FULLERENE C_{60} SINGLE CRYSTAL PHOTOCONDUCTIVITY IN MAGNETIC FIELDS

Golovin Yu. I., Lopatin D.V.*, Nikolaev R.K.(1), Rodaev V.V., Umrikhin A.V.

Tambov State University, 392622 Tambov, Russia

(1) Institute of Solid State Physics, Russian Academy of Sciences, 142432 Chernogolovka, Russia

* *Fax: +7 (0752) 710307, E-mail: lopatin@tsu.tmb.ru*

Introduction

Fullerenes and their chemical compounds are perspective materials for application in nanotechnology, spintronics and one-electronics [1]. Thus, the search of the ways of high-speed, contactless, selective management of electron-optical properties of fullerenes - based materials becomes actual problem. It is well known, that a weak magnetic field (MF) with an induction B<1 Tl effectively influences electron-optical properties of some organic compounds (for instance, anthracene, tetracene, etc.) [2].

The aim of the present work was revealing and research effects connected with influence of static and resonant microwave magnetic fields on photoconductivity of fullerene C_{60} single crystal.

Results and discussion

Influence of a weak MF on photoconductivity of fullerene C_{60} single crystal was researched for main optical transitions with energies 2.64, 3.07, 3.87 eV forming photoconductivity spectrum of fullerite C_{60} [3].

For these transitions dependences of an increase of photocurrent versus an induction of a magnetic field B are shown in figure 1. Form of these field dependences indicates the processes connected with modulation of concentration of singlet and triplet excitons by a weak MF [2].

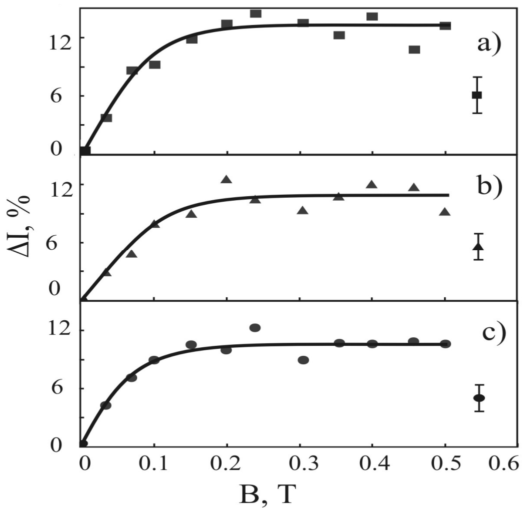

Fig 1. Magnetic field dependences of photocurrent for optical transitions with energies: a) 2.64 eV, b) 3.07 eV, c) 3.87 eV.

Magnetic resonance of the excited complexes of paramagnetic particles was studied with the aid of the ESR spectrometer RadioPan SE/X 2547 operating in the X-band and adjusted for the application of the PCDMR (photoconductivity-detected magnetic resonance). The C_{60} single crystal sample was excited at 470 nm (2.64 eV) by the light of xenon lamp transmitted through a high-aperture monochromator. The measurements were carried out at room temperature. Figure 2 shows PCDMR spectrum of C_{60} single crystal. The spectrum consists of one positive peak at g~2 with half-width ΔB=0.007 T. Occurrence of PCDMR signal is most probably connected with $\Delta m_S = \pm 1$ spin transitions in electron-hole pairs, which are produced during the free charge carriers generation. The half-width ΔB makes it possible to estimate the lifetime of these intermediate complexes as $\tau = h/(g\mu\Delta B) \sim 10^{-9}$ s, where (μ - Bohr magneton).

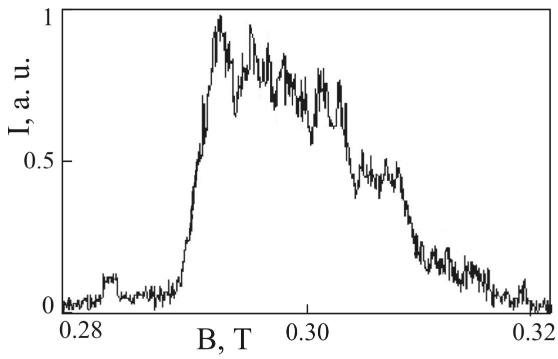

Fig 2. PCDMR spectrum of C_{60} single crystal (microwave frequency ~ 8.99 GHz).

