Electrostatics of a nanowire heterostructure radial *p-i-n* diode

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Introduction

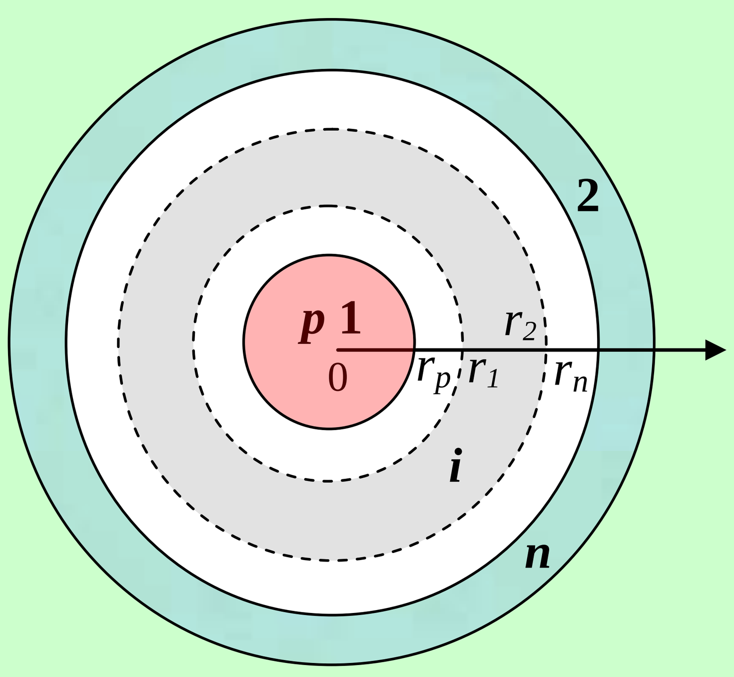
Radial core-shell nanowires have got broad applied in modern nano electronics as radiation detectors, photodiodes, solar cells, light emittind diodes and so on. All those applications are based on *p-n* junction. However in many cases, *p-i–n* junctions prove to be more effective than simple *p-n* junctions because they extend a region of the built-in electric field.

Furthermore, not homo but hetero *p-i–n* junctions are used often in the applications when it is necessary for a certain layer to have another substantial properties. It is known that in nanostructures, restrictions connected with lattice mismatch are eliminated in significant degree because stress in them relaxes and do not create interface defects. This fact expands significantly the range of possible materials for construction of such devices.

Therefore it is of interest to consider in details electronic properties of radial heterostructure *p-i–n* diode.

Method and results

The problem consists of solution of Poisson’s equation for 3-layer semiconductor structure with cylindrical symmetry.



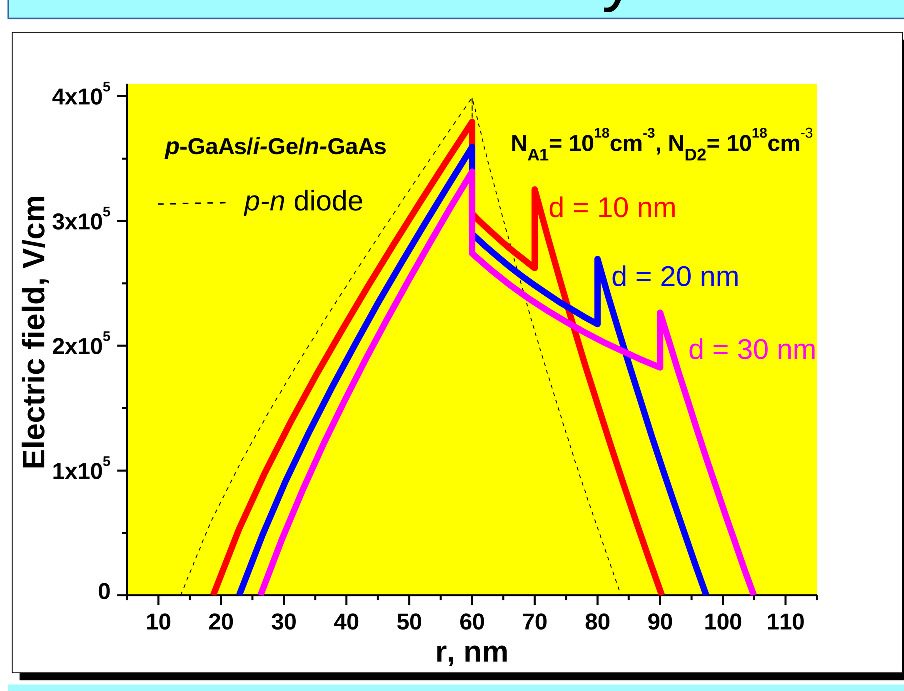
Two types of the structures have been considered – symmetrical by doped materials (i.e. when *p-* and *n*-layers are made of the same semiconductor and i-layer – of other material) and asymmetrical (when all 3 layers are made of different semiconductors).

