A simple theory of LEDs

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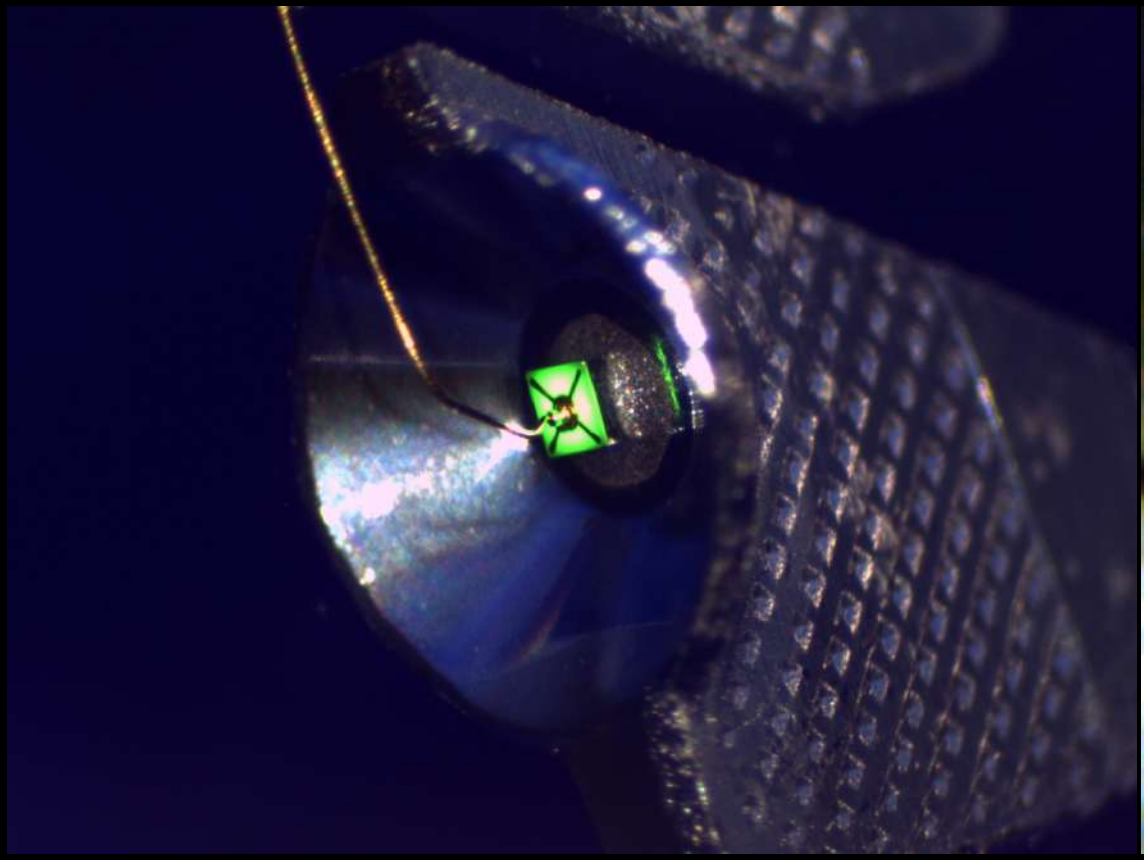
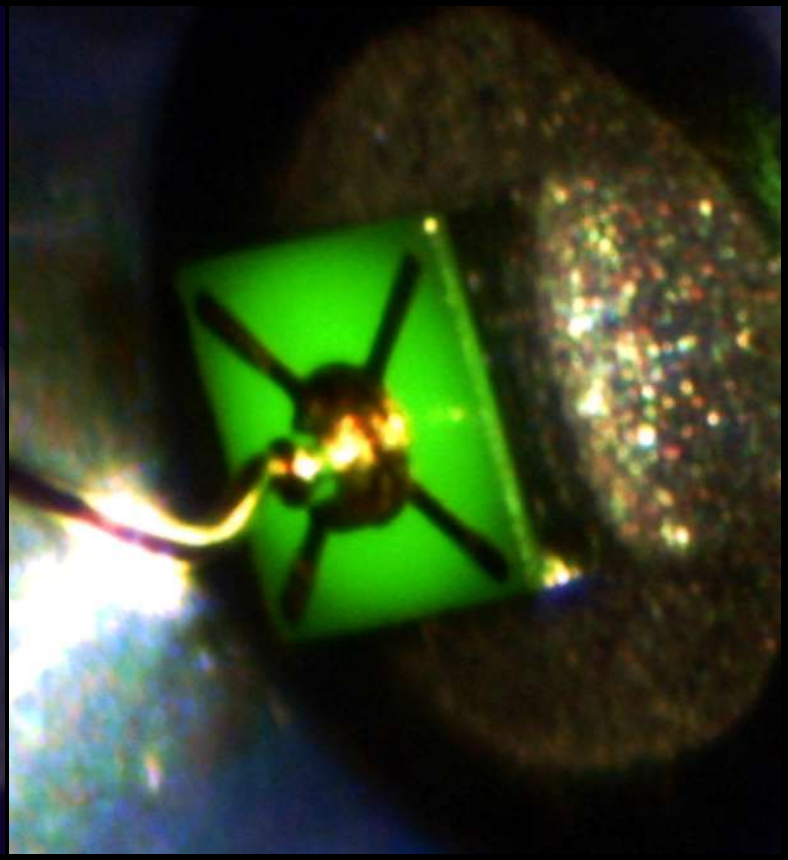
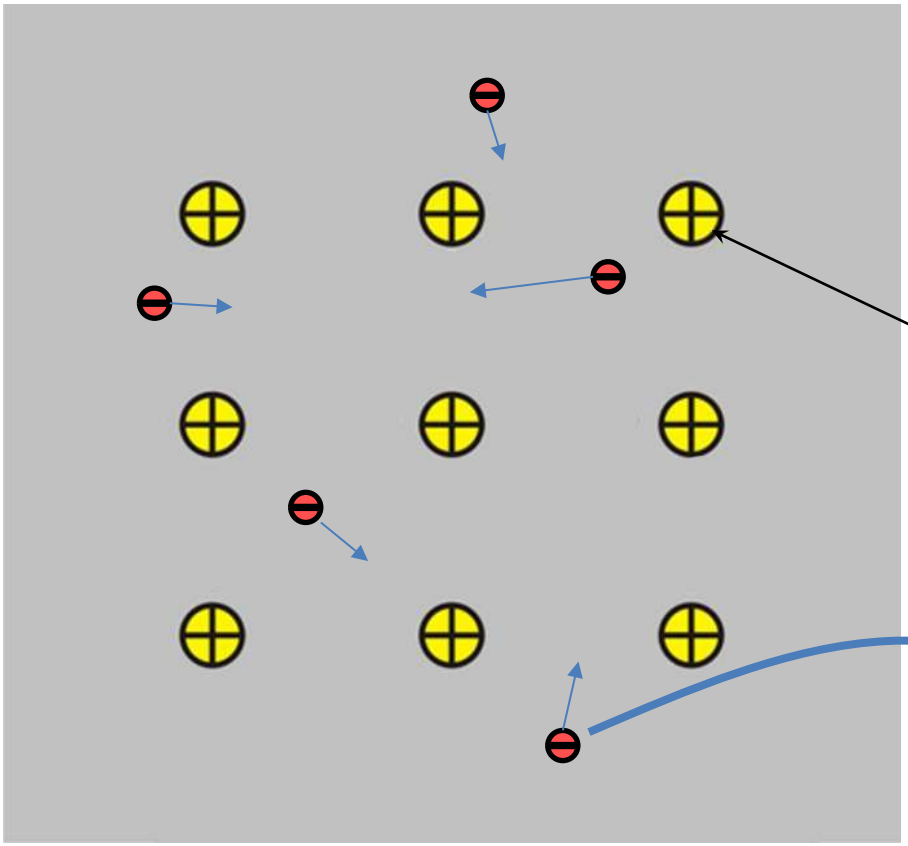




