Effects of non-reciprocity in multilayer semiconductor nanowires with radial subsequence of the layers

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Introduction

In recent time, a great attention is attracted by multilayer semiconductor nanowires in which the material and/or doping type changes in radial direction. In particular, core/shell nanowires have found broad application as radiation detectors, solar cells, light emitting devices, devices for energy harvesting, field-effect transistors, high electron mobility transistors, and heterojunction bipolar transistors.

As distinct of traditional electronics (microelectronics) where semiconductor structures are planar objects, core-shell nanowires are characterized by cylindrical geometry. This fact changes their properties radically. In particular, if material of the core becomes the shell material and material of the shell becomes the core material ("inverting" of the structure), we obtain (at the same layer's parameters) completely another device. I.e. an effect of non-reciprocity takes place.

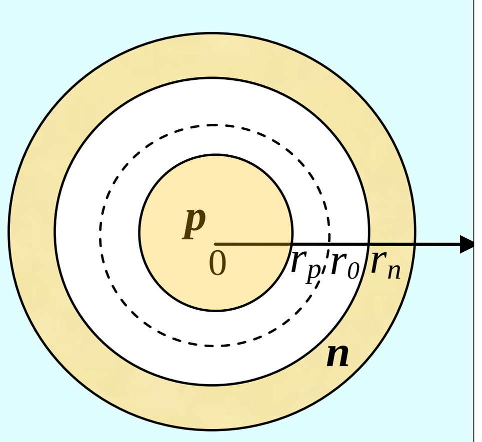
Method and results

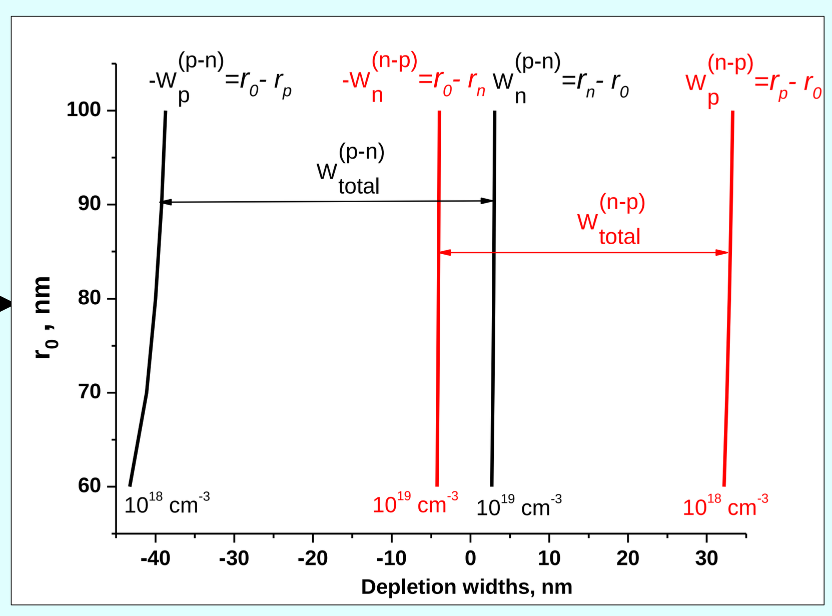
Below for illustration of non-reciprocity effects in semiconductor core-shell nanowires, a number of radial *p-n* junction structures are considered. In designation of the junctions, we stand conductivity type of the core material at the **first** place.

The results concerning of electrostatic properties are obtained by solution of Poisson equation in cylindrical geometry in depletion approximation. The results concerning transport properties are based on solution of continuity equation for current density, also in cylindrical coordinate system.

