EXCITON BANDWIDTH IN DILUTE MAGNETIC SEMICONDUCTORS WITH QUANTUM WELLS: INFLUENCE OF INTERFACE ROUGHNESS AND SPIN-FLIP PROCESSES

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The influence of interface roughness and spin-flip processes on the exciton bandwidth and absorption optical spectra in quantum wells in dilute magnetic semiconductors is studied theoretically. The interface roughness is studied under the assumption that there are islands with magnetic impurities in the non-magnetic layers near interfaces. These islands have form of disks and the radii of disks are less than the exciton radius. The calculations for a CdMnTe/CdTe/CdMnTe quantum well have shown that different components of the spectrum have different dependence of the bandwidth on a magnetic field: the bandwidth of the σ^--component of the exciton transition increases as the magnetic field rises while it decreases for the σ^+-component. This phenomenon is explained by a coherent summation of the spin-dependent and spin-independent parts of the interaction between an exciton and a magnetic impurity. Numerically, the value of the bandwidth depends on the number of defects, radii of islands, and their distribution over radii and may reach 1—10 meV. It is shown that the contribution of inelastic spin-flip scattering to the exciton bandwidth is small.

1. Introduction

A bandwidth is an important parameter of optical spectra. It contains information about microscopic processes in a system and determines the possibility of its application in optical devices. So, numerous investigations have been devoted to the study of an exciton bandwidth in quantum wells [1—4]. In [5, 6], the authors have studied the exciton band broadening caused by the exciton scattering on component distribution fluctuations in semimagnetic semiconductor quantum wells. In these systems, some interesting effects in the exciton bandwidth behavior in an external magnetic field are observed. The bandwidth increases as the magnetic field rises for the σ^--component of the spectrum, while it decreases for the σ^+-component. The effect has been explained by a coherence summation of the spin-dependent and spin-independent parts of the exciton-impurity interaction in scattering processes [6]. The bandwidth narrowing induced by a magnetic field was reported in [7] for bulk semimagnetic crystals. Also it was observed in the photoluminescence spectrum of an exciton band in the ZnSe/Zn(Cd,Mn)Se system [2]. So, it is interesting to study the magnetic field effect on another exciton scattering mechanisms.

In the present article, the influences of some technology-induced heterogeneities of the magnetic impurity distribution as well as spin-flip processes on the exciton bandwidth in semimagnetic semiconductors with quantum wells are investigated.

2. Method of the Bandwidth Calculation

To study the exciton band broadening, the Pekar's approximation [8] was used. According to this method, the electronic states of a crystal are divided into two groups. The states of the first group interact with light directly. The optical transitions to the states of the second group are forbidden. The system can transfer to these states via nonradiation transitions. For the crystal with a quantum well, the excitonic state with in-plane wave vector $\vec{k} = 0$ is an example of the first group state in the case of normal incidence of the electromagnetic wave. The states with $\vec{k} \neq 0$ belong to the second group of states. They can be excited by the second-order processes: by the interaction with light and scattering on defects. We will suggest that the light wave frequency is close to the resonance frequency of the exciton transition in the quantum well. Using the traditional theory of interaction of an electromagnetic field with a system, the current of polarization connected with the exciton creation for the normal incidence in a linear approximation as to the electric field intensity can be defined as

$$\vec{J}(z) = i\,\frac{e^2|\vec{p}_{cv}|^2}{m_0^2\omega}\,\frac{\Phi(0,z,z)\ \int \Phi(0,z',z')\ \vec{E}(z')\ dz'}{\hbar\omega - \hbar\omega_{i0} + H_{ii}(\omega)}, \quad (1)$$

where ω is the light frequency, $\hbar\omega_{i0}$ is the energy of the bottom of the i-th exciton band of the quantum well, $\vec{p}_{cv}$ is the interband matrix element of the momentum, $\vec{r}_{e\,(h)} = \left(\vec{\rho}_{e\,(h)}, z_{e\,(h)}\right)$ is the position of an electron (hole), $\vec{\rho} = \vec{\rho}_e - \vec{\rho}_h$, $m_0$is the free electron mass, z is the crystal growth direction, $\Phi(\vec{\rho},\ z_e,\ z_h)$ is the exciton envelope wave function [6],

$$H_{ii} = \sum_{\alpha} \frac{U_{i\alpha}U_{\alpha i}}{E_\alpha - \hbar\omega}, \quad (2)$$