Metal (at room T)

neutral atom

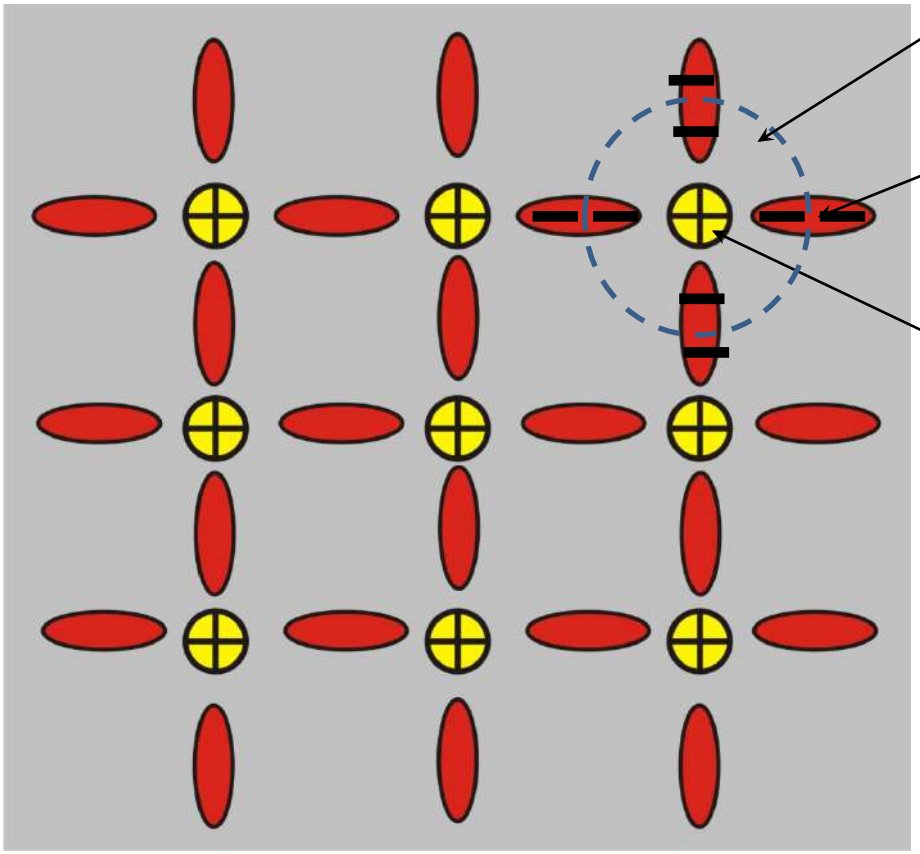


positive ion
(fixed)

free electrons

Pure semiconductor at T = 0 K

4-valent atoms

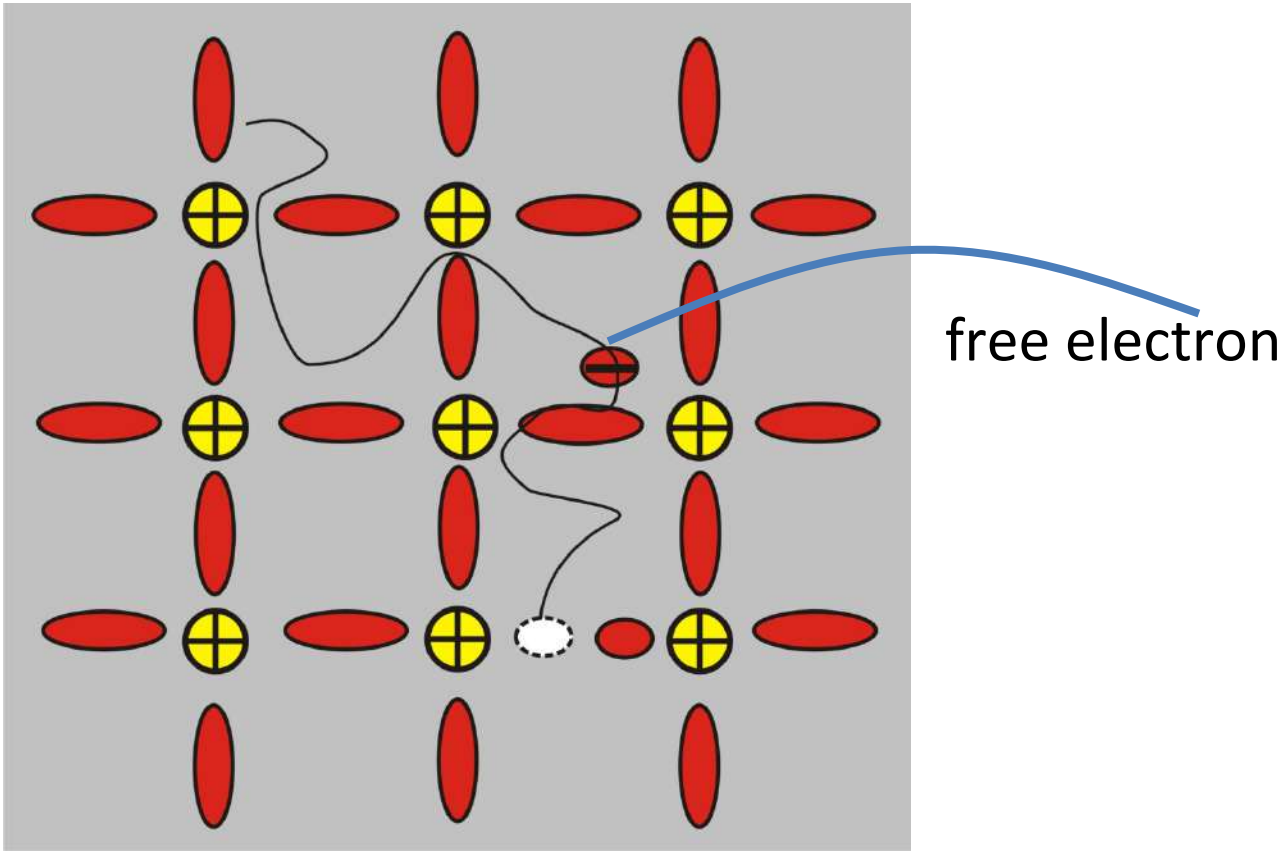


neutral atom

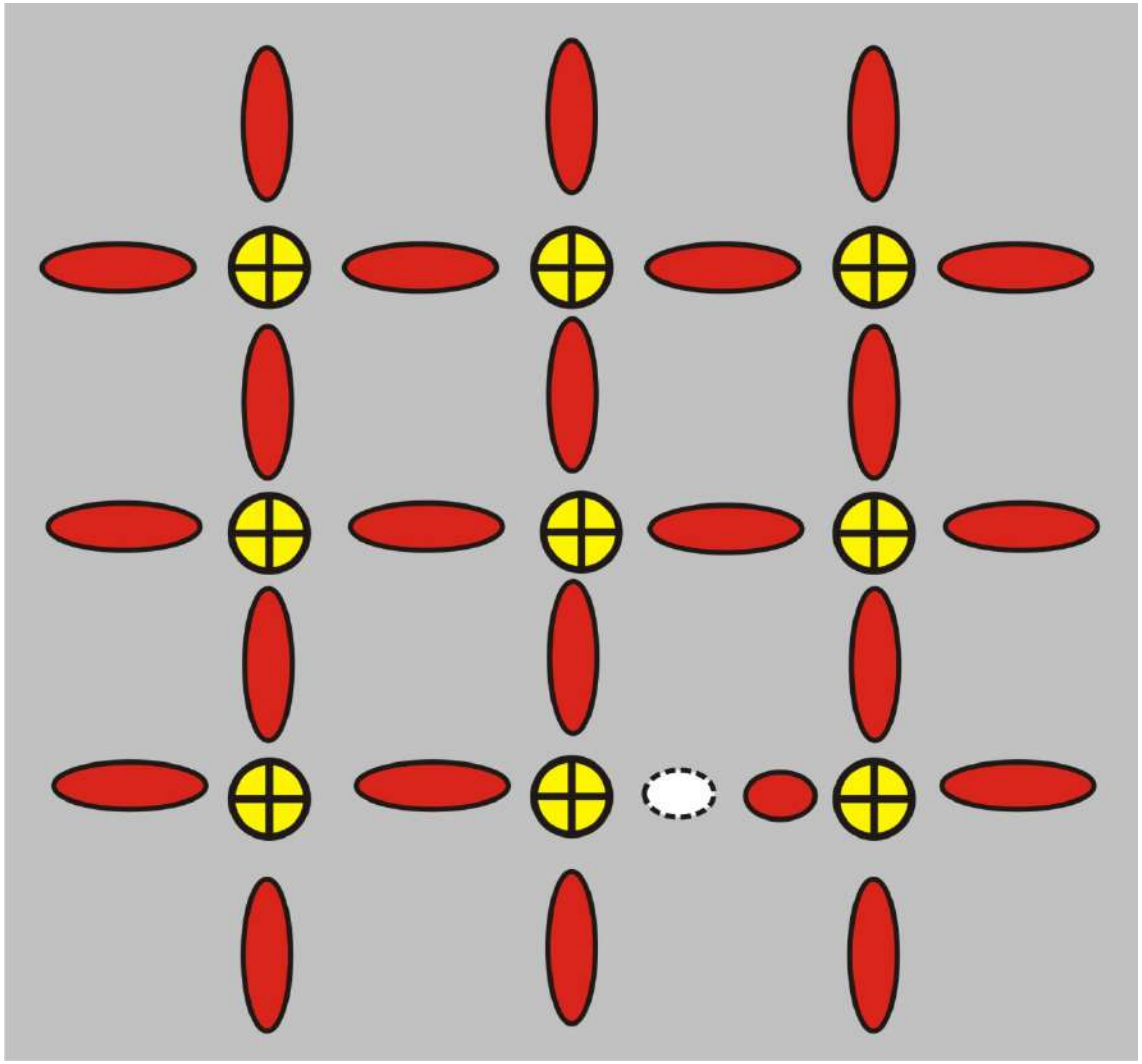
2-electron "cloud"

positive ion (fixed)

