Bistability and hysterisis in self-organized quantum dot structures

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Field effect transistors with embedded InAs quantum dots (QD) near a two dimensional electron channel are showing a distinct **hysterisis (gibt es das Wort?)** in their electron concentration versus gate voltage characteristic [1] which makes them potentially applicable for new memory devices. The **measurable** shift in those characteristics remains for several seconds [1]. We investigate this bistable behaviour with a numerical approach and therefore can discuss different explanations for capture and escape mechanisms which have to lead to a lifetime **comparable** with the experimental values [1].

Applying a voltage to a device as shown in the inset of figure 2 fills the QDs with electrons. The charge captured within the QDs is detected by a change of the electron concentration within a two dimensional electron gas. For fast switching the electrons may be erased by light illumination [1]. In this work we investigate the dark charging and **discharging** process.

Our model takes into account the highly **non-homogeneous** electron charge distribution of this hetero-structure, i.e. bulk electrons, two dimensional electron gas, electrons localized in the QDs [2].The simulation solves self-consistently the Poisson equation, the drift-diffusion equation, and the rate equation which describes the dynamics of the QD electron capture and escape mechanism. For the Auger effect **as well as** for phonon-assisted capture and escape one finds

$$\partial_t n_{QD} = T_{Auger} n(np_{QD} - nn_1) \qquad (1)$$

$$\partial_t n_{QD} = T_{therm}(np_{QD} - nn_1) \qquad (2)$$

While the number of electrons in the QDs increases or decreases linear with the free electron density n around the QDs for the phonon-assisted mechanism a square dependence is found for the Auger effect. The calculation shows that the lifetime determined by the Auger effect is significant longer than for the phonon-assisted mechanism. A comparison with experimental values for the lifetime [1] allows a discussion about which capture and escape process dominates.

[1] G. Yusa and H. Sakaki, Appl. Phys. Lett. **70**, 345 (1997)
[2] R. Wetzler, A. Wacker, E. Schöll, C.M.A. Kapteyn, R. Heitz and D. Bimberg, Appl. Phys. Lett. **77**, 1671 (2000)

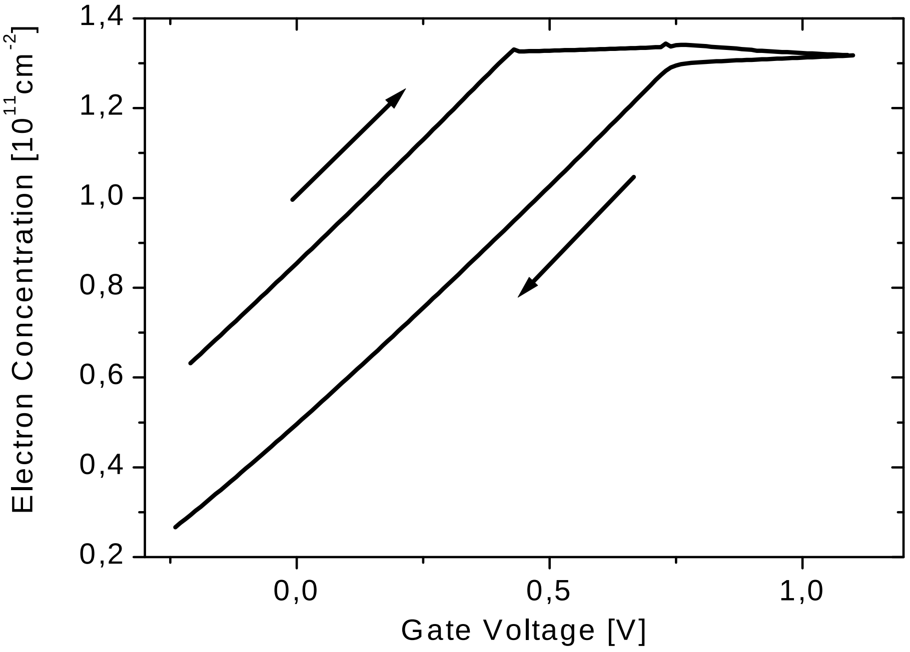

Figure 1: Hysterisis in the electron concentration vs. gate voltage characteristic, calculated for 77 K in the dark

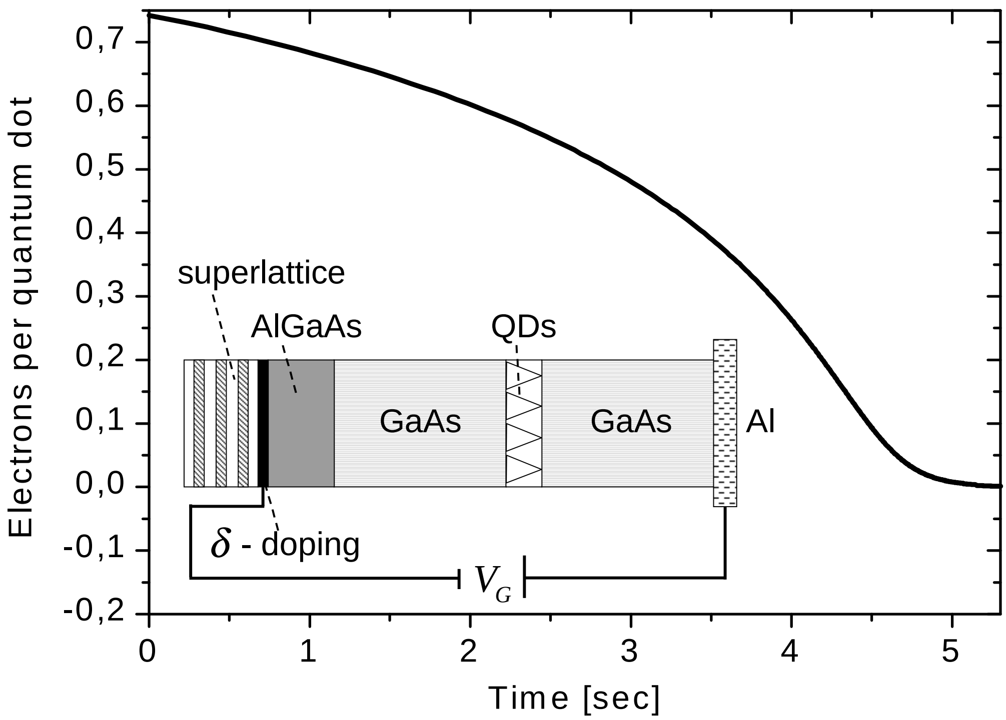

Figure 2: Decay of the number of electrons captured within dots vs. time, modeled with the Auger process at 300 K, inset shows the investigated device [1]