Light Emitting Diode with Charge Asymmetric Resonance Tunneling

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We suggest a LED structure based on a system of two wells with Charge Asymmetric Resonance Tunneling (CART) which allows to enhance the number of the electrons captured into the active layer with quantum well and fabricate highly efficient LED devices.

In LEDs the single quantum well or multiple quantum wells are used as the active layer. For fabrication of a highly efficient device the number of carriers recombined inside the active layer should be maximized and the number of carriers recombined outside the active layer should be minimized. This needs optimization of capture rates for electrons and holes into the active layer. Usually in semiconductors effective masses of heavy holes are much higher and mobilities much less then those for electrons. Therefore, part of the electrons not captured in the active layer, escapes the active layer and recombines outside of it. This reduces the efficiency of LED devices.

To provide a highly efficient LED structure for semiconductors with different masses and mobilities of electrons and holes such as III-V and II-VI group semiconductors we suggest a system of two wells with Charge Asymmetric Resonance Tunnelling, Fig.1. The system consists of an emitter of the electrons, an emitter of holes and an active layer. The hole emitter is coupled with active layer in such a way that holes can be freely supply into the active layer without a barrier. The electron emitter is coupled to the active layer via a barrier. The barrier design uses the charge asymmetric resonance tunnelling phenomenon which allows to make the barrier transparent for electrons and blocking for holes. The phenomenon of the charge asymmetric resonance tunnelling uses the quantum mechanical effect of strong exponential dependence of the potential barrier tunnel penetrability on the mass of the tunnelling particle. This phenomenon can be used in LED design for all semiconductors which have heavy hole masses significantly higher than electron masses. Such semiconductors are most of III-V and II-VI Group semiconductors. To achieve the CART phenomenon the electron energy level positions in active layer should be fitted to the electron energy level position in the emitter by the adjusting material composition and sizes of the emitter and the active layer. The height and the width of the tunnel barrier should be chosen in range 5- 50 to make it transparent for electrons and not transparent for holes.

At the same time the hole energy level positions in active layer should be chosen lower than the energy level positions for holes in the electron emitter. This forbid the hole penetration without thermal activation into the electron emitter. It is important that even the small amount of thermally activated holes have no possibility to tunnel into the electron emitter for the chosen barrier width because of their heavy mass.

Advantages of this design are:

- increase of capture efficiency of the electrons into the active layer due to direct tunneling of the electrons from the electron emitter into the active layer
- suppression of the electron leakage into the hole emitter
- elimination of the parasitic light generated outside the active layer
- the electron emitter function also as a good current spreading layer
- no need to use electron current blocking layers as an element of the technology

In the paper we report results of experimental investigation and theoretical modelling of the LED with CART devices for green and blue light.

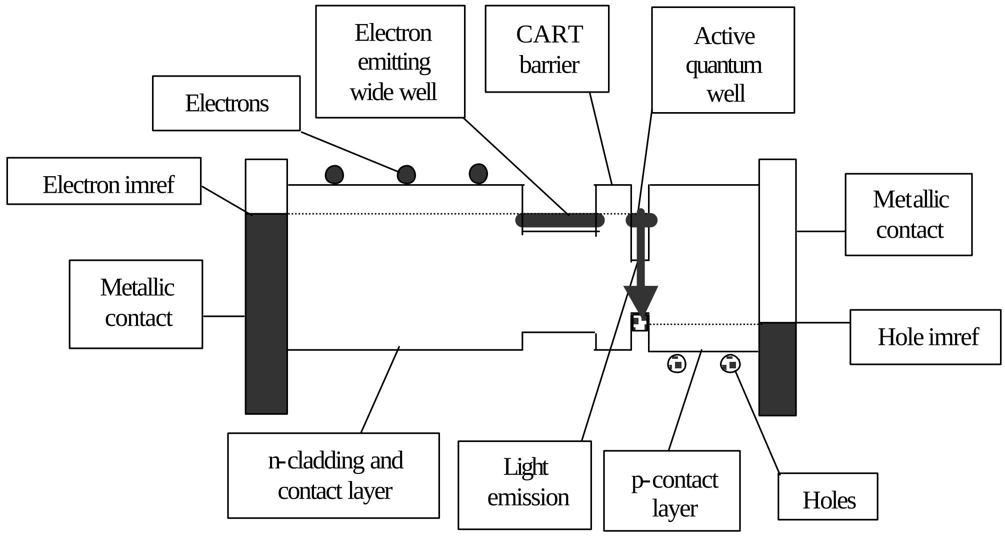

Fig.1. General scheme of the CART LED.