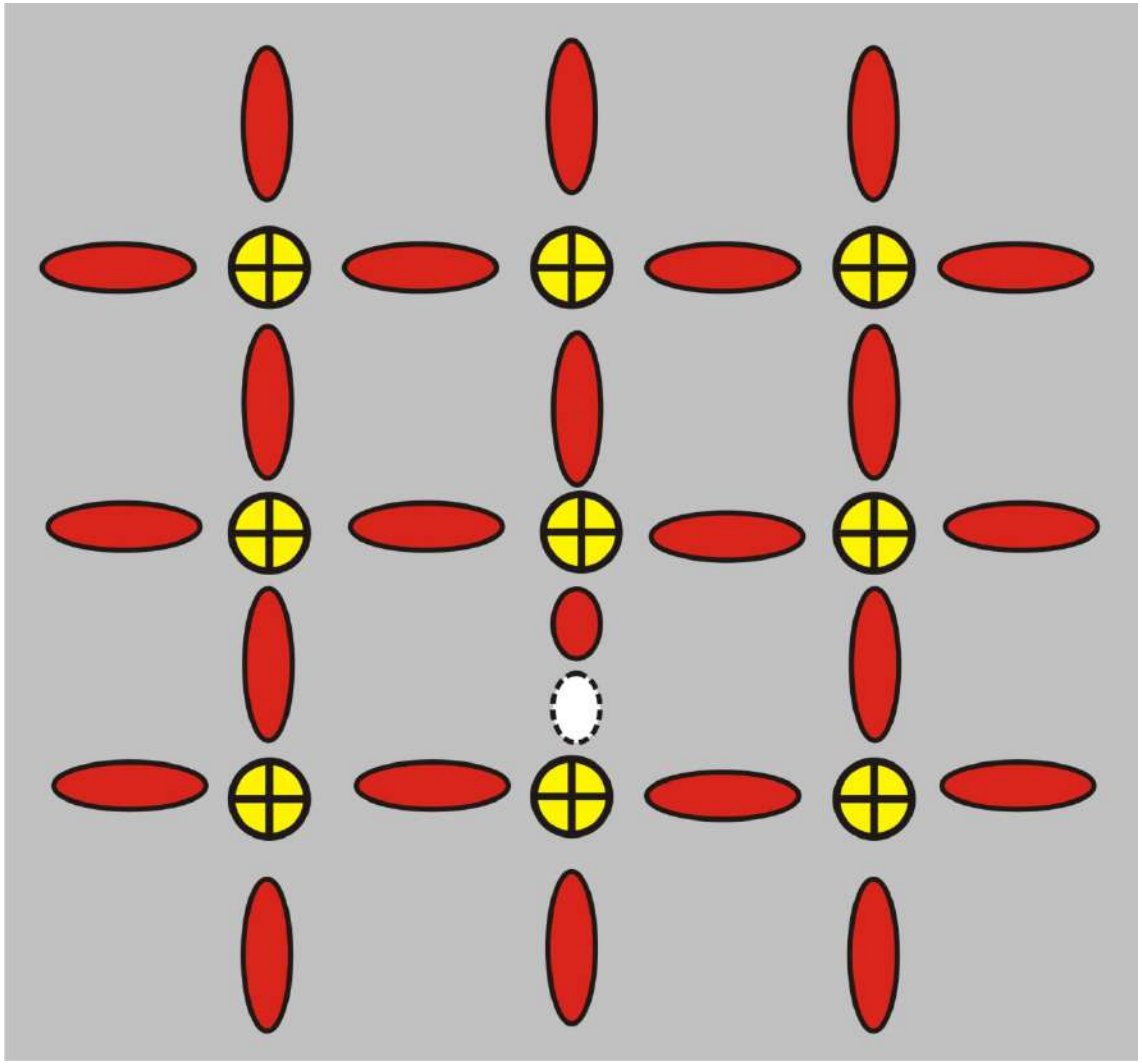
Pure semiconductor at T 300 K

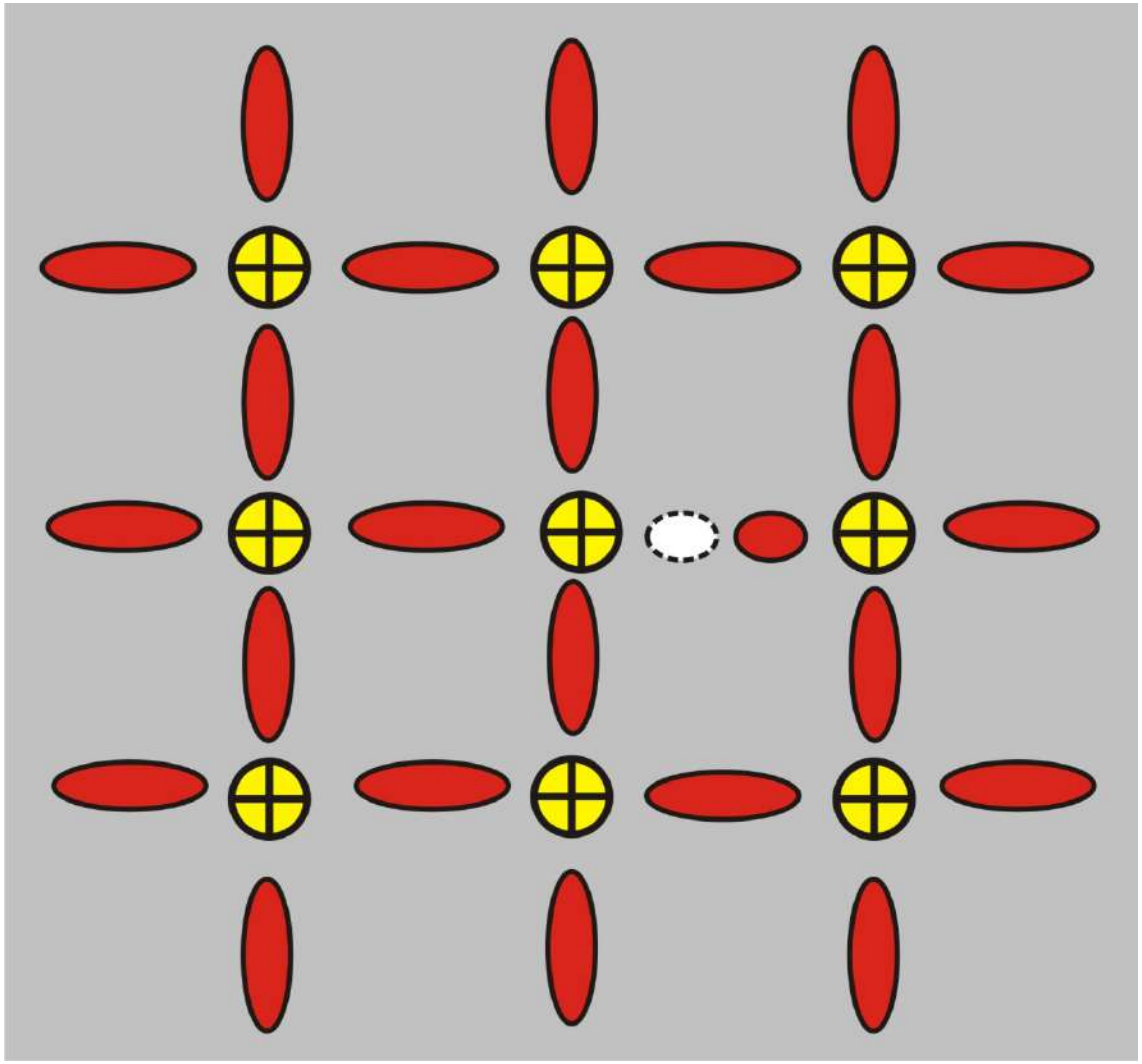


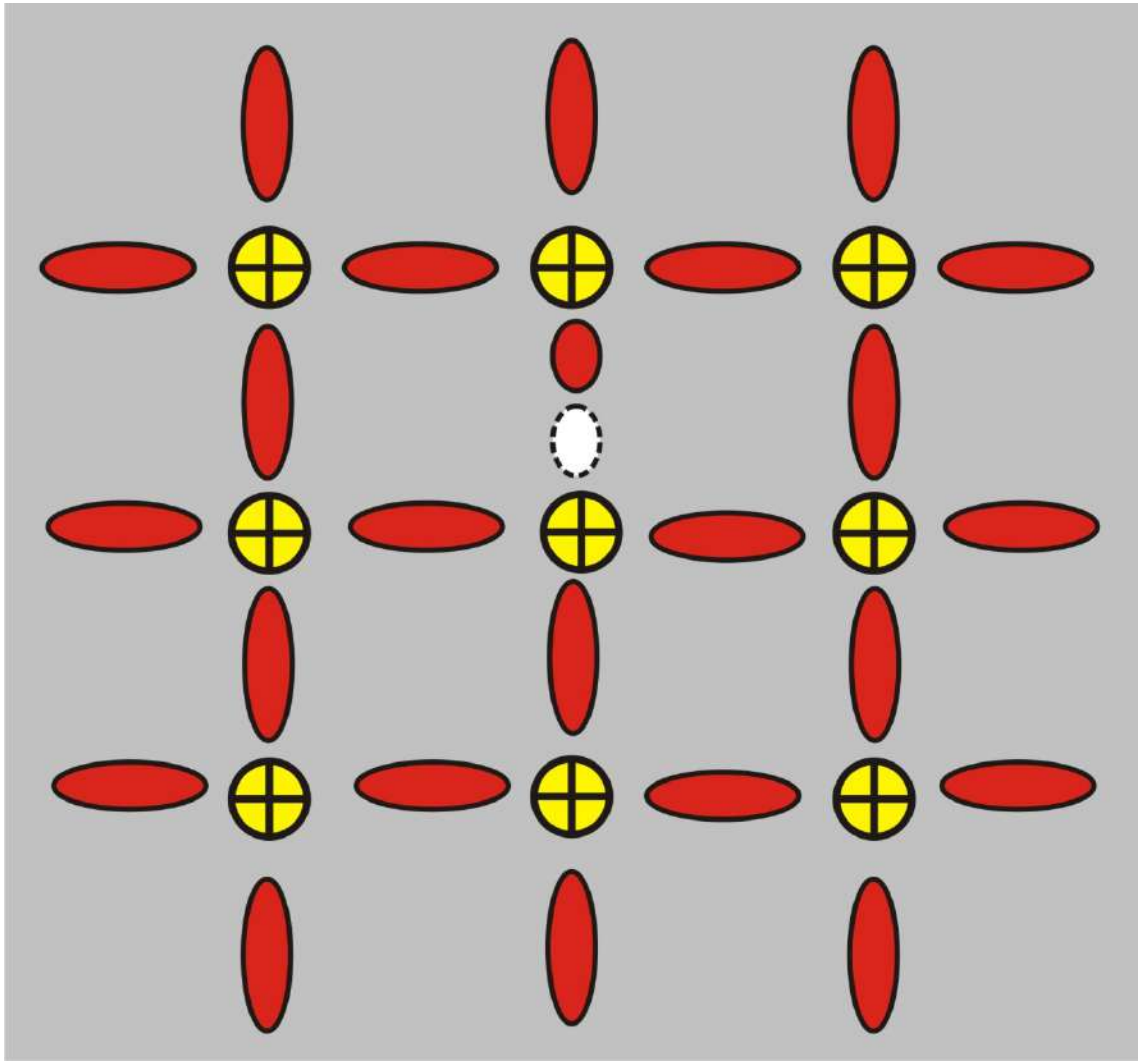
Pure semiconductor at T 300 K

