Enhanced numerical design of HgCdTe MWIR HOT $P^{+}\nu N^{+}$ photodiodes

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***Abstract*- Various configurations of $Hg_{1-x}Cd_xTe$ heterostructures were investigated to find the best solution for MWIR non-equilibrium photodiodes. A promising solution is the use of a complementary barrier infrared detector [1] in which we can limit the impact of generation on contact areas and significantly reduce surface leakage currents. We have choose for simulation $P^{+}\nu N^{+}$ photodiodes structure working at 230K.**

I. Introduction

In recent years, we have been observing the development of research on photon infrared detectors operating at temperatures above 200 K [2]. An important place is occupied by detectors operating in the mid-infrared (MWIR) range. In order to suppress the Auger generation, which is the decisive mechanism limiting parameters of the detectors, the non-equilibrium operating conditions resulting from the polarization of the detector in reverse direction are used. This effect is achieved by the phenomenon of exclusion and extraction from the absorber area. The absorber should be slightly doped, while the surrounding areas should be strongly doped and have an extended energy gap. The extension of the energy gap reduces the thermal generation rate in these areas, while a strong doping decreases the series resistance. By polarizing the structure, we want a built-in electric field to be deposited in the absorber area causing the effect of exclusion and extraction. However, the built-in electric field may cause deterioration of parameters by increasing the rate of SHR processes (mainly caused by trap assistant tunneling). SHR processes are related to both mercury gaps and dislocations. In the simulations, we consider the contribution of these mechanisms to the parameters of the detectors based on calculation for previously described model [3] for detectors operating in the long-term operating range (LWIR) by using our own computer program.

II. Results of calculations

The influence of detector architecture on current sensitivity and dynamic resistance of photodiodes was investigated. Below, in the Figure 1 is an example of $P^{+}\nu N^{+}$ type heterostructure with implemented complementary barrier ($P^{+}b\nu bN^{+}$ type detector) used for calculations of physical parameters along AA' cross section. Figure 2 shows the spatial distribution of donors (N_D), acceptors (N_A) concentration and trap centers (N_T) and mole fraction x calculated for the $P^{+}\nu N^{+}$ type reference structure without implementing potential barriers.

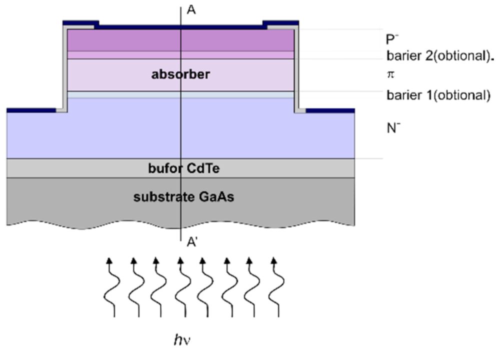

Fig. 1. Model of $P^{+}\nu N^{+}$ mesa type photodetector used for simulations.

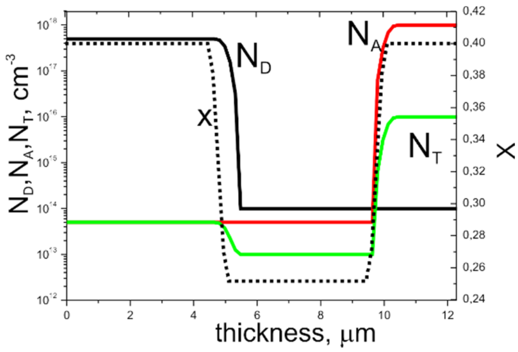

Fig. 2. Special distribution of donor N_D, acceptor N_A mercury vacancy N_T concentration N_T and x mole fraction.

Figure 3 shows the current-voltage characteristics I(V) and dynamic resistance for the same $P^{+}\nu N^{+}$ type reference structure. The quantum efficiency is also presented in the function of the bias voltage in the reverse direction (Fig. 4). These figures refer to the structure shown in Figure 2.

To improve the above detector's parameters, two additional barriers were implemented, thus creating a complementary barrier detector. Figure 5 shows simulation results for the spatial distribution of donors (N_D), acceptors (N_A) concentration and trap centers (N_T) and mole fraction x in complementary barrier detector. Figure 6 shows the spatial distribution of thermal generation rate determined by different mechanism such as Auger 1, Auger 7, SHR, caused by mercury vacancies and dislocations, radiative mechanism with taken into account photon reabsorption effect.