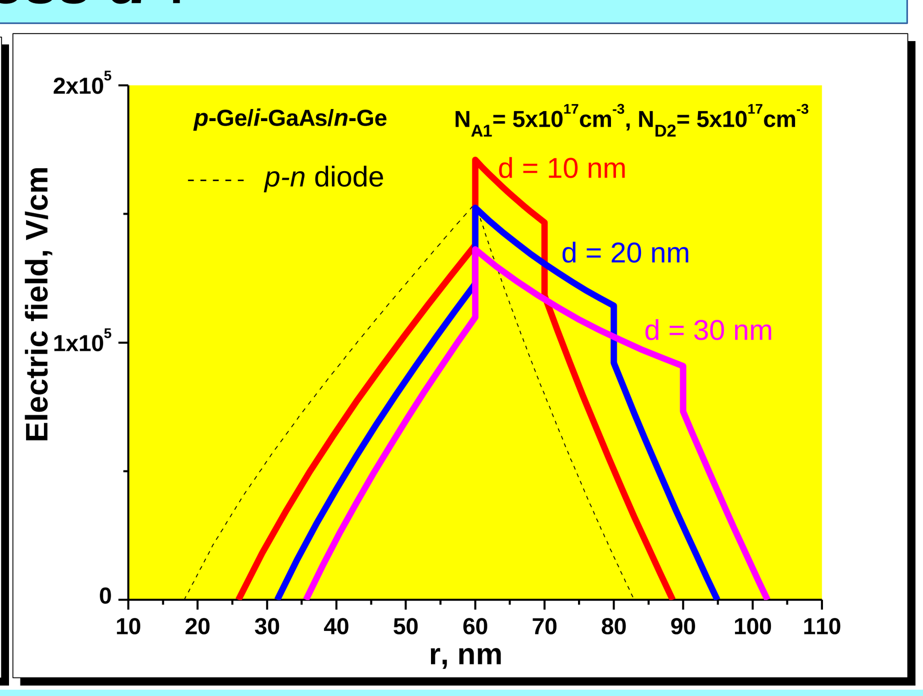
In the first case two different situations can appear - the i-layer with narrower band gap than that of the doped layers and vise versa.

In the second case two distinct situation are possible as well – band gap of the core material is narrower than that of the doped shell and vise versa.

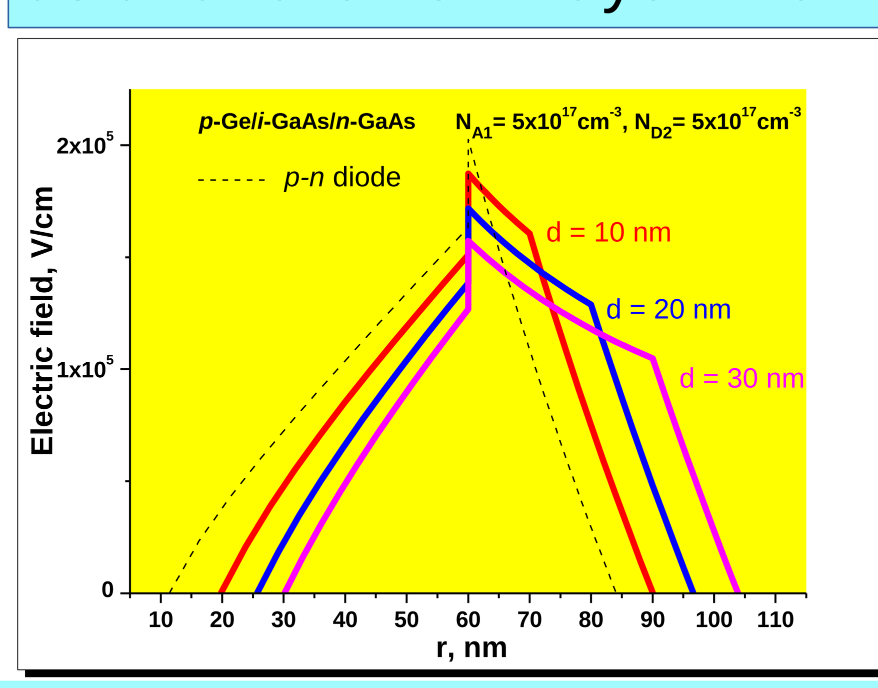
The numerical calculations are performed for radial *p-i-n* structures on the base of Ge and GaAs because this heteropair has good lattices matching; therfore no appreciable density of interface states can be associated with this heterojunction.