α designates the states of the second group, E_α is the α-state energy, $U_{\alpha\, i}$ is the matrix element of the perturbation which connects the states of different groups (for example, the state with zero wave vector with other states). If the spectrum of α is continuous, expression (2) may be transferred to the form

$$H_{ii} = \Delta(\omega) + i\,\Gamma(\omega), \quad (3)$$

where $\Gamma(\omega)$ is the exciton damping and $\Delta(\omega)$ is the resonance frequency shift.

The calculations of the quantum well optical parameter become simpler if the well width is considerably smaller than the wavelength, which is valid for most of the real systems [9]. The above-mentioned expressions enable one to describe the quantum well optical properties, particularly to calculate the light reflection and absorption coefficients [5, 6].

Let us consider a semimagnetic semiconductor, in which some atoms of a metal are substituted by magnetic impurities (for example, by Mn atoms). The interaction of an exciton with magnetic impurities $H_{\rm int}$ consists of the spin-dependent and spin-independent parts [7]. The spin-dependent part is caused by the exchange interaction of carriers with the unpaired electrons of impurities. The spin-independent part arises from the different values of the electron densities of impurity atoms and atoms of the crystal, a deformation of the lattice in the vicinity of an impurity, etc. The Hamiltonian of the interaction of an exciton with magnetic impurities can be written as

$$H_{\rm int} = \sum_{\vec{n}} \frac{1}{N_0}\left[\left(\Delta_e - J_e\vec{S}_e\vec{S}_{\vec{n}}\right)\delta(\vec{r}_e - \vec{n}) + \right.$$

$$\left. + \left(\Delta_h + J_h\vec{S}_h\vec{S}_{\vec{n}}\right)\ \delta(r_h - \vec{n})\right] x_{\vec{n}}, \quad (4)$$

where N_0 is the concentration of cationic lattice sites, $\vec{n}$ is the coordinate of a cationic lattice site, $\Delta_{e\,(h)}$ is the potential of the non-magnetic interaction of an electron (hole) with an impurity ion, $J_{e(h)}$ is the exchange integral for the electron (hole), $\vec{S}_{e\,(h)}$is the spin of an electron (hole), $\vec{S}_{\vec{n}}$ is the spin of a magnetic ion, $x_{\vec{n}}$=0 if there is an ion of the crystal at the lattice site $\vec{n}$ and $x_{\vec{n}}$=1 if the site is occupied by a Mn^{2+} ion. Hamiltonian (4) can be written as

$$H_{\rm int} = H_{\rm int}^{\rm meanfield} + U, \quad (5)$$

where $H_{\rm int}^{\rm meanfield}$ is the Hamiltonian in the mean field approximation [9, 10]. In this approximation, the impurity concentration and spin orientation $x_{\vec{n}}$ and $\vec{S}_{\vec{n}}$ are replaced by their mean values x and $\bar{S}_{{\rm Mn},\,z}$. The interaction U describes a deviation from the mean field approximation and leads to the scattering of an exciton to another states. The term U can be divided into two parts:

$$U = U_{\rm fluct} + U_{\rm s\text{-}f} \quad (6)$$

The first term in (6) describes the interaction of an exciton with fluctuations of both the magnetic impurity concentration and orientation of the impurity spins. The second term corresponds to the spin-flip processes

$$U_{\rm s\text{-}f} = \frac{1}{2}\sum_{\vec{n}} \frac{1}{N_0}\left[J_h(S_h^+S_{\vec{n}}^- + S_h^-S_{\vec{n}}^+)\delta(r_h - \vec{n}) - \right.$$

$$\left. - J_e(S_e^+S_{\vec{n}}^- + S_e^-S_{\vec{n}}^+)\delta(\vec{r}_e - \vec{n})\right] x_{\vec{n}}. \quad (7)$$

The interaction U leads to the scattering of an exciton to another states and determines the exciton optical properties according to (2). The effect of fluctuations on the optical parameters of the crystal with a quantum well was studied in [5, 6] for the case of a statistically equivalent distribution of impurities. Below, the results of investigations of the spin-flip processes and non-homogeneities of the impurity distribution caused by imperfections of a crystal on its optical properties are presented.