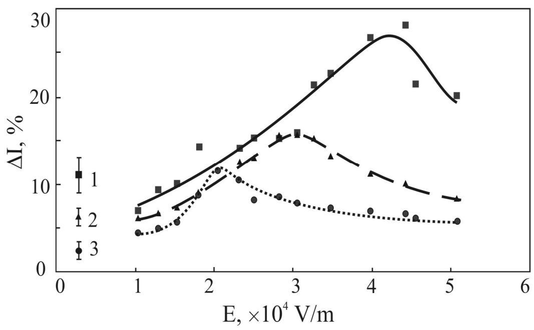

Fig 3. Electric field dependences of photocurrent for optical transitions with energies: 1) 2.64 eV, 2) 3.07 eV, 3) 3.87 eV.

It was revealed, that dependences of an

increase of photocurrent in MF with B=0.4 Tl versus intensity of electric field E (EF) applied to contacts of the sample are characterized by maxima at 4.2×10^4, 3.1×10^4 and 2×10^4 V/m at excitation by quanta of light with energies 2.64, 3.07, 3.87 eV, accordingly (fig. 3).

Influence of MF and EF on the photoconductivity of C_{60} single crystal can be presented as the following scheme. Light absorption gives rise to singlet (S) charge-transfer (CT) excitons. At the same time the more energy of quantum of excitation light, the more distance between electron and hole in the pair (exciton). Because of interaction with lattice the part of singlet CT-excitons will transfer to triplet state (T_0). As a rule, in molecular crystals recombination from singlet state *S* occurs more effectively than from triplet T one**.** The role of MF can be reduced to increase of population of T_0 in time τ due to intercombination transitions between S and T_0 caused by distinction of CT-exciton's components g-factors. This results in an increased probability of pair dissociating into free charge carriers and in a reduced probability of electron-hole recombination and, as a consequence, in an enhancement of the photoconductivity in the presence of a MF. Resonant microwave magnetic field includes $T_{\pm1}$ Zeeman levels in spin conversion. Transitions between $T_{\pm1}$ and T_0 deplete mixed state S-T_0 and increase the yield of triplet CT-excitons. It explains the appearance of positive ESR signal on photoconductivity of fullerene C_{60} single crystal.

Necessary requirement of efficient influence of MF on photoconductivity within this mechanism is the next condition providing the absence of spin system's thermolysation during the time particles stay in the pair and, simultaneously, high enough rate of S – T transitions: the lifetime τ of the particles' pair must be longer than the time needed for mixing of the spin states τ_{ev} , but shorter than the relaxation time τ_{rel}: $\tau_{ev}<\tau<\tau_{rel}$. For the majority of molecular crystals $\tau_{rel} = 10^{-6} - 10^{-8}$s. In our case, τ_{ev} for fullerene C_{60} single crystal can be estimated as 10^{-10} s.

Influence of EF on magnitude of photoconductivity of fullerene C_{60} single crystal in a weak MF can be explained in the following way. Increasing intensity of electric field causes the increase of radius of initial division r_0 between the components of electron-hole pairs and, consequently, the decrease of probability of geminate recombination. As a result, ΔI rise at small values of E. At higher values of E the probability of dissociation of pairs in states with uncorrelated spins increases, that causes nonlinear character of electrofield dependences of photoconductivity of fullerite C_{60} in MF. The distance between components of electron-hole pairs in states with uncorrelated spins was estimated as R≥3.4 nm.

Conclusions

It is shown, that the photoconductivity of C_{60} single crystal essentially depends on a spin state of the intermediate electron-hole pairs.

Acknowledgements

The work was supported by Governmental Research Program: "Development of Scientific Potential of the Higher Education School" (project № 717).

References

1. Trefilov V.I., Shchur D.V., Tarasov B.P., *et al.* Fullerenes – the foundation of materials of future, ADEF – Ukraine, Kiev, 2001.
2. Zel'dovich B. Ya., Buchachenko A. L., Frankevich E. L. Magnetic-spin effects in chemistry and molecular physics. Usp. Fiz. Nauk 1988; 155 (3): 3-45.
3. Golovin Yu. I., Lopatin D. V., Nikolaev R. K., Umrikhin A. V., Shmurak S. Z. Photoconductivity Spectrum of C_{60} Single Crystals Placed in a Magnetic Field. Doklady Physics 2002; 387 (12): 849-822.