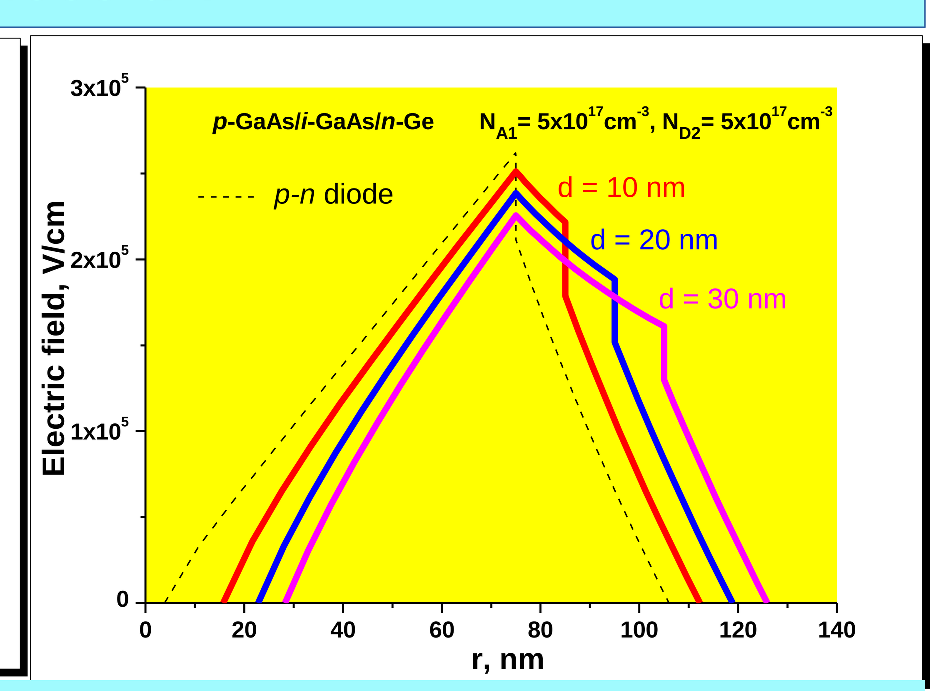
Radial electric field distribution in **symmetrical** *p-i-n* structures *p*-GaAs/i-Ge/*n*-GaAs and *p*-Ge/*i*-GaAs/*n*-Ge as a function of *i-* layer thickness ***d*** .