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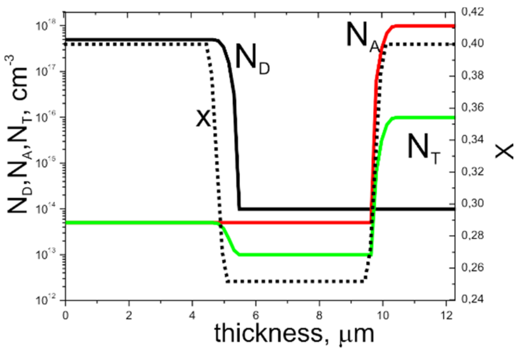

Fig. 2. Special distribution of donor N_D, acceptor N_A mercury vacancy N_T concentration N_T and x mole fraction.

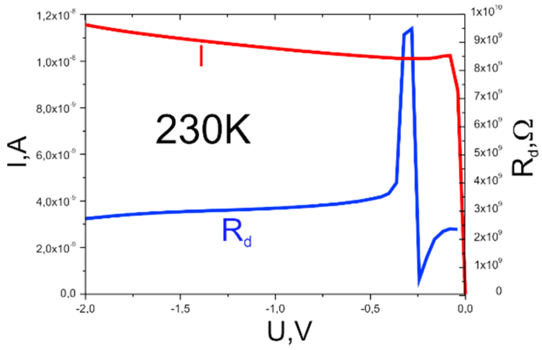

Fig. 3. Current and dynamic resistance as a function of reverse bias voltage.

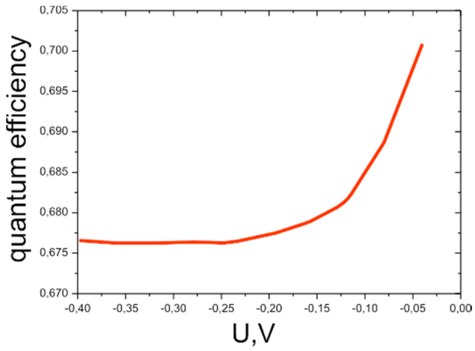

Fig. 4. Quantum efficiency as a function bias voltage.

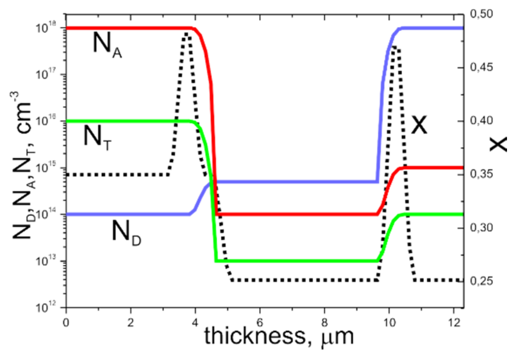

Fig. 5. Special distribution of donor N_D, acceptor N_A mercury vacancy N_T concentration N_T and x mole fraction in two barrier structure.

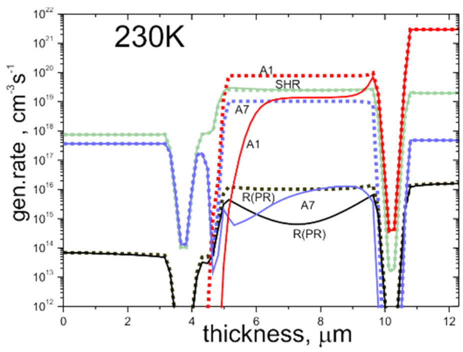

Fig. 6. Special distribution of thermal generation rate determinant by different mechanism. Dashed lines-unbiased structure, solid lines U=-400 mV.

Figure 7 shows the dependence of current and dynamic resistance as a function of reverse bias voltage.

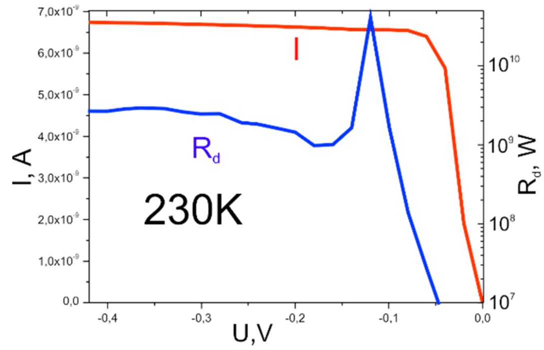

Fig. 7. Current and dynamic resistance as a function of reverse bias voltage in two barrier photodiode.

III. Conclusion

The use of the phenomenon of exclusion and extraction in HgCdTe heterostructures allows us to obtain photodiodes working at near room temperatures with quantum efficiency of above 60%. A promising solution is the use of a complementary barrier detectors in which we can limit the impact of generation in contact areas and significantly reduce surface leakage currents. We will carry out further calculations to design optimal photodiodes with the highest parameters.

Acknowledgment

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