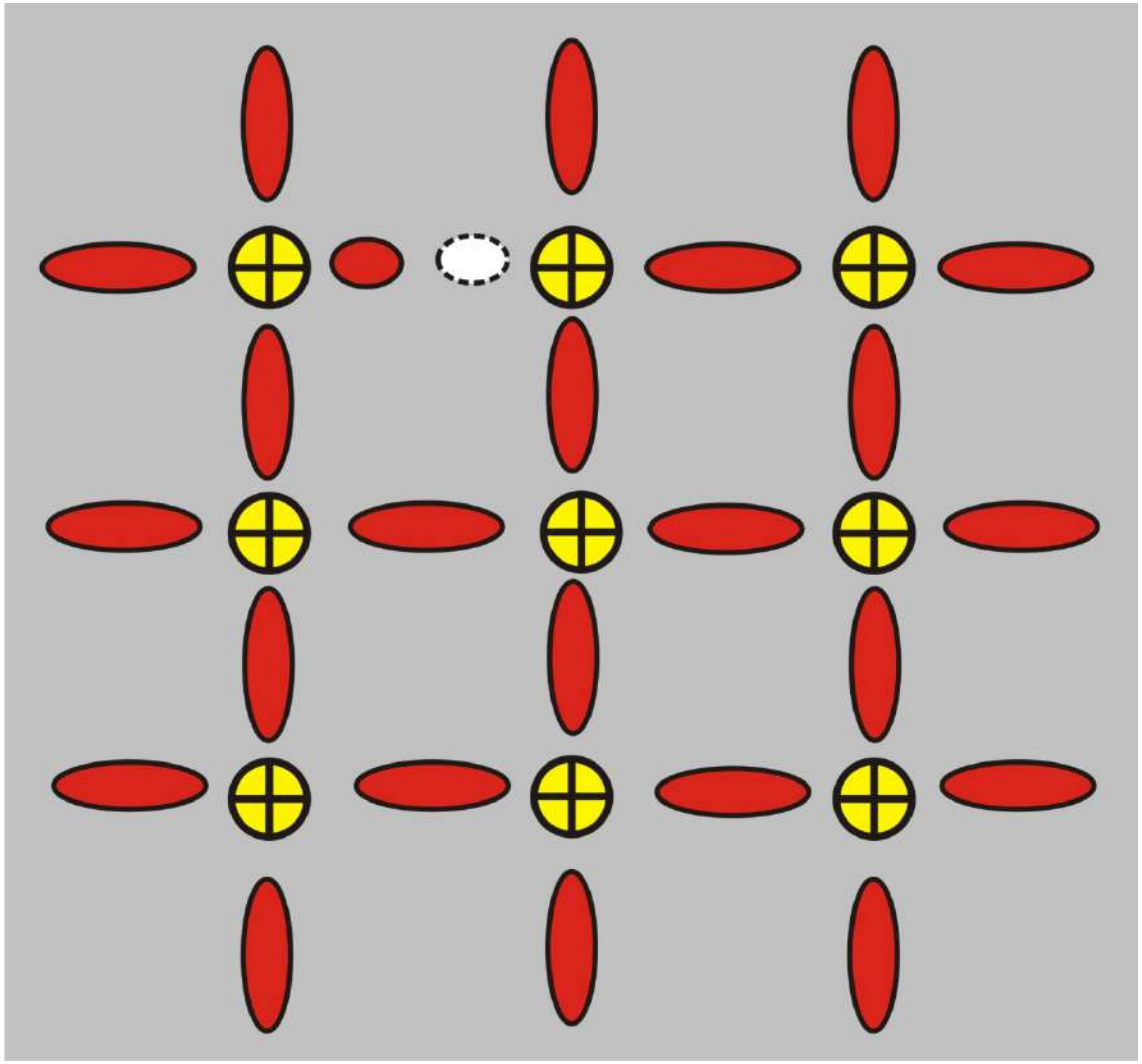


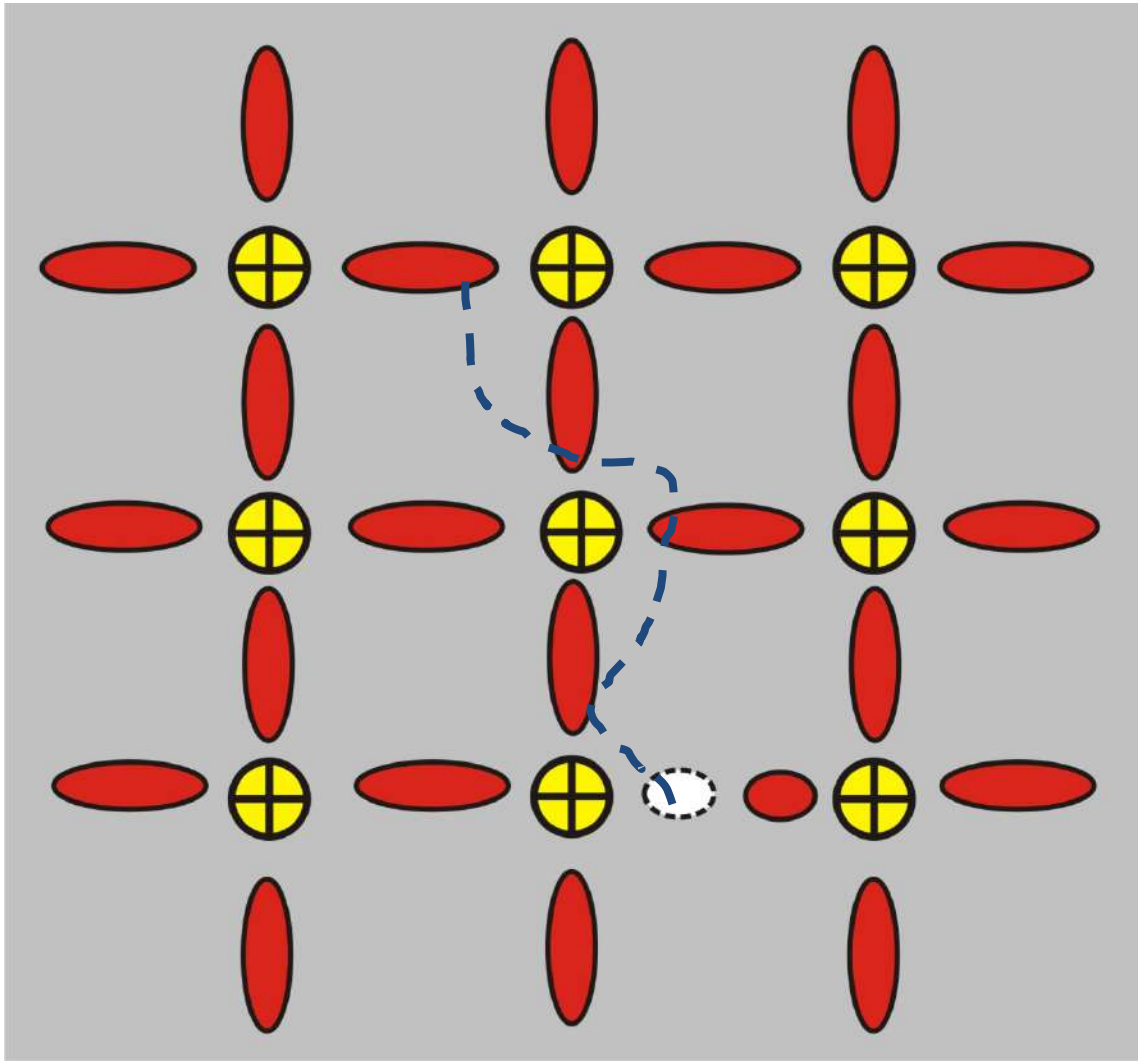
“jumping” bound electrons = moving hole

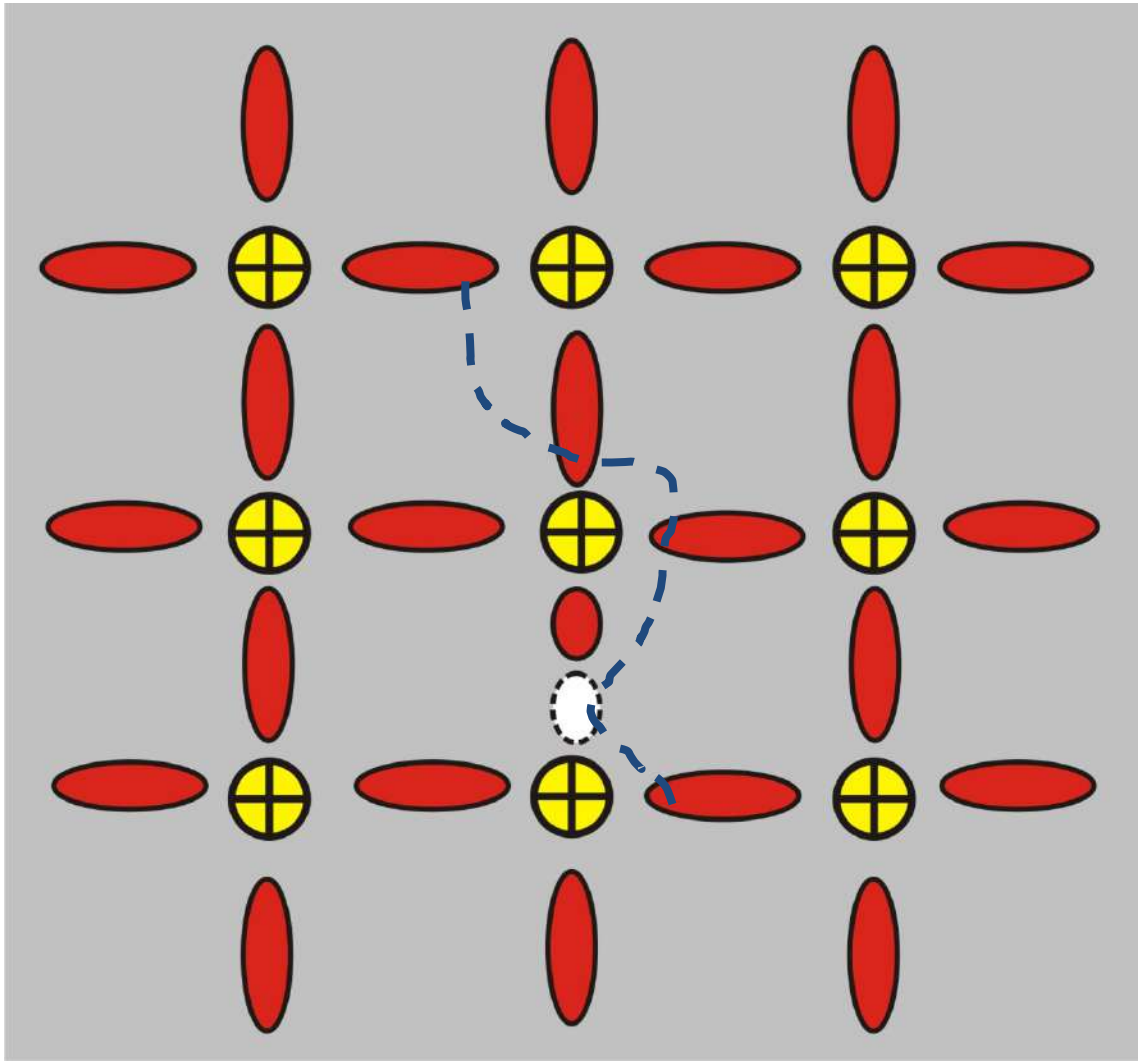


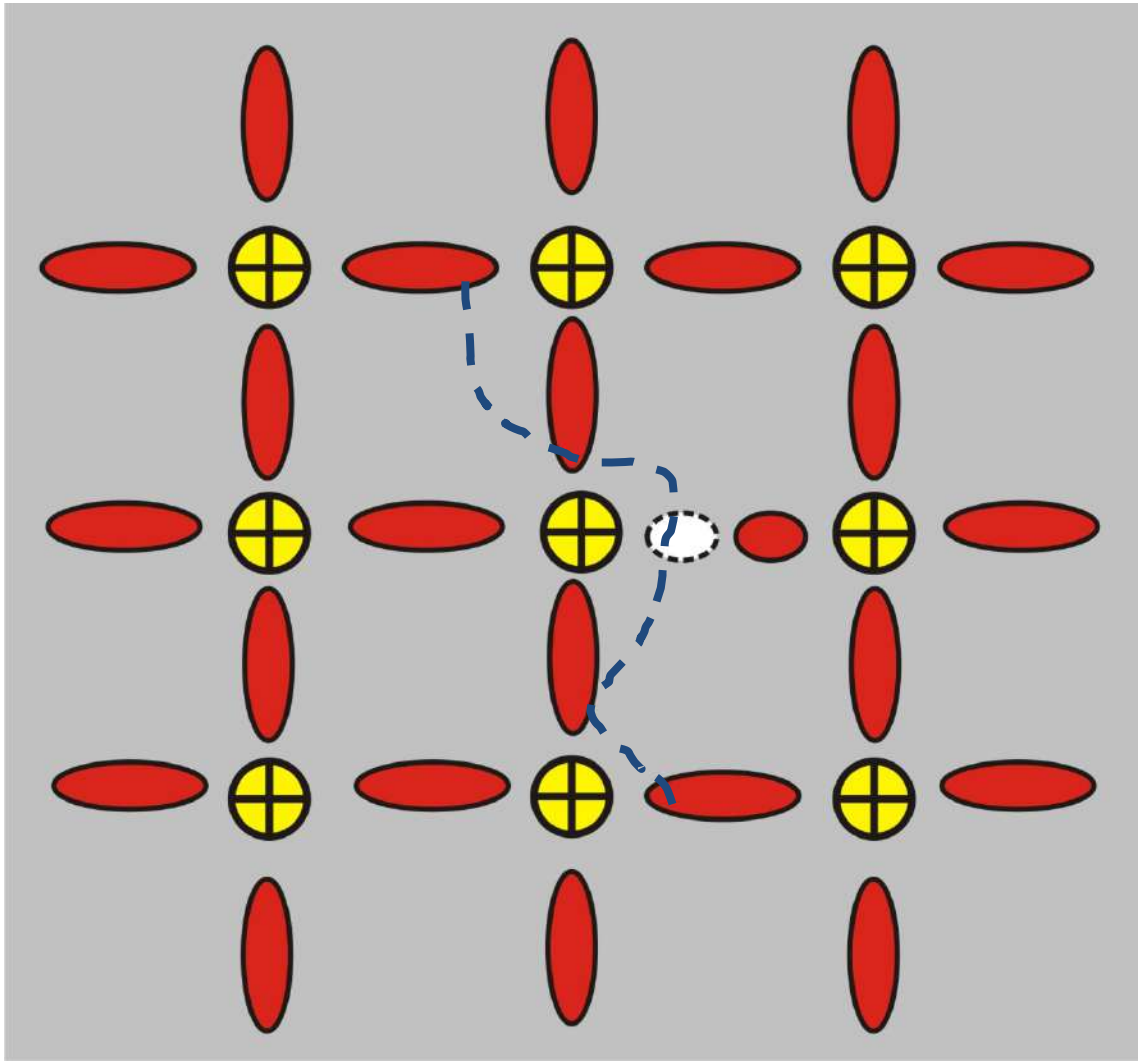