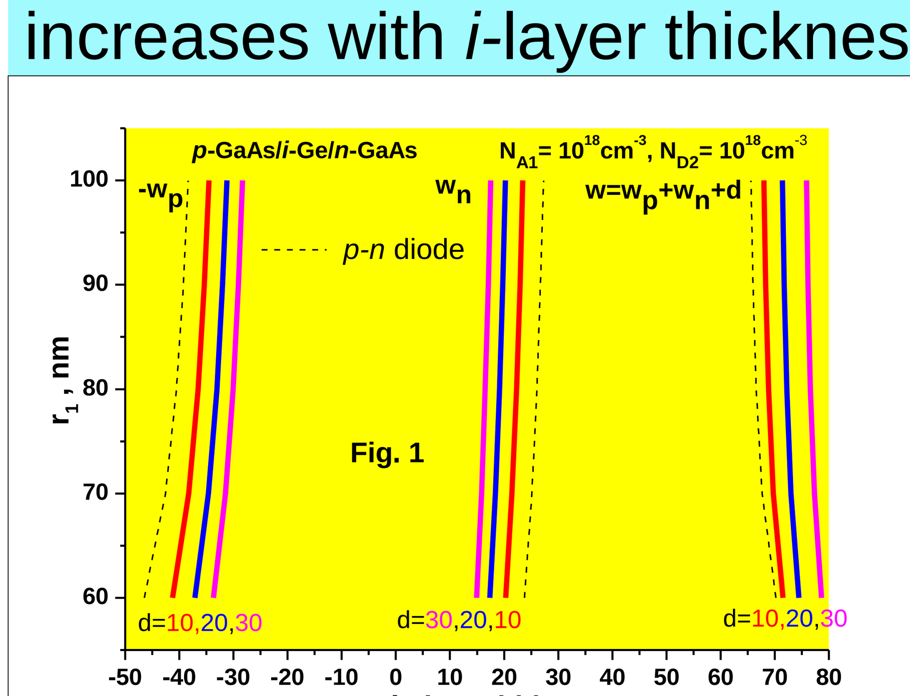


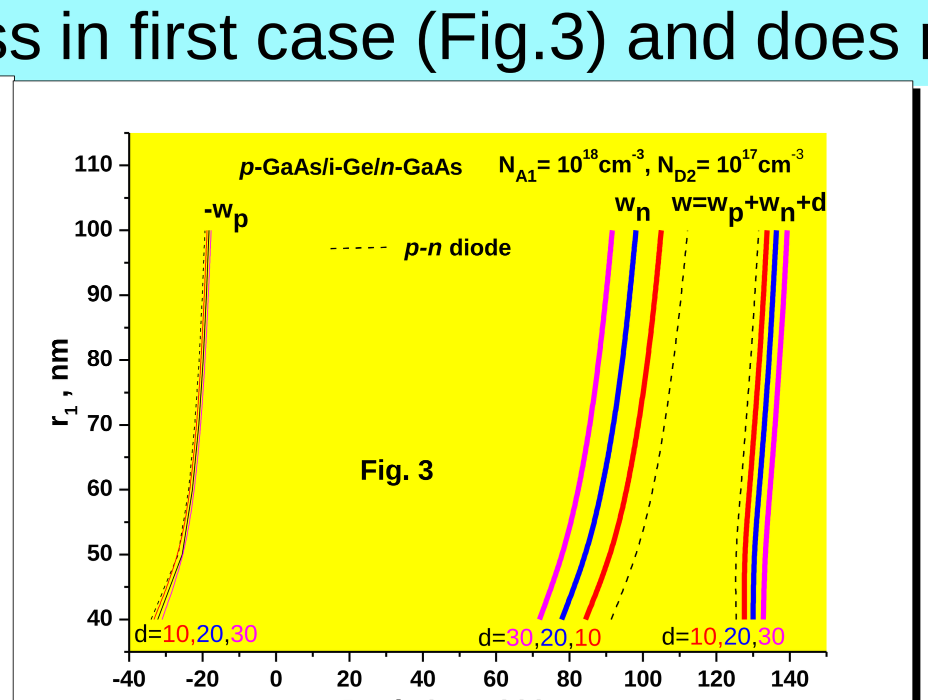
Radial electric field distribution in **asymmetrical** *p-i-n* structures *p*-Ge/*i*-GaAs/*n*-GaAs and *p*-GaAs/*i*-GaAs/*n*-Ge as a function of *i-* layer thickness ***d*** .

