Nanostructured surfaces

Oxidized silicon structures with surface II-VI nanocrystals

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Nanotechnologies of II-VI nanocrystals in oxidized macroporous silicon structures are perspective for the manufacture of light emitting elements. There were proposed the oxidized macroporous silicon structures with surface CdS and ZnO nanocrystals [1, 2] to produce efficient light-emitting elements by reducing the flow of electrons and its recombination outside the nanoparticle structure. In this work Si-SiO_2 interface in oxidized silicon structures with surface CdS and ZnO nanocrystals was investigated by methods of electroreflectance and photoconductivity. Direct interband transition energy, the broadening parameter and the relaxation time of charge carriers were identified from electro-reflectance spectra of silicon structures with silicon oxide layer of a 7, 15 and 30 nm thickness and ZnO, CdS nanocrystals. Photoconductivity spectra of silicon structures with ZnO nanocrystals on silicon oxide layer and structure of macroporous silicon with oxide layer with thickness of 30 were measured too.

There were revealed Franz-Keldysh effect [2], a built-in electric field and surface quantization of charge carriers in the Si-SiO_2 region (Fig.1). High-energy Franz-Keldysh oscillations with photon energy higher 3.6 eV indicate the presence of the built-in electric field for ZnO and CdS nanocrystals on silicon oxide thickness 15 and 30 nm. It is possible to determine the dependence of the slope $(4/3\pi)*(Em-Eg)^{3/2}$ on the number of oscillations and the value of the built-in electric field for the thickness of the oxide layer 15 nm and 30 nm equaled to $(3\div8)*10^5$ V/cm. Broadening parameter increases with the oxide thickness from 183 meV to 228 meV for CdS nanocoating, and from 147 meV to 203 meV for ZnO nanocoating, and relaxation time of charge carriers decreased.

In the main peak area (Fig.1) of the electroreflectance spectra there were detected splitting of peaks as a result of the quantization of charge carriers in the near-surface region of silicon. The splitting of peaks corresponds to one quantized energy level of 40 meV (oxide thickness of 15 nm) and two quantum levels with energies of 70 meV and 140 meV (oxide thickness of 30 nm). The electric field intensity F_S was determined based on the model of the triangular potential well. The electric field intensity in the near-surface region of silicon with ZnO nanocrystals is equaled to $(2\text{-}2.3)*10^5$ V/cm for first quantum level and to $3*10^5$ V/cm for second one. In the near-surface region of silicon with CdS nanocrystals F_S is equaled to $(0{,}8\text{-}2)*10^5$ V/cm for first quantum level and to $3*10^5$ V/cm for second one. Such data are lower of the F_S values obtained via Franz-Keldysh oscillations.

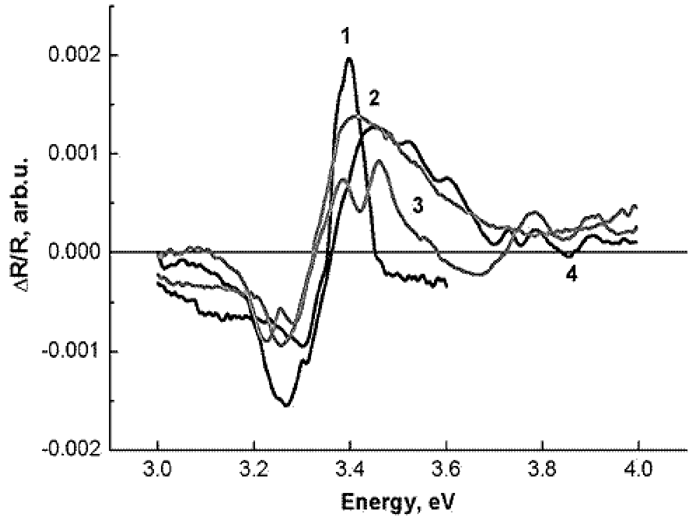

Fig.1. Electroreflection spectra of silicon substrate (1) and silicon structures with ZnO nanocrystals on silicon oxide layer of a: 7 nm (2), 15 nm (3), 30 nm (4) thickness.

Photoconductivity spectra of oxidized silicon structures with CdS and ZnO nanocrystals were measured at room temperature. Photoconductivity maxima of investigated structures were shifted 0.17÷0.20 eV to the higher photon energies, which can be attributed to the quantum-sized effect in the boundary silicon - SiO_X. This conclusion is confirmed by measuring the photoconductivity in spectral range 1.4-2.0 eV. It was detected splitting in the area of main peak of photoconductivity of indirect interband transition for silicon oxide thickness 15 nm and 30 nm due to surface quantization of charge carriers in the Si-SiO_2 region. The electric field intensity F_S was determined based on the model of the triangular potential well too. The electric field intensity in the near-surface region of silicon with ZnO nanocrystals is equaled to $1{,}9*10^5$ V/cm for first quantum level and for silicon with CdS nanocrystals F_S is equaled to $1{,}8\text{-}2*10^5$ V/cm for first quantum level and to $3*10^5$ V/cm for second one. Obtained data correlate with the results of electroreflectance spectra measurement in the main peak area (Fig.1) for oxidized macroporous silicon structures with surface CdS and ZnO nanocrystals.

1. *Karachevtseva L., Kuchmii S., Lytvynenko O., Sizov F., Stronska O, Stroyuk A.* Oscillations of light absorption in 2D macroporous silicon structures with surface nanocoatings // Appl Surf Sci. – 2010. – **257**, №8. – P.3331–3335.
2. *Karachevtseva L.A., Ivanov V.I., Lytvynenko O.O., Parshin K.A., Stronska O.J.* The impurity Franz-Keldysh effect in 2D photonic macroporous silicon structures // Appl Surf Sci. – 2008. – **255**, №5. – P.3328-3331.