Рассмотрено затухание коллективных возбуждений в модели половинного металла и представлен результат качественного расчета времени затухания и пороговых квазиимпульсов магнонов. Испускание магнонами фононов при нулевой температуре обеспечивается за счет отбора магнитной подсистемой энергии от источника внешнего электромагнитного поля. В области полюсов массового оператора основным эффектом спин-решеточного взаимодействия является затухание магнонов, что и должно отразиться, главным образом, на спектрах магнитного поглощения. Эффект же от перенормировки магнонных энергий в этой спектральной области становится менее значимым для формы кривой магнитного поглощения.
Ключевые слова: фонон, магнон, спин-решеточное взаимодействие, затухание магнонов, массовый оператор.

Розглянуто загасання колективних збуджень в моделі половинного металу і представлений результат якісного розрахунку часу загасання і порогових квазіімпульсів магнонів. Випускання магнонами фононів при нульовій температурі забезпечується за рахунок відбору магнітною підсистемою енергії від джерела зовнішнього електромагнітного поля. У області полюсів масового оператора основним ефектом спін-граткової взаємодії є загасання магнонів, що і повинне відбитися, головним чином, на спектрах магнітного поглинання. Ефект же від перенормування магнонних енергій в цій спектральній області стає менш значимим для форми кривої магнітного поглинання.
Ключові слова: фонон, магнон, спін-граткова взаємодія, загасання магнонов, масовий оператор.

Introduction

The model of half-note metals is widely used for description of row of oxides with the mixed valency, possessing a “giant magnetoresistance” effect (GMR) [1]. Magnetoelastic interaction substantially influences on forming of basic properties of these connections. However the known methods [2] calculation of parameters of damping of magnons, as a result magnon–phonon interaction appear of the little use for these systems, as an indirect exchange in them has not Heisenberg nature [1,3]. This paper presents the results of qualitative calculation of the damping time and threshold quasimomenta of magnons.

Magnon damping time

The characteristic magnon damping time is given by the expression [7]

$$\tau_{\mathbf{q}} = \frac{\hbar}{2\,\mathrm{Im}\,\varepsilon(\mathbf{q})}\ , \tag{1}$$

where $\hbar$ is Planck’s constant, and $\mathrm{Im}\ \varepsilon\ (\mathrm{q})$ is the imaginary part of the magnon energy. Last, concordantly [5], equal

$$\mathrm{Im}\,\varepsilon_{ac(op)\xi}(\mathbf{q}) = \frac{2\left\langle s^z\right\rangle S_{ac(op)}}{\left\langle S^z + s^z\right\rangle} M''\left(\mathbf{q}, \varepsilon_{ac(op)\xi}(\mathbf{q})\right), \tag{2}$$

where $M''\left(\mathbf{q}, \varepsilon_{ac(op)\xi}(\mathbf{q})\right)$ is imaginary part of mass operator of magnon–phonon interaction; $\mathbf{q}$ is a quasimomenta of magnons; $\left\langle S^z\right\rangle = \frac{1}{N}\sum_{\lambda}\left\langle 0\left|S^z_{\lambda}\right|0\right\rangle$, $\left\langle s^z\right\rangle = \frac{1}{N}\sum_{\mathbf{k}}\left(n_{\mathbf{k}\uparrow} - n_{\mathbf{k}\downarrow}\right)$ are mean values of local and quasilocal spins; $S_{ac}=\left\langle S^z\right\rangle$, $S_{op}= \left\langle s^z\right\rangle$.

Magnons with quasimomenta not exceeding a critical value $\mathrm{q}_{0ac(op)}$, are not damped [3], and therefore one is interested in an estimate of (2) near the edge of the magnon band, where $\mathrm{q} \approx \mathrm{q}_{\mathrm{B}}$. Maximal value of imaginary part of mass operator in (2) does not exceed a value

$$M''_{ac(op)\max} = \frac{0.7\pi\xi^2 \left\langle s^z \right\rangle S_{ac(op)}}{\left\langle S^z + s^z \right\rangle} N_{ac(op)\nu\max} \quad , \qquad (3)$$

where $\text{î} = W\dfrac{A_0}{a}$, W=2zT is a width of magnon zone, z is a coordinating number of crystalline lattice, T is the hopping integral of electrons between nearest-neighbor sites; $A_0 = \dfrac{\hbar}{\sqrt{2M_a\nu_0}}$ it is the rms amplitude of zero vibrations of ions with border frequency of $\nu_0 \approx \theta_D$ [6], a is a constant of crystalline lattice; M_a is mass of atom.