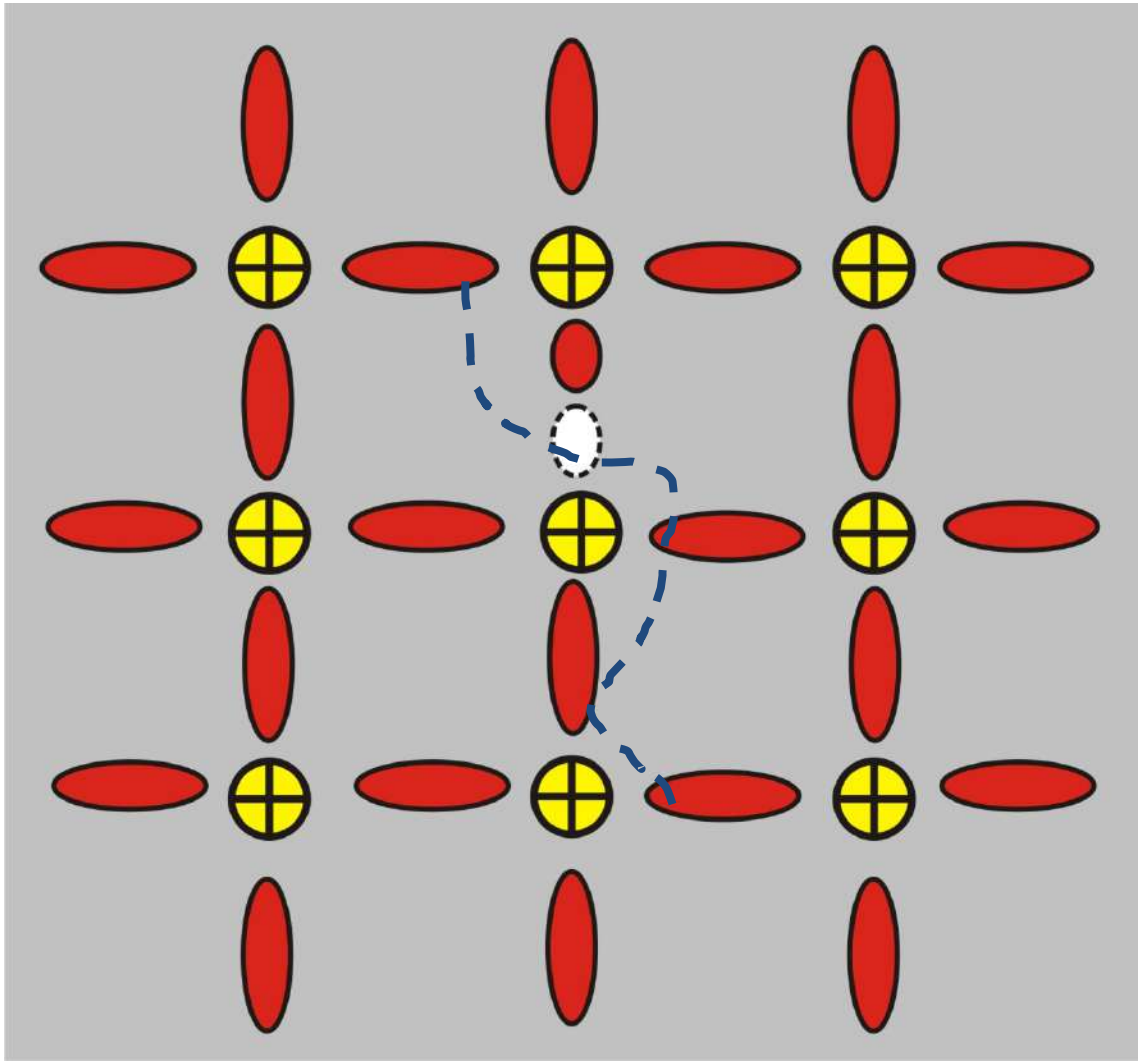


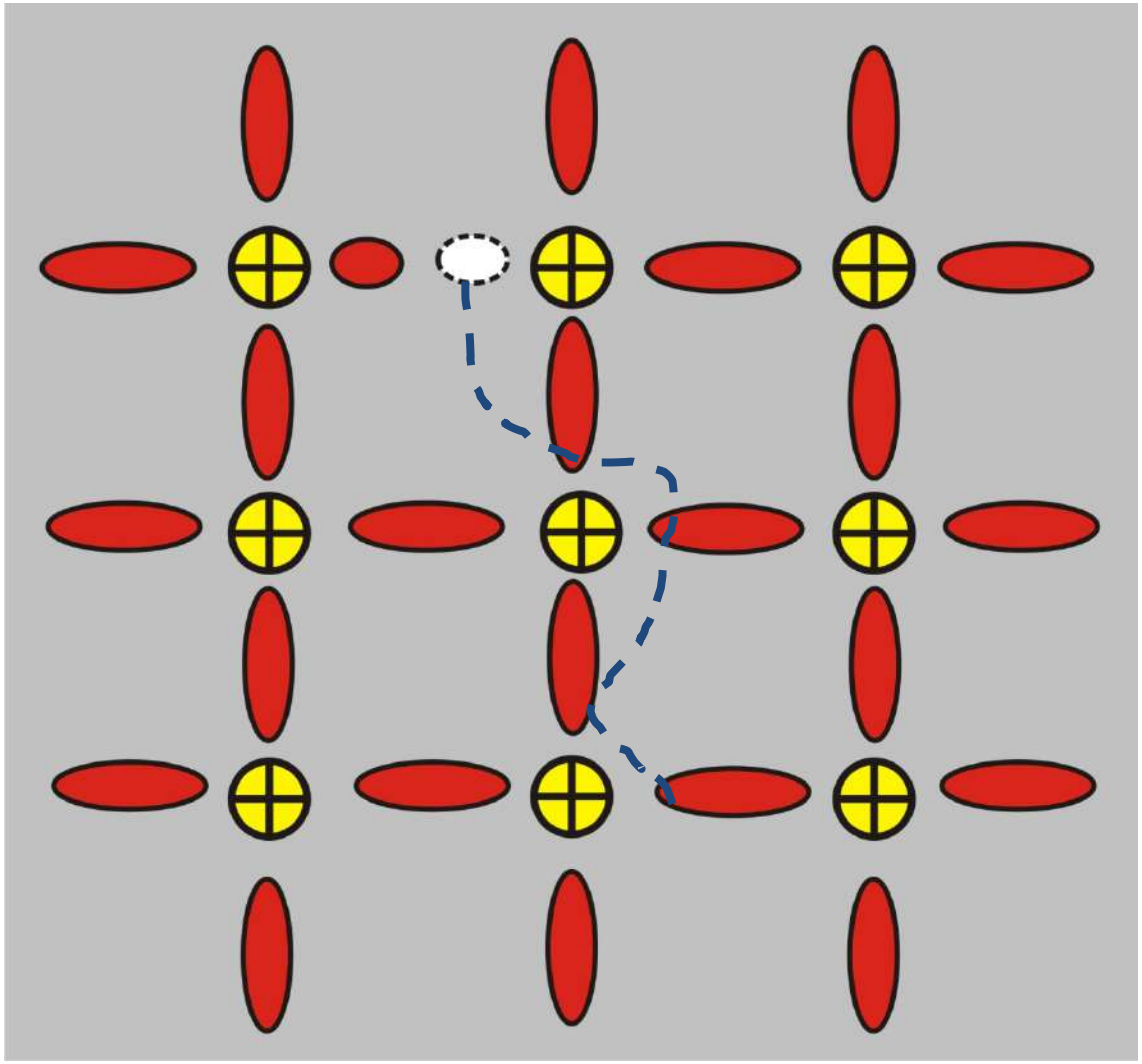




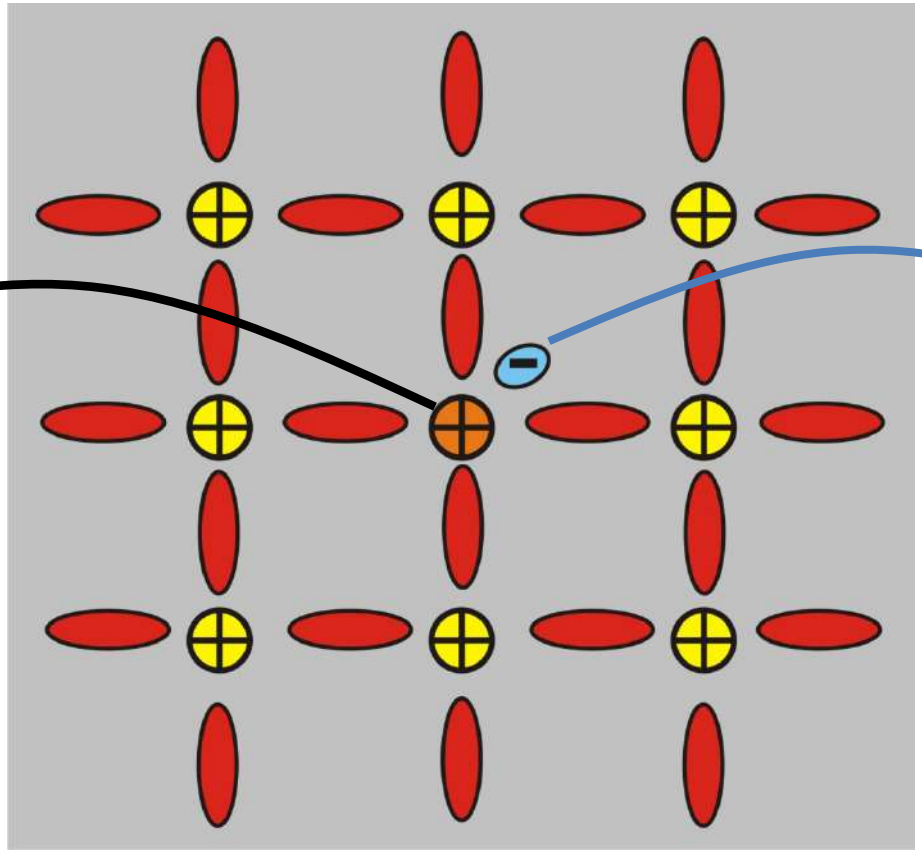








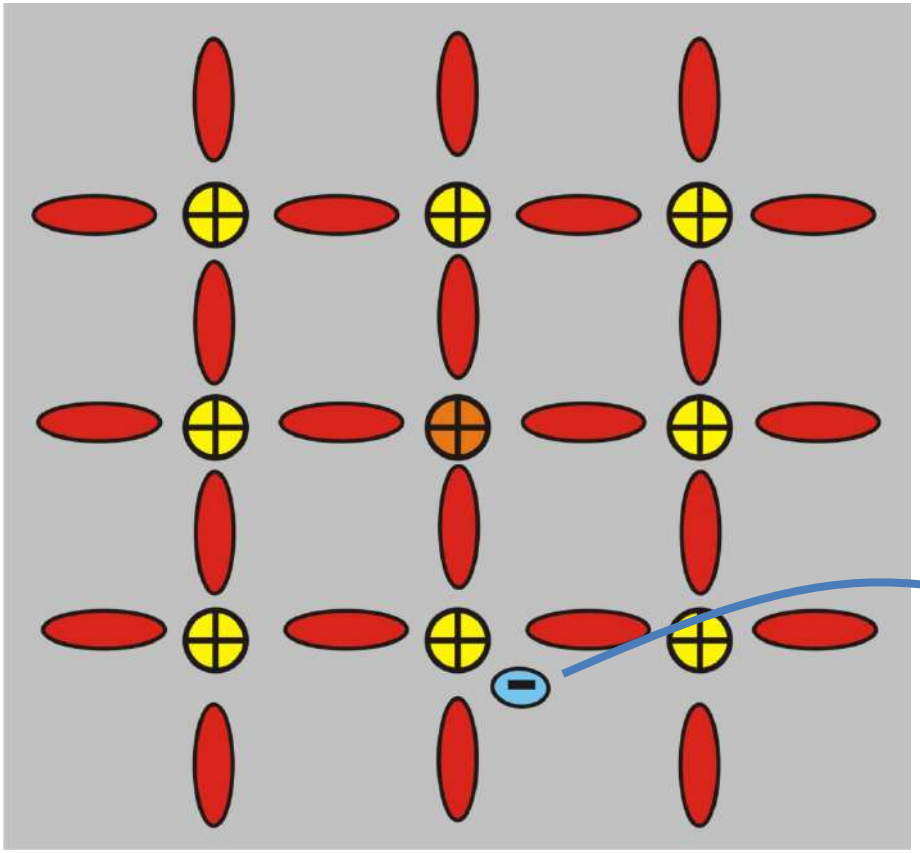
n-doped semiconductor



5-valent atom

