Electroreflectance and Electronic Processes in Nanostructures with Fullerenes

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Nanostructures with C_{60} fullerenes are new promising materials for electronic, sensors and biomedical application. Their physical properties are determined by the film growth conditions and different external actions [1]. Inner mechanical stresses appears in the films during their manufacturing process. Their relaxation deteriorated the characteristics and reduced reliability of the corresponding devices. The C_{60} energy gap value dispersion is of 1.43 to 2.35 eV [2]. Therefore, an investigation of internal mechanical stresses and electronic processes in nanostructures with fullerenes is important for the technology development and for C_{60} films electronic properties prediction.

We present the results of studies on the films production and their structure perfection, mechanical stresses, the features electronic band structure and electronic processes in C_{60} nanostructures depending on the substrate type, and the influence on them microwave treatment. To reduce internal mechanical stresses, the films were deposited onto various non-heated substrates (Si, glass). Sublimation of microcrystalline C_{60} powder from effusion tantalum cell in vacuum at a pressure of 10^{-4} Pa and of 800 K temperature was used [3]. The films had a polycrystalline structures, their thickness was of 0.1 to 2 μm. The films mechanical stresses were determined on the heterosystems bending, using the Stoney's equation. The films were compressed on Si and too on glass substrate. The electroreflectance method was used to determination of mechanical stresses in C_{60} films and in Si substrate on interface.

This method was applied for the control of electron parameters of the nanostructures. Study of electronic band structure modulation spectroscopy method should help in understanding the nature and mechanism of light absorption of C_{60} solid. The high sensitivity of this method to details of the band structure is well known. The advantage of modulation spectra over classical spectra lies in the fact that they allow the find thin structure, usually hidden by the structureless background. This method is the most sensitive, since its signal is determined by the third energy derivative of the optical constants. He signal exist only at the critical points of the Brillouen zone in direct-transition region, vanishes as we move away from these point, and determined by both optical and electron properties of the semiconductor surface under investigation.

The electroreflectance spectra were measured by an electrolytic method in quartz electrolytic cells with 0.1 normal KCl water solution at the room temperature in of 1.5 to 3.6 eV range for C_{60} films and Si substrate in interface. Calculation of the electron parameters was realized, using energy location of the dominant peaks in the spectrum and its intensity. There were determined the

transitions energy E_g, the value of the phenomenological broadening parameter Γ (they depend on the type electron transition), the relaxation energy time of charge carriers τ and their mobility μ. Important data were obtained too concerning the film and interface film - substrate band structures, their structure perfection, the conductivity type of the films and the substrate on the interface, change of elastic stresses and charge scattering processes, as well as the effect of microwave irradiation on the properties of the heterostructures.

It been established, that C_{60} solid is direct - gap semiconductor with about 1.6 eV band gap (E_0) in the singular X point of the Brillouen zone. The next direct transition in this point (E_1) was observed in spectral range about 2.2 eV. The value of band gap depend on inner mechanical stresses. We calculated the value of this dependence on the basis of the data on electrorefletance spectra and the heterosystem bending. They were established: $-2.8 \cdot 10^{-10}$ eV/Pa and $-4.2 \cdot 10^{-10}$ eV/Pa for E_0 and E_1 transitions, respectively.

The electro-optical Franz-Keldysh effect in a built-in electric field was observed in C_{60}/glass on alternating-sign oscillations in electroreflectance spectra above fullerene optical absorption edge. There was determined the electro-optical energy and electric field value. In this heterosystem the doublet nature of the peaks of electroreflectance was observed. This was explained by the effect of surface size quantization of the electron energy in the electron enriched fullerene surface in interface and the presence of $E_g + e_1$ transitions.

To translate nanostructures in a state of equilibrium, we used the microwave irradiation. The relaxation mechanical stresses takes place, and after 10 s irradiation the mechanical stresses disappear, that is confirmed by substrate E_0 transition energy shift to a value 3.38 eV, which corresponds to the surface unstressed Si. In [1] it been show, that C_{60} film can change composition with the formation of the other carbon structures both in processes of the films deposition and by γ - irradiation. By microwave irradiation, the possibility was found to reduce the mechanical stresses in heterosystems and technological defects, to improve electronic parameters of C_{60} films and interface, and to fabrication of the nanostructures with C_{60} fullerene without their decomposition and the bending deformation.

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