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Letter to the Editor

THE SUSCEPTIBILITY OF MAGNETIC MULTILAYERS[1])

ВОСПРЕЕМЧИВОСТЬ МАГНИТНЫХ МУЛЬТИСЛОЕВ

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The paper contains an application of the recursion method to calculations of the ***HF*** susceptibility of multilayers. The susceptibility is given in the form of a set of recurrential equations. Resonance fields and local amplitudes of eigenmodes are given by the spectral density.

The Hamiltonian for a localized spin model of an sc lattice comprisess exchange, dipolar, Zeeman and interface anisotropy contributions. The direction [100], the ***DC*** field and the magnetization are perpendicular to the surface. In the Hamiltonian, we make two transformations. The first transforms the spin operators to the Bose operators $a^+(j,l)$ and $a^-(j,l)$ by means of the Holstein—Primakoff transformations. The location of the spins is described by the index j within the atomic layer, and l labels an atomic layer parallel to the surface. The second transformation is a Fourier transformation in the plane of the multilayer

$$a^{\pm}(j,l) = N^{-1/2} \sum_{k} \exp(\mp \boldsymbol{k} \boldsymbol{r}_{jl})\, b_{k}^{\pm}(l), \tag{1}$$

N is the number of the spins in the plane, and $\boldsymbol{k}$ the wave vector lying in the plane. In the plane, the translate symmetry is not broken, and the Hamiltonian is brought to the form

$$H = \tilde{E}_0 + \sum_{k} H_k, \tag{2}$$

where $\tilde{E}_0$ is the energy of the ground state $|0\rangle$... The part H_k of the Hamiltonian with $\boldsymbol{k} \neq 0$ has no influence on the magnon excitations in resonance, and

$$H_0 = \sum_{l} \left\{ g\mu_B B - 2K_s(l)/S(l) + \sum_{l'} S(l')\,[2J_0(l',l) + 4E_0(l',l)] \right\} b_0^+(l)\, b_0^-(l) + \\ + 2\sum_{l,l'} [S(l')\,S(l)]^{1/2}\, [E_0(l,l') - J_0(l,l')]\, b_0^+(l)\, b_0^-(l). \tag{3}$$

Here, B is the magnetic induction, $K_s(l)$ the coefficient of the local anisotropy, $S(l)$ the local spin quantum number, $J_0(l,l')$ the Fourier transformation of the exchange interaction in the plane of the multilayer, $E_0(l,l')$ denotes the dipole-lattice sum.

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In this paper, we calculate the susceptibility at absolute temperature tending to zero ($T \to 0$), $\chi(l,l') = -\gamma[S(l)\,S(l')]^{1/2} G_{ll'}$. The retarded Green function is restricted to the form

$$G_{ll'} \cong 2\pi \langle\langle b_0^-(l);\, b_0^+(l') \rangle\rangle_{\omega + i\epsilon} \cong \langle 0 |\, b_0^-(l)\, [\omega + i\epsilon - (H - \tilde{E}_0)/\hbar]^{-1}\, b_0^+(l') | 0 \rangle, \tag{4}$$

where ϵ represents the damping of the spin waves.

The element $G_{ll'}$ of the Green function is calculated by the recursion method [1, 2], which involves setting up a new orthonormal basis set $|u_n\rangle$, $n = 1, 2, \ldots, N_L$. Here, N_L is the number of atomic layers parallel to the surface. In the new basis, the Hamiltonian takes the threediagonal form. The state $|u_n\rangle$ may be expanded in terms of $b_0^+(l)|0\rangle$

$$|u_n\rangle = \sum_{l} C(n,l)\, b_0^+(l)|0\rangle,\ \tilde{b}_n |u_n\rangle = \sum_{l} \tilde{C}(n,l)\, b_0^+(l)|0\rangle, \tag{5}$$

where $C(n,l)$ is the projection of $|u_n\rangle$ on the vector $b_0^+(l)|0\rangle$. The recursion method [1, 2] enables us to calculate the amplitudes $C(n,l)$ and the elements a_n, $\tilde{b}_n$ of the Hamiltonian in $|u_n\rangle$.

$$a_n = \sum_{l} C^*(n,l) \left\{ C(n,l) \left[g\mu_B B - 2K_s(l)/S(l) + 2\sum_{l'} S(l')\,[J_0(l',l) + 2E_0(l',l)] \right] + \\ + 2\sum_{l'} C(n,l')\,[S(l)\,S(l')]^{1/2}\, [E_0(l,l') - J_0(l,l')] \right\} / \hbar, \tag{6}$$

$$\tilde{C}(n+1,l) = \left\{ C(n,l) \left[g\mu_B B - 2K_s(l)/S(l) + 2\sum_{l'} S(l')[J_0(l,l') + 2E_0(l',l)] \right] + \\ + 2\sum_{l'} C(n,l')\,[S(l)\,S(l')]^{1/2}\, [E_0(l,l') - J_0(l,l')] \right\} / \hbar - a_n C(n,l) - \tilde{b}_n C(n-1,l), \tag{7}$$

$$\tilde{b}_{n+1}^2 = \sum_{l} |\tilde{C}(n+1,l)|^2, \quad C(n+1,l) = \tilde{C}(n+1,l)/\tilde{b}_{n+1}. \tag{8}$$

Here, the components $C(1,l)$ of the starter function $|u_1\rangle$ are defined and $\tilde{b}_1 = \tilde{b}_{N_L+1} = 0$. Secondly, a diagonal element of the Green function is expressible by a continued fraction

$$G_{ll} = \langle u_1 | [\omega + i\epsilon - (H - \tilde{E}_0)/\hbar]^{-1} | u_1 \rangle = \\ 1/(\omega + i\epsilon - a_1 - \tilde{b}_2^2/(\omega + i\epsilon - a_2 - \tilde{b}_q^2/(\omega + i\epsilon - a_q - \ldots - \tilde{b}_{N_L}^2/(\omega + i\epsilon - a_{N_L})\ldots))). \tag{9}$$

The amplitude of the eigenmode $|v\rangle$ on the lth atomic layer may be calculated as the limit $P_v(l) = \lim_{\epsilon \to 0} [i\epsilon G_{ll}] = \lim_{\epsilon \to 0} [-\epsilon \operatorname{Im} G_{ll}]$. The resonance field and the local amplitude are numerical given by the peaks of the local spectral density. For some typical parameters, the method is illustrated in papers [3, 4].

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