electron

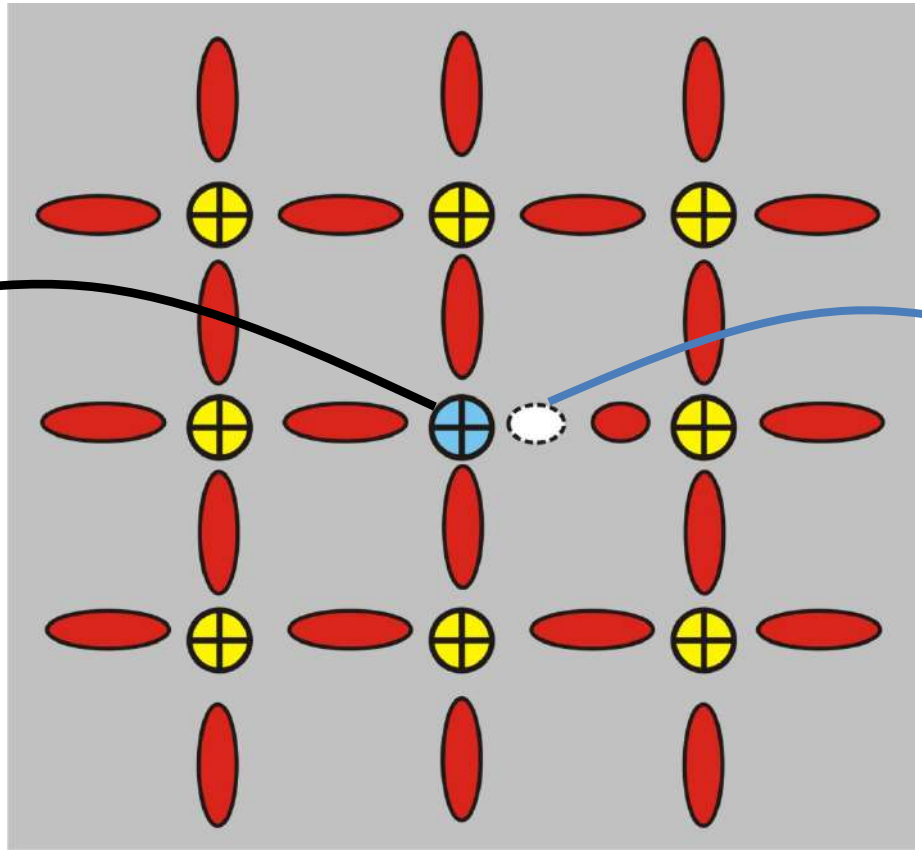
n-doped semiconductor



free electron
(negative charge)

NOTE: the material as a whole is neutral!

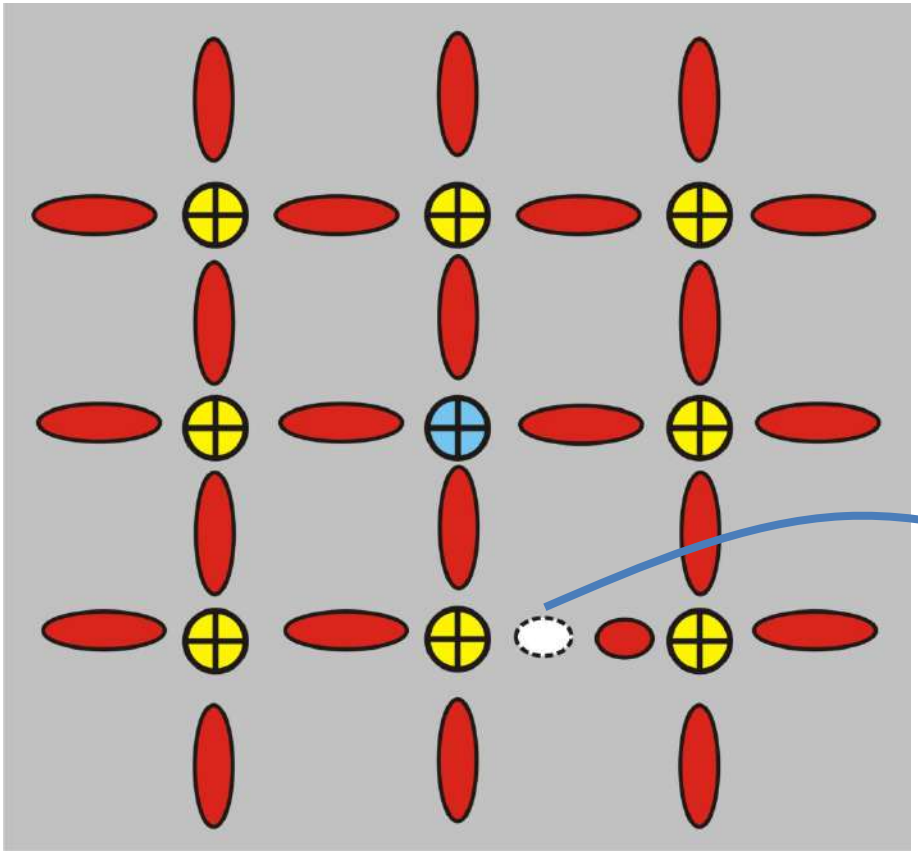
p-doped semiconductor