A size $N_{ac(op)\nu\max}(\mathbf{q},\varepsilon)$ is a maximal value of function

$$N_{ac(op)\nu}(\mathbf{q},\varepsilon) = \frac{1}{N}\sum_{\mathbf{p}} \delta\left(\varepsilon - \varepsilon_{ac(op)+}(\mathbf{q},\mathbf{p})\right),$$

arrived at, in three-dimensional case, at the value of quasimomenta of magnon of q_{max}~q_B. The interval of nonzero values of $N_{ac(op)\nu\max}(\mathbf{q},\varepsilon)$ is equal to the sum of the widths of the magnon and phonon bands. Using the normalization

$$\int N_{ac(op)\nu\max}(\mathbf{q},\varepsilon)d\varepsilon = 1$$

we estimate $N_{ac(op)\nu}(\mathbf{q},\varepsilon)$ by the quantity $(\text{è}_C + \text{è}_D)^{-1}$ for the acoustic band and $(\text{è}'_C + \text{è}_D)^{-1}$ for the optical band, where $\text{è}' = \text{è}\dfrac{\left\langle S^Z \right\rangle}{\left\langle s^Z \right\rangle}$. Using (3) and and supposing W=1.5 eV, S=1.5, $A_0/a \approx 4\times10^{-3}$ (values characteristic of GMR are connections of $La_{2/3}Ca_{1/3}MnO_3$ [1]), we obtain from (1) and (2) the following estimate for the magnons with Brillouin quasimomentum q_B:

$$\operatorname{Im}\varepsilon_{ac}(q_B) \approx 6.8\cdot10^{-5}\theta_C, \tau_{ac} \approx 1.5\cdot10^{-10}s,$$

$$\operatorname{Im}\varepsilon_{op}(q_B) \approx 7.5\cdot10^{-6}\theta'_C, \tau_{op} \approx 8\cdot10^{-11}s.$$

Thus, material part of mass operator determines renormalization of magnon spectrum, and imaginary is fading of magnons. Both effects depend on a temperature. Fading of magnons at a zero temperature is caused by the spontaneous emitting of phonon, at eventual - also and by their absorption.

Threshold of magnon damping

The effect at zero temperature, as follows from [3], has a threshold character: only those magnons with a quasimomentum exceeding the value

$$q_{0ac} = \frac{1}{a}\cdot\arcsin\frac{\pi\left\langle S^z + s^z \right\rangle \text{è}_D}{2T\sin(k_F a)} \qquad (4)$$

for an acoustic branch, and value

$$q_{0op} = \frac{1}{a}\cdot\arcsin\frac{\pi\left\langle s^z \right\rangle\left\langle S^z + s^z \right\rangle \text{è}_D}{2T\left\langle S^z \right\rangle \sin(k_F a)} \quad - \qquad (5)$$

for the optical branch are damped (for simplicity we have given the expressions obtained for the one-dimensional case[3]).

It should be noted that existence of threshold quasimomentums of (4) and (5) has direct attitude toward the effect of Tcherenkov [8]: group speed of magnons with a quasimomentum exceeding these values more speed of sound appears in an environment, in this connection and there is a spontaneous radiation by them phonon. If speeds of magnons do not exceed speed of sound, i.e. if argument of the arcsine in (4) and (5) more unit (in the threedimensional case with allowance for the estimate of the Curie temperature, this should correspond to the inequality $\theta_D > \theta_C$) appears, the magnon–phonon coupling at a zero temperature does not result in fading of magnons.

The emission of phonons by magnons at zero temperature is made possible by the extraction of energy from the source of the external electromagnetic field by the magnetic subsystem. In area of poles of mass operator the basic effect of spin-lattice coupling is fading of magnons, what must be reflected, mainly, on the spectrums of magnetic absorption. An effect from renormalization of the magnons energies in this spectral region becomes less meaningful for the form of curve of magnetic absorption.

Conclusions

Thus, the magnon–phonon coupling at a zero temperature qualitative does not change character of spectrum of magnetic absorption at $q < q_{0ac(op)}$. It changes the form of магнонных zones only, frequencies of heterogeneous resonances fall down in this connection. At an eventual temperature, as a result of absorption of thermal phonons, all of the magnons will be damped.

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