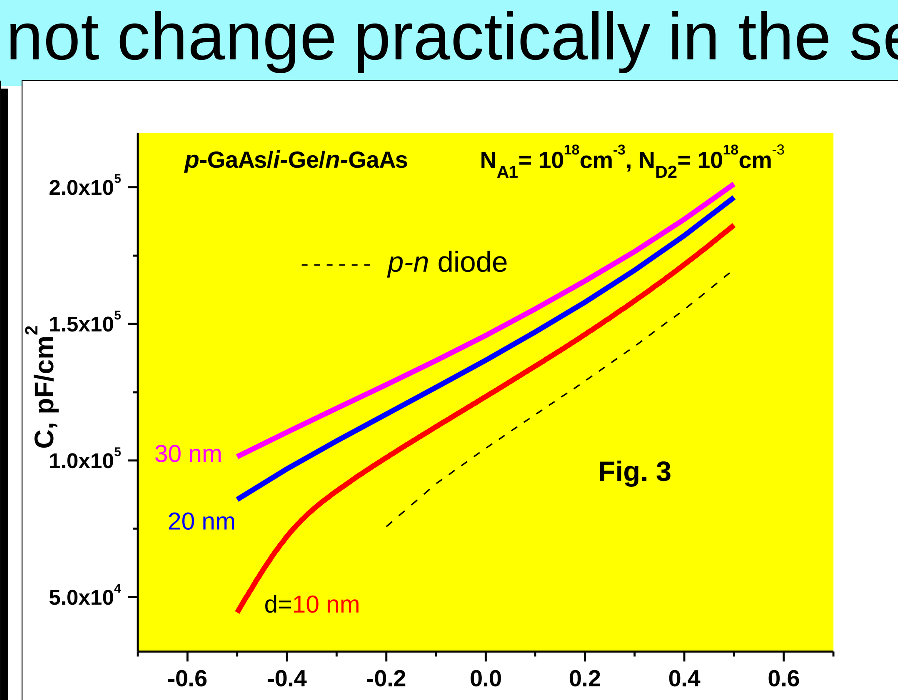


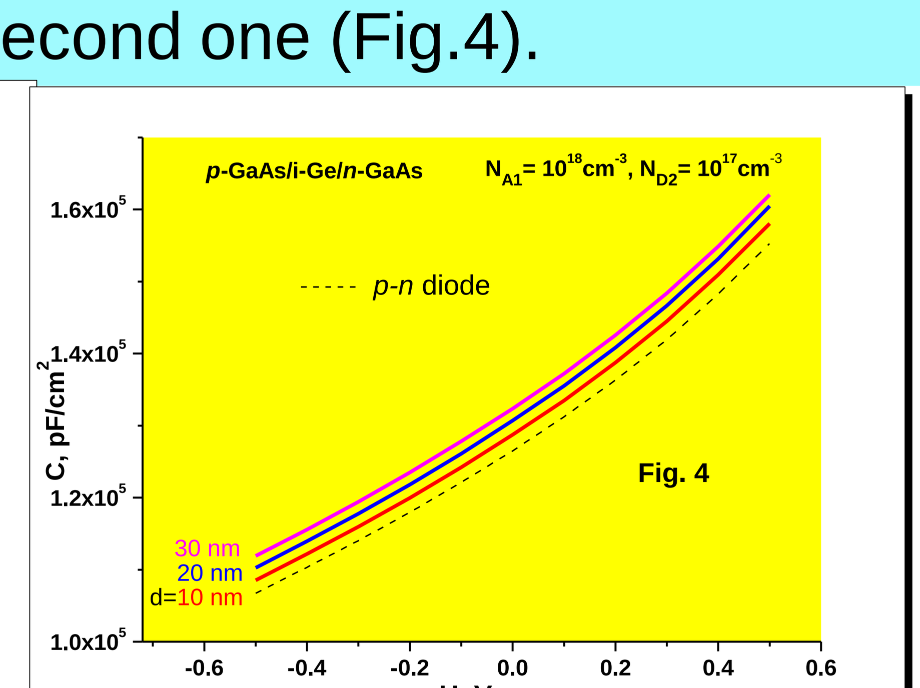


Inserting *i*-layer into *p-n* junction extends the electric field region not always. At high enough doping levels (when depletion widths in *n-* and *p*-layers are rather small), increasing of electric field region at the expense of *i*-layer is really achieved (Fig.1). But at middle doping levels, the depletion widths so decrease under inserting *i*-layer that total width of the region of built-in electric field does not increase practically (Fig.2). Accordingly, capacity of the *p-i-n* diode essentially increases with *i*-layer thickness in first case (Fig.3) and does not change practically in the second one (Fig.4).









Conclusion

So heterostructure character of the *nanowire p-i-n* diode changes essentially profile and magnitude of the built-in electric field in comparison with homo *p-i-n* diode (*Borblik V.L.* Electrostatics of nanowire radial *p–i-n* diode. SPQEO, 2019, **22**, N 2. P. 201-205).