3-valent atom

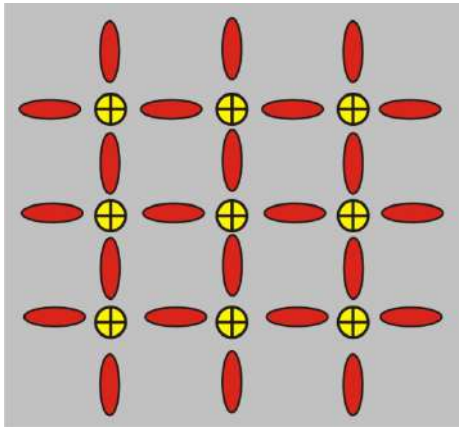
missing bound electron **= hole**

p-doped semiconductor

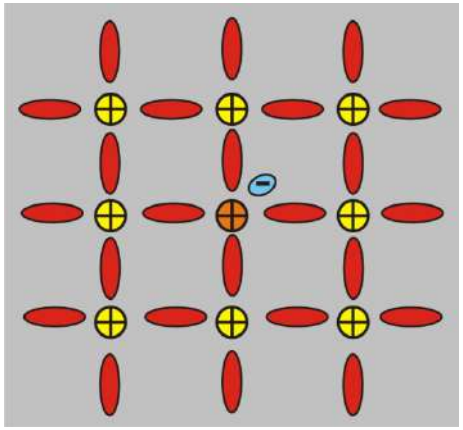


"moving" hole (behaves like a positive charge)