3. Effect of Defect Structure of Interfaces on Exciton Bandwidth

The approximation of equiprobable magnetic impurity distribution in space [5, 6] can be realized in the limit of ideal interface. Really, the state of an interface depends significantly on the technological processes of the crystal preparation. The assumption about fluctuations of the well width [11, 12] is some description of the interface effect. According to this model, the different parts of a well differ in width by one or two periods of the lattice. As a result, the interface presents the surface with inclusions (islands) that have different concentrations of magnetic impurities. If the region with the same well width exceeds significantly the exciton radius, the energy spectrum of the well is presented as a superposition of the exciton bands of quantum wells with different widths. Such mechanisms cause a splitting of exciton bands rather than a broadening. We will consider another case where the size of islands is less than the exciton radius. But, because the exciton radius is large (50—100 Å), these inclusions may have macroscopic sizes. Excitons scatter on inclusions that causes the broadening of exciton bands.

We will consider the interface defects as disks separated by one monolayer step across and will study the broadening caused by the exciton scattering on the disks. The main attention will be paid to the dependence of the interface-roughness-induced bandwidth in a semimagnetic system on a magnetic field, because this question has not been studied so far.

To simulate an interface roughness in the quantum well CdMnTe/CdTe/CdMnTe with width L, we have supposed that there are semimagnetic islands with thickness D in the non-magnetic layers near interfaces, which corresponds to the well width fluctuations. To simplify the problem, we have assumed that these islands are CdMnTe disks with radius R_d which are placed randomly in the monolayer nearest to the interface CdTe (Fig. 1). The magnetic impurity concentration in the disks and in the barriers are equal. We suggest that there is no overlapping of disks. The additional potential caused by the well width can be expressed as

$$U_{\rm int} = \sum_{i=e,h} \sum_{\vec{n}} C_{\vec{n}}\, V_i\left(\vec{\rho}_i - \vec{n}\right) \times$$

$$\times \left\{\Theta\left(L/2 - |z_i|\right) - \Theta\left(L/2 - D - |z_i|\right)\right\}, \qquad (8)$$

where $C_{\vec{n}}$=1 if the center of the disk is placed at the lattice site $\vec{n}$ and $C_{\vec{n}}$=0 otherwise, $V_{e(h)}\left(\vec{\rho}\right)$ is the potential of the interaction of an electron (hole) with a semimagnetic disk:

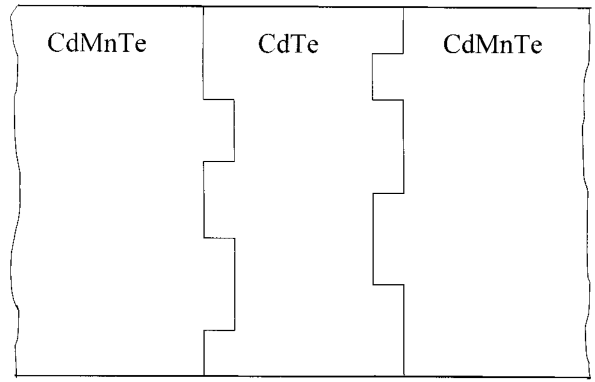

Fig. 1. Schematic representation of a heterostructure CdMnTe/CdTe/CdMnTe showing the interface roughness

$$V_{e(h)}\left(\rho_{e(h)}\right) = W_{e(h)}\Theta\left(R_d - \rho_{e(h)}\right),$$

$$W_{e(h)} = \left(\Delta_{e(h)} \mp J_{e(h)}\, S_{e(h),z}\bar{S}_{Mn,z}\right) x.$$

The additional potential of disks can be presented as

$$U_{\rm int} = \bar{U}_{\rm int} + \delta\, U_{\rm int},$$

where $\bar{U}_{\rm int}$ is the mean value of (8) calculated by using the wave function of an exciton. Its value does not depend on ρ and determines a shift of the exciton level due to the defects of the interface. The value $\delta\, U_{\rm int} = U_{\rm int} - \bar{U}_{\rm int}$ describes the scattering of excitons in the well plane and, therefore, the bandwidth.