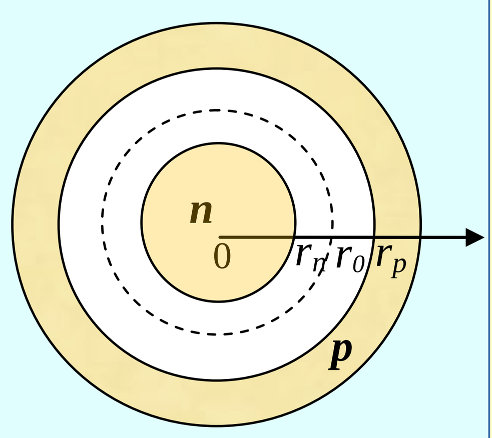
1. Radial homo p-n and n-p junctions

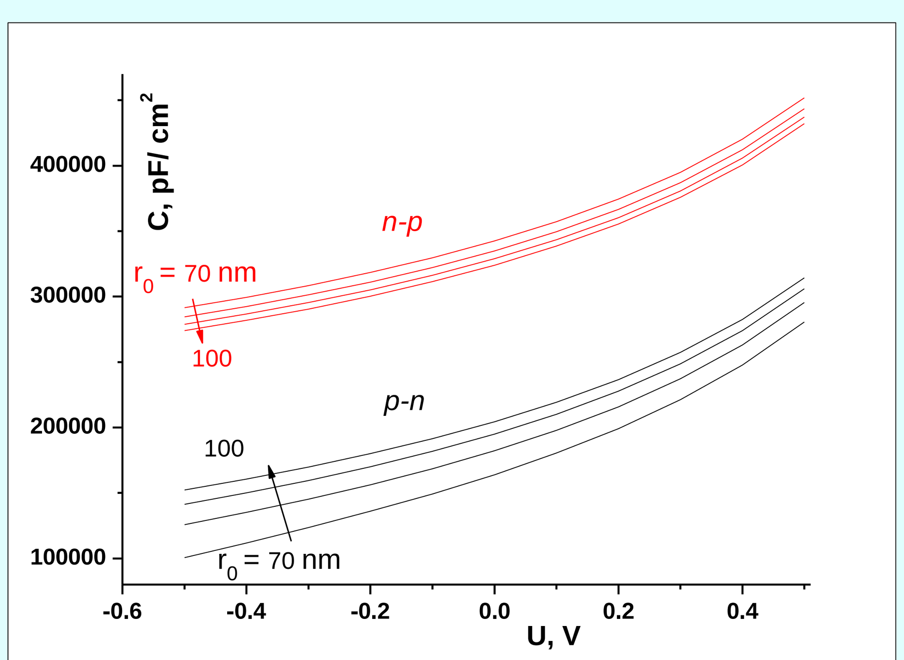
'Original'





"Inverted"

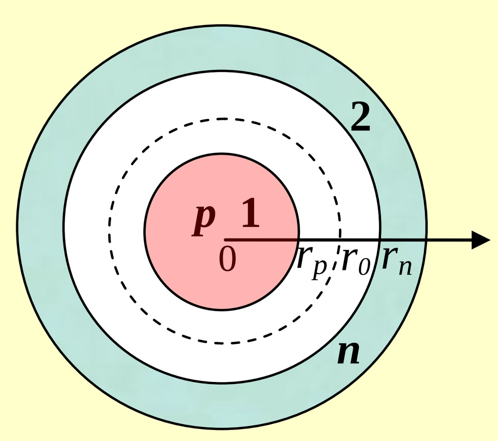


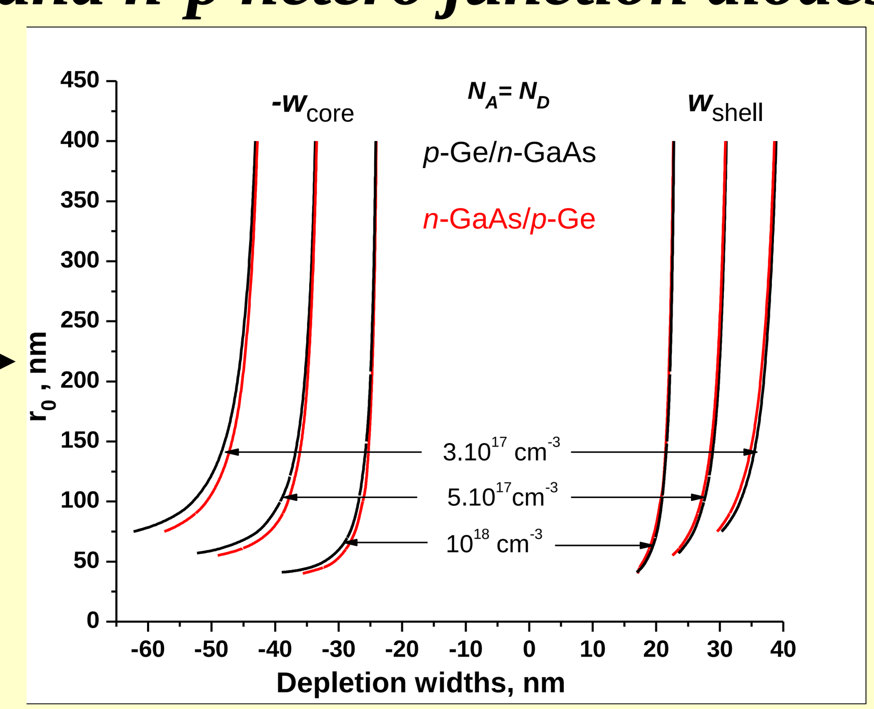


Depletion widths and capacitances of the "original" (black). and "inverted" (red) structures prove to be completely different (at the same doping levels).

