Peculiarities of Electric Current Propagation in Silicon Samples with Quantum Dots

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It is well known that the volt-ampere characteristics (VAC) of semi-conductors with deep levels (DL) may consist of three or more regions. In the first region, a linear dependence of the electric current on the applied voltage is observed, i.e. Ohm's law is valid. In the second region, there is a power law dependence of the electric current on the applied voltage. In the third region, a sharp increase in the electric current is observed above a certain applied voltage. With rising electric stress, a decrease in the electric current is observed, and a region with a negative differential conductivity (NDC) may be observed. Usually, the NDC is an N- or S-type. Combinations of NDC's with both N- and S-types are also possible. Under certain conditions they may replace each other, and transformations of S-like VAC's into N-like ones are possible. The statistical characteristics may be described by a more complicated law (polysemy or accumulation of current). Observation of VAC within the NDC region is related to the instability of the electric current, i.e., depending on the experimental conditions, one may observe oscillations of the current or voltage with various frequencies and shapes.

In this work, we present experimental results on the dependence of the electric current density, j, on the electric stress of the field for strongly compensated samples of Zn–doped silicon with quantum dots. In experiments, we used silicon samples of N-type conductivity diffusively doped with Zn. The implantation of Zn (99.99 % purity) was carried out by the high-temperature diffusion method into N-type silicon, with a P concentration of ~ 5×10^{15} cm^{-3}. The concentration of Zn was ~ 4×10^{15} cm^{-3}. After the process of high-temperature diffusion, the samples possessed relatively high electric resistances (~ 1.1×10^{3} Ω·cm at T = 300 K), with concentrations of electrons ~ 1.47×10^{12} cm^{-3}.

A study of the VAC in samples of N-Si<P,Zn> was carried out, at different background illuminations of integral light, at a temperature T = 80 K. Dark VAC was not measured at T = 80 K, due to high specific resistance of the N-Si<P,Zn> sample. The VAC of studied samples consists of several regions. The first region (where the electric stress is less than 8 V/cm) has a linear dependence. The second region (where 8 V/cm ≤ E ≤10 V/cm) has a quadratic law dependence. In the third region (where 10 V/cm ≤ E ≤ 20 V/cm), we observed a sharp increase in the electric current. Further increase of E leads to the saturation of the electric current. After that, we observed two consistent regions with NDC (i.e. in the N region), which are observed when 80 V/cm ≤ E ≤ 120 V/cm and 140 V/cm ≤ E ≤ 180 V/cm, respectively. In the first region with NDC, within a certain range of E, we observed the current's infra-low frequency oscillations, with modulation depths of 99.9 %, which disappear after approaching some magnitude of E. In the second region with NDC, after approaching some magnitude of E, we observed quasi-harmonic current oscillations, which occur from one time-like peak to two time-like ones, with modulation coefficients of 50 % and 99.99 %, respectively, with rising E. A further increase of E leads to a sharp increase in current at some critical E, i.e. we observe an S-like region of VAC.