For calculations, we have used the following form of the variational wave function of a confined exciton in a quantum well with the Hamiltonian $\bar{H}_0$:

$$\Psi_{\vec{k},S_{ez},S_{hz}} = \frac{1}{\sqrt{A}} e^{i\vec{k}\,\vec{R}}\, \Phi_{S_{ez},S_{hz}}\left(\vec{\rho},\, z_e,\, z_h\right), \qquad (9)$$

$$\Phi_{S_{e,z},S_{h,z}}\left(\vec{\rho},\, z_e,\, z_h\right) =$$

$$= f^e_{S_{e,z}}\left(z_e\right) f^h_{S_{h,z}}\left(z_h\right) \sqrt{\frac{2}{\pi\,\lambda^2}}\, e^{-\rho/\lambda}, \qquad (10)$$

where $f^e_{S_{e,z}}\left(z_e\right)$ and $f^h_{S_{h,z}}\left(z_h\right)$ are the wave functions of an electron and a hole in the lowest subbands of the quantum well [6], $\vec{k}$ and $\vec{R}$ are the wave vector and the position of the exciton center of mass in the plane of the layers, λ is the variational parameter, and A is the layer area.

To find the exciton damping and the resonance frequency shift caused by the interface roughness

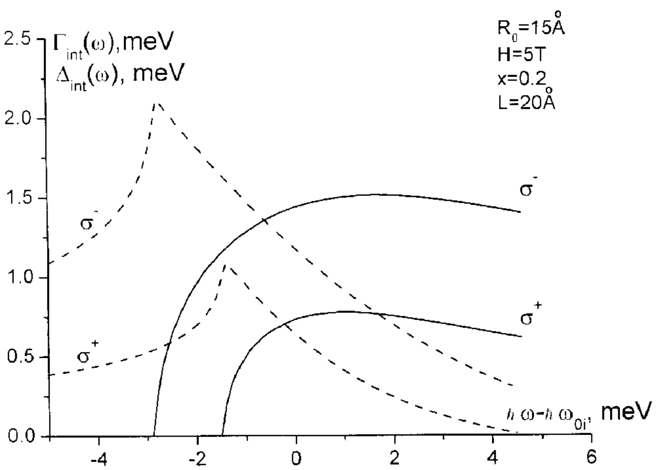

Fig. 2. Interface-roughness-induced exciton damping $\Gamma_{\rm int}(\omega)$ (solid lines) and the resonance frequency shift $\Delta_{\rm int}(\omega)$ (dashed lines) for the σ^-- and σ^+-components of the excitonic band as a function of the electromagnetic wave frequency for $H = 5$ T (ω_0^i is the exciton resonance frequency in the magnetic field $H = 5$ T: ω_0^- for the σ^--transition and ω_0^+ for the σ^+-transition)

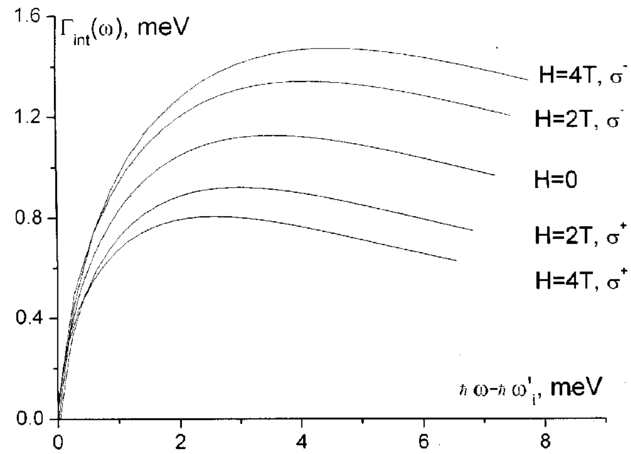

Fig. 3. Interface-roughness-induced exciton damping $\Gamma_{\rm int}(\omega)$ for the σ^-- and σ^+-components of the excitonic band as a function of the electromagnetic wave frequency (curves were shifted to the origin for convenience) for several values of the magnetic field intensity H