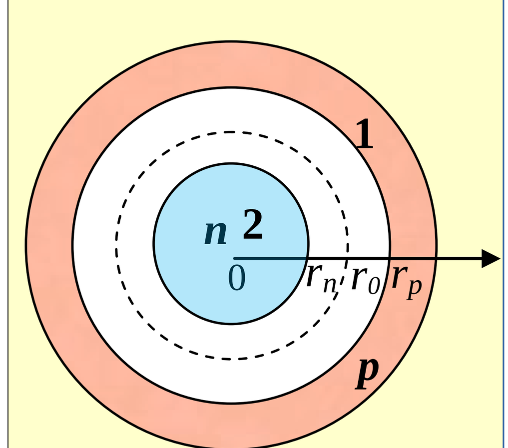
2. Radial p-n and n-p hetero junction diodes

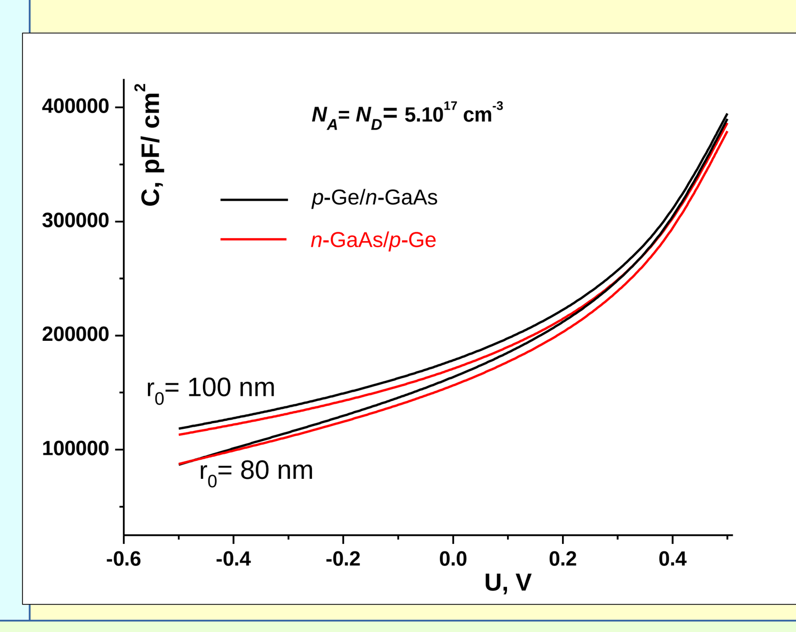
'Original'





"Inverted"



