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NEW TYPE OF PHOTOGALVANIC CURRENT IN FERROELECTRICS

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The current which is proportional to the degree of light circular polarization is discused. It is shown that this type of current can be detected by the optical recording holographic lattice.

Photocurrent in the crystals without symmetry center is quadratic with respect to light wave field E_ω when the constant electric field is absent:

$$j_i^\rho = \beta_{ij\ell} E_{j\omega} E^*_{\ell\omega}, \quad \beta_{ij\ell} = \beta^*_{i\ell j} \tag{1}$$

$\beta_{ij\ell}$ is photogalvanic (PG) tensor. The most important peculiarity of PG-effect is dependence upon the light polarization. In particular there is contribution to j^ρ which does not equal zero for elliptical polarized light

$$j_i^\rho = i\beta^a_{i\ell} [E \times E^*]_\ell, \quad \beta^a_{i\ell} = -i\beta_{iab}\varepsilon_{ab\ell} \tag{2}$$

The current (2) is proportional to degree of light circular polarization δ: $\delta = |E \times E^*|/|E|^2$ and it was observed in semiconductor crystal Te [3]. In the crystals of symmetry classes C_{3v}, C_{4v}, C_{6v} which contained the well known ferroelectrics $BaTiO_3$, $LiNbO_3$ and others, the circular photocurrent (2) is determined by a single constant: $\beta_{ij}^{\alpha} = \beta_{\alpha}\varepsilon_{ij\ell)}c_{\ell}$, where c is the vector along polar direction of crystal.*)

The microscopic theory of photocurrent (2) was suggested in the papers [2,3,7]. The origin of photocurrent according to paper [2] is asymmetry of the dipole matrix element of impurity-band transition and band-band transition: $D_{-k} \neq \pm D_k$, when the condition $D_k^* = D_{-k}$ is valid. In this case the probability of ionization is asymmetric, i.e. $|D_{-k} E|^2 \neq |D_k E|^2$ if $E^* \neq E$, which is the origin of photocurrent [2]. In the papers [3,7] the origin of photocurrent was asymmetry of the spin-orbit interaction. The photoelectrons come in conducting band polarized, and the spin polarization leads to photocurrent due to intraband spin-orbit interaction.

Let us pay attention to important property of current (2): in many ferroelectric crystals particularly in crystals with symmetry C_{3v}, C_{4v}, C_{6v} , the photocurrent (2) is not uniform in space. Really, the product $[E \times E^*]$ oscillates in space with frequency equal to the difference of ordinary and unordinary wave vectors for such directions in which the tensor β_{ij}^{α} is not equal to zero. In the stationary state the current lines must be closed, therefore the current domains form in the crystal. The current lines, for instance, may be directed perpendicularly to light propagation direction and close on the illumination boundary. The total current which flow through the crystal is equal to zero in this case. PG-effect can be detected by the optical recording of holographic lattice,and the holographic lattice recording is possible even if the usual drift and diffusion mechanisms do not lead to the recording such situation is realized, for example, when incident waves have the orthogonal polarizations. The refractive index lattice arises due to electric field of charges separeted by current transport,

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*) At present the essential photocurrent dependence upon linear light polarization was detected in some semiconductors [4,5].

$$\Delta\varepsilon_{ij} = \alpha_{ij\ell} E_\ell \qquad (3)$$

where E is electrostatic field, and $\alpha_{ij\ell}$ is electrooptic tensor. The field E can be determined if we equate with zero the component longitudinal to interference strip of total current,

$$j_L = s(sj^{\rho}) + \sigma E = 0; \quad s = (k_1 - k_2)/|k_1 - k_2| \qquad (4)$$

where $k_{1,2}$ are light wave vectors, σ is conductivity of the crystal. On the basis of relations (2), (3), (4) using the standard method one can easily calculate diffractive efficiency η of recording lattice [9]

$$\eta = \frac{\pi^2}{4} n^2 (k\ell)^2 \frac{\beta_a^2 r_{s1}^2}{\sigma^2 c^2} I_1 I_2 \qquad (5)$$

where ℓ is the cyrstal length, n is refracteve index, r_{s1} is electrooptic constant, $I_{1,2}$ are intensities of recording beams. Formula (5) can be applied only if $\eta \ll 1$, when diffractive efficiency is large the influence of diffraction wave on the recording process should be taken into account [11]. This nonlinear problem was treated in detail in paper [9]. It was shown in this paper that the energy interchange processes are determined by the imaginary part of PG-tensor $\beta_{ij\ell}$, i.e. by β_{ij}^{a} . In this case the processes of strengthening or weakening of wave amplitude are determined by the sign of PG-constant β_a , and they do not depend from the correlation of the light waves intensities.

We beleive that described the peculiarities of the optical recording of the holographic lattice help to determine the structure of PG-tensor $\beta_{ij\ell}$ in ferroelectric crystals.

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