according to (2), (3), the matrix element $U_{\vec{k}_0,S_{e,z},S_{h,z};\vec{k},S_{e,z},S_{h,z}}$ of the transition between different states of the system was calculated and was averaged with respect to the disk concentration distribution assuming this distribution to be chaotic, but the distance between the centers of the disks should not be less than the sum of their radii. This matrix element was averaged over the disk radius with the probability distribution $P(R) = P_0\, e^{-(R_d-R_0)^2/\sigma^2}$, where P_0 is the normalizing constant, σ and R_0 are the parameters. So Eqs. (2), (3) can be written as

$$\sum_{\vec{k}} \frac{\left\langle \left| U_{\vec{k}_0,S_{e,z},S_{h,z};\vec{k},S_{e,z},S_{h,z}} \right|^2 \right\rangle_R}{\hbar\omega_0 + \frac{\hbar^2 k^2}{2M} - \hbar\omega - \Delta_{\rm int}(\omega) - i\,\Gamma_{\rm int}(\omega)} =$$

$$= \Delta_{\rm int}(\omega) + i\,\Gamma_{\rm int}(\omega),$$

where ω_0 is the resonance frequency of the exciton transition in the quantum well. The exciton damping $\Gamma_{\rm int}(\omega)$ and the resonance frequency shift $\Delta_{\rm int}(\omega)$ caused by the interface roughness were calculated numerically. The presence $\Delta_{\rm int}(\omega)$ and $\Gamma_{\rm int}(\omega)$ in the denominator of the integral takes into account a shift of the exciton band bottom which appears due to the scattering processes. Here, we neglect the system energy change due to fluctuations of the well width.

In Fig. 2, the frequency dependence of the exciton damping $\Gamma_{\rm int}(\omega)$ and the resonance frequency shift $\Delta_{\rm int}(\omega)$ for the σ^-- and σ^+-components of the excitonic band are shown for x=0.2, L=20 Å, D=3.5 Å, R_0=15 Å, $C = 10^{-3}$, σ=3 Å, T=1.6 K, H=5T. We have used the following parameters in the calculations: the effective masses of an electron and a heavy hole are equal to $m_e = 0.096 m_0$ and $m_h = 0.64 m_0$, the valence band offset α=0.4, the energy gap for CdTe E_g=1.606 eV [13], J_e=0.22 eV, $J_h = -0.88$ eV, the dielectric constant ε=9.7. To calculate the total energy band gap diskontinuity and the average spin projection $\bar{S}_{{\rm Mn},z}$ for high Mn^{2+} concentrations, empirical expressions were used [10].

It can be seen that the effect of the interface roughness on the band broadening is considerable, and the linewidth value depends essentially on a magnetic field. The dependence of the exciton damping on a magnetic field in a quantum well with the parameters given above can be distinctly seen in Fig. 3. This strong dependence of the damping leads to the essential difference in the bandwidths of the σ^-- and σ^+-components of the exciton absorption spectrum (Fig. 4), which was calculated using the parameters given above as well as the longitudinal-transverse splitting $\hbar\omega_{\rm LT}$=1.25 meV [9] and the damping due to another scattering mechanisms $\hbar\tilde{\Gamma}_0$=0.25 meV at T =2 K.