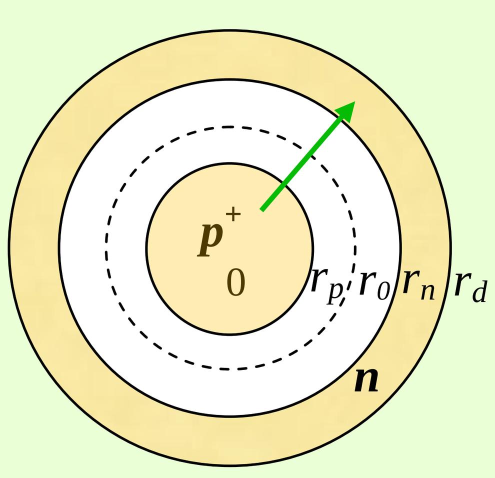


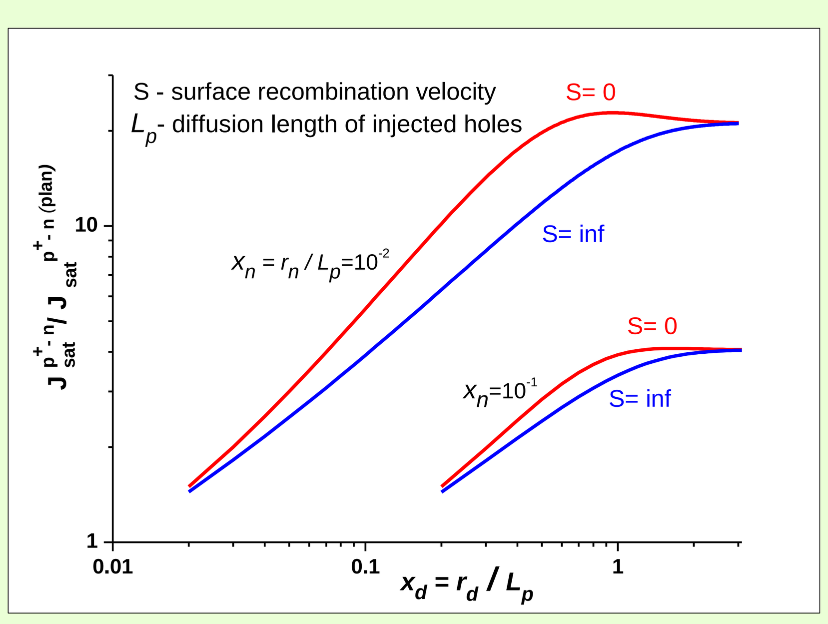
Here increasing the core depletion width along with decreasing the shell depletion width (under decreasing junction radius r_0) results in change of relative share of the constituent materials in full depletion region.

3. Density of the saturation current in radial p+-n and p-n+ diodes

'Original'

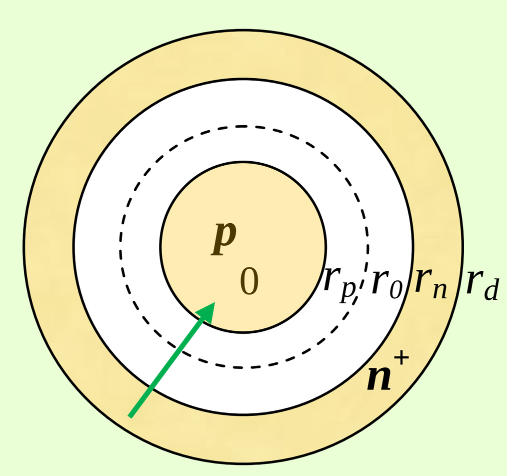
$N_A >> N_D$

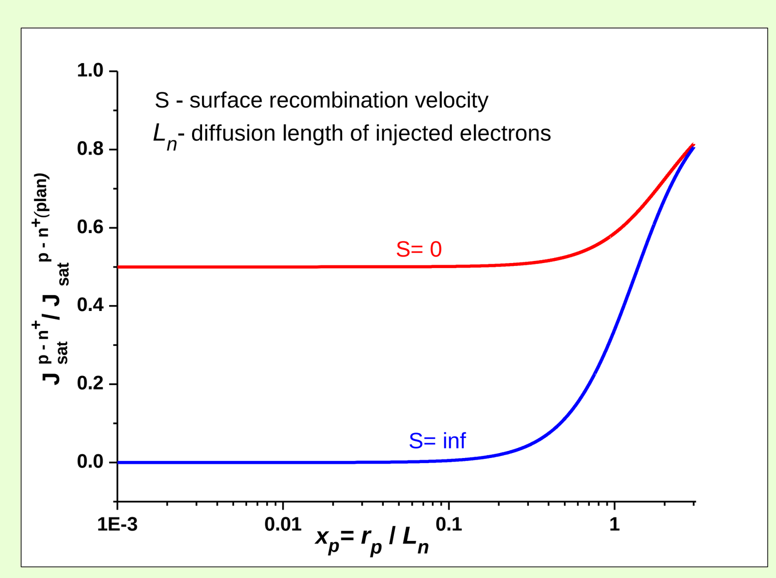




"Inverted"

$N_D >> N_A$





When injecting out of the core to shell, density of the saturation current is larger than that of planar diode with the same parameters, but when injecting in opposite direction (out of the shell to core), density of the saturation current is smaller than "planar" one.

Conclusion

So, change of sequence of deposited layers in the core-shell nanowires changes their electronic properties and can be additional degree of freedom when designing semiconductor devices based on such the structures.