It was noted in [5, 6] that another mechanism of the exciton scattering (namely, the scattering on the magnetic impurity concentration fluctuations) causes the exciton band broadening which is also very sensitive

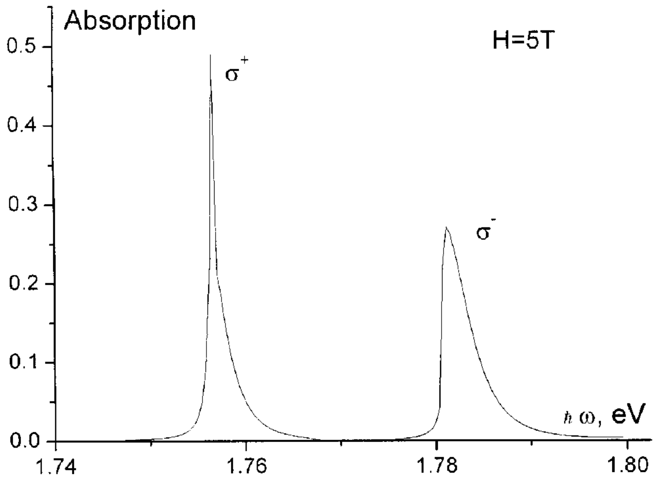

Fig. 4. Normal incidence absorption spectrum for the quantum wells with L=20Å, x=0.2, $H = 5$ T

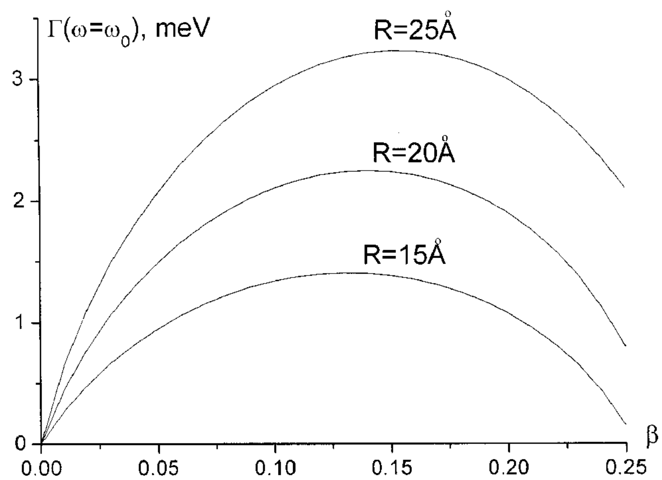

Fig. 5. Frequency dependence of the exciton damping versus the parameter of disorder β for $\bar{R}$=15Å, $\bar{R}$=20Å and $\bar{R}$=25Å, $\omega = \omega_0$, x=0.2, L=20 Å, d=3.5Å, T=1.6 K, H=0

to the external magnetic field. Both scattering mechanisms (interface roughness and above-mentioned fluctuations) result in the qualitatively identical magnetic dependence: the linewidth increases as the field rises in the case of the σ^--transition and decreases as the field increases for the σ^+-transitions. To explain this result, we note that, for the spin orientation corresponding to the σ^--component, the spin-dependent part of the exciton-impurity interaction adds to the spin-independent one. Whereas for the σ^+-component, they tend to compensate each other. Since the scattering is caused in both cases by this interaction between the exciton and the magnetic impurity, the results are qualitatively similar.

Turning back to the effect of interface roughness, we should mention that the interface-roughness-induced exciton damping $\Gamma_{\text{int}}(\omega)$ depends considerably on the interface profile disorder degree. To describe the disorder degree, we have introduced the parameter $\beta = S_{\text{disk}}/A$, where S_{disk} is the summary area of disks in the layer of the quantum well which is nearest to the interface, and A is the layer area. This parameter describes which part of the layer area is occupied by disks. Let us suppose that all disks have radius $\bar{R}$. Then $\beta = C N_0^{2/3} \pi \bar{R}^2$. In Fig. 5, the dependence of the interface-roughness-induced exciton damping $\Gamma_{\text{int}}(\omega)$ on β is depicted. $\Gamma_{\text{int}}(\omega)$ increases as β rises for small β, because a disorder of the interface rises. But, for β exceeding some value, the damping $\Gamma_{\text{int}}(\omega)$ begin to decrease as β rises, because disks fill the layer nearest to the interface, and the system becomes more ordered. The results of calculations of the damping are very sensitive to the parameters, especially to the average value of the radii of disks (Fig. 5). Therefore, the width of the exciton spectrum bands is very sensitive to the size of islands or, in other words, to the technology of the sample growth.

4. Contribution of Spin-Flip Processes to Exciton Bandwidth Formation

Spin-flip processes are manifested in the Raman spectra of quantum wells [14, 15]. We will study the broadening of the σ^--band (transition to the state $(1/2,\ 3/2, \vec{k})$ and the σ^+-band (transition to the state $(-1/2, -3/2, \vec{k})$) caused by the spin-flip processes. These bands are most intensive in optical spectra. As a result of the spin-flip scattering, an exciton transfers to another band changing the value of its wave vector from $\vec{k}$ to $\vec{k}'$ simultaneously with the overturn of the impurity spin. Interaction (7) leads to a change of the electron (or hole) spin. According [16], we will consider the scattering processes, in which the spin of an electron takes part only. Under the action of a normally incident wave, these processes are as follows:

$$(1/2, 3/2, 0) \to (-1/2, 3/2, \vec{k}')$$

and

$$(-1/2, -3/2, 0) \to (1/2, -3/2, \vec{k}').$$

Let us use the wave function $\tilde{\Psi} = \Psi_{\vec{k}, S_{e,z}, S_{h,z}} \times \times \sum_{\vec{n}} |S_{z\vec{n}}\rangle$ to describe a crystal with magnetic impurities. In order to calculate the broadening of the σ^--component of the exciton band, it is necessary to take

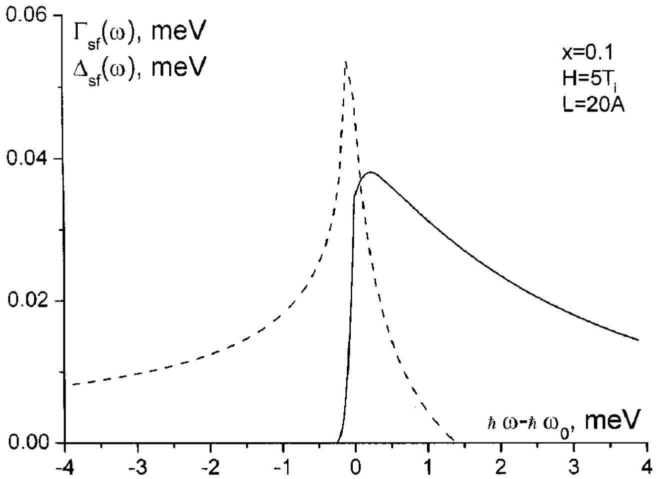

Fig. 6. Spin-flip scattering induced exciton damping $\Gamma_{\text{s-f}}(\omega)$ (solid lines) and the resonance frequency shift $\Delta_{\text{s-f}}(\omega)$ (dashed lines) for the σ^--component of the excitonic band as a function of the electromagnetic wave frequency at $H = 5$ T

into account all possible transitions caused by the spin-flip interaction (7) from the initial state of the system $\tilde{\Psi}_0^- = \Psi_{\vec{k}_0, 1/2, 3/2} \sum_{\vec{n}} \left|S^0_{z\vec{n}}\right\rangle$ to the final state $\tilde{\Psi}_f^- = \Psi_{\vec{k}, -1/2, 3/2} \sum_{\vec{n}} \left|S^f_{z\vec{n}}\right\rangle$ for all possible $S^0_{z\vec{n}}$, $S^f_{z\vec{n}}$ and to calculate the matrix element of the transition $\left\langle \tilde{\Psi}_0^- \middle| U_{\text{s-f}} \middle| \tilde{\Psi}_f^- \right\rangle$.

Equations (2), (3) for the spin-flip scattering of the σ^--component of the exciton transition can be written as

$$\sum_{\vec{k}} \frac{\sum\limits_{S^0_{z,\text{Mn}}, S^f_{z,\text{Mn}}} \left| \left\langle \tilde{\Psi}_0^\pm \middle| U_{\text{s-f}} \middle| \tilde{\Psi}_f^\pm \right\rangle \right|^2 P(S^0_{z,\text{Mn}})}{\hbar\omega^\pm + \frac{\hbar^2 k^2}{2M} - \hbar\omega - \Delta^\pm_{\text{s-f}}(\omega) - i\,\Gamma^\pm_{\text{s-f}}(\omega)} =$$

$$= \Delta^\pm_{\text{s-f}}(\omega) + i\,\Gamma^\pm_{\text{s-f}}(\omega),$$

where $\hbar\omega^+ = E_g + E^e_{1/2} + E^h_{-3/2} - E_b$ is the energy of an exciton with $S_{ez} = 1/2$ and $S_{h,z} = -3/2$ in the quantum well, $\hbar\omega^- = E_g + E^e_{-1/2} + E^h_{3/2} - E_b$ is the energy of an exciton with $S_{e,z} = -1/2$ and $S_{h,z} = 3/2$, $E^{e(h)}_{Sz}$ is the energy level of an electron (hole) in the quantum well, E_b is the exciton binding energy, $P(S^0_{z,Mn})$ is the probability of the impurity spin orientation. We suppose that the binding energy of the exciton is not changed considerably after the electron spin overturn. The frequency dependence of the exciton damping for the σ^-– component of the excitonic band is shown in Fig. 6 for x=0.1, L=20 Å, T=2 K, H = 5T. It can be seen that the damping caused by the spin-flip processes is essentially less than the interface-roughness-induced damping.

5. Conclusions

In this paper, two different mechanisms of the optical property formation in semimagnetic semiconductors with quantum wells are investigated, namely the interface roughness and the spin-flip processes. The main attention has been paid to the dependence of the interface-roughness-induced bandwidth in a semimagnetic system on a magnetic field. Contributions of the mentioned mechanisms (the interface roughness and compositional fluctuations [3, 6]) to the damping have the same order of magnitude. The interface-roughness-induced damping depends on frequency; it rises with the relative area of an island and next it drops, because the infill of the system becomes more uniform with increase in the number of islands. In dilute magnetic semiconductors, all scattering mechanisms under consideration (the interface roughness, the spin-flip scattering, and compositional fluctuations) have common feature: the bandwidth increases as the magnetic field rises for the σ^--component of the spectrum, while it decreases for the σ^+-component. The phenomenon is explained by a coherent summation of the spin-dependent and spin-independent parts of the interaction between an exciton and a magnetic impurity.

Therefore, it is possible to tune the bandwidth through the application of a magnetic field in semimagnetic semiconductors. The effect of the inelastic spin-flip scattering on the exciton spectrum is small. Numerically, the interface-roughness-induced bandwidth depends on the number of defects, radii of islands, and their distribution over radii and may reach 1—10 meV. The study of the bandwidth can provide an important information concerning the interface quality of semiconductor layered systems.

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ШИРИНА ЕКСИТОННОЇ СМУГИ В НАПІВМАГНІТНИХ НАПІВПРОВІДНИКАХ З КВАНТОВИМИ ЯМАМИ: ВПЛИВ НЕРІВНОСТЕЙ ГЕТЕРОМЕЖ ТА СПІН-ФЛІП ПРОЦЕСІВ

Г.В.Верцімаха

Р е з ю м е

Теоретично досліджено розширення оптичних екситонних смуг, спричинене розсіянням екситонів на дефектах меж поділу та спін-фліп процесами в напівмагнітних квантових ямах. Нерівності межі поділу гетероструктури розглядали як острівці магнітних домішок у немагнітних шарах структури поблизу гетеромеж. Розрахунки для квантової ями CdMnTe/CdTe/CdMnTe показали сильну магнітопольову залежність ширини смуги: смуга σ^--компоненти екситонного переходу розширюється з ростом напруженості магнітного поля, в той час як смуга σ^+-компоненти звужується. Цей результат пояснено когерентним додаванням спін-залежної та спін незалежної складових взаємодії екситона з магнітними домішками. Ширина смуги залежить від кількості острівців, їх розподілу за радіусами і може досягати 1—10 меВ. Показано, що внесок непружного спін-фліп розсіяння в ширину екситонної смуги малий.