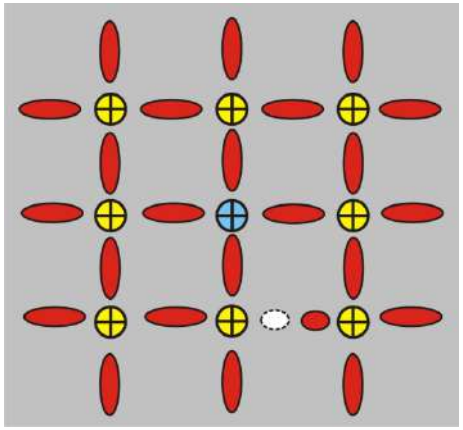
NOTE: the material as a whole is neutral!



pure semiconductor



n-type

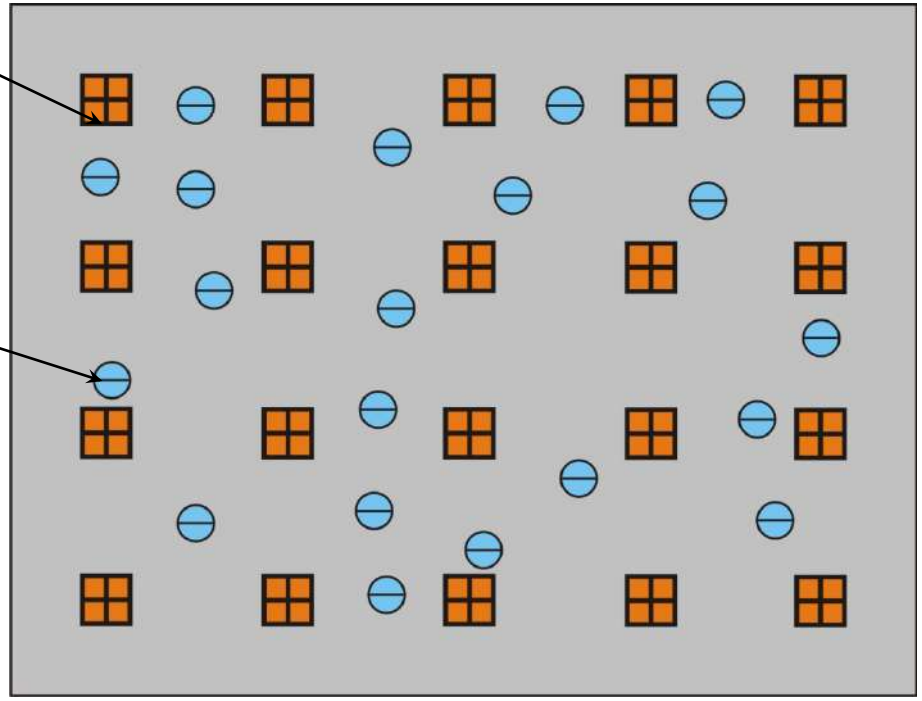


p-type

n-type

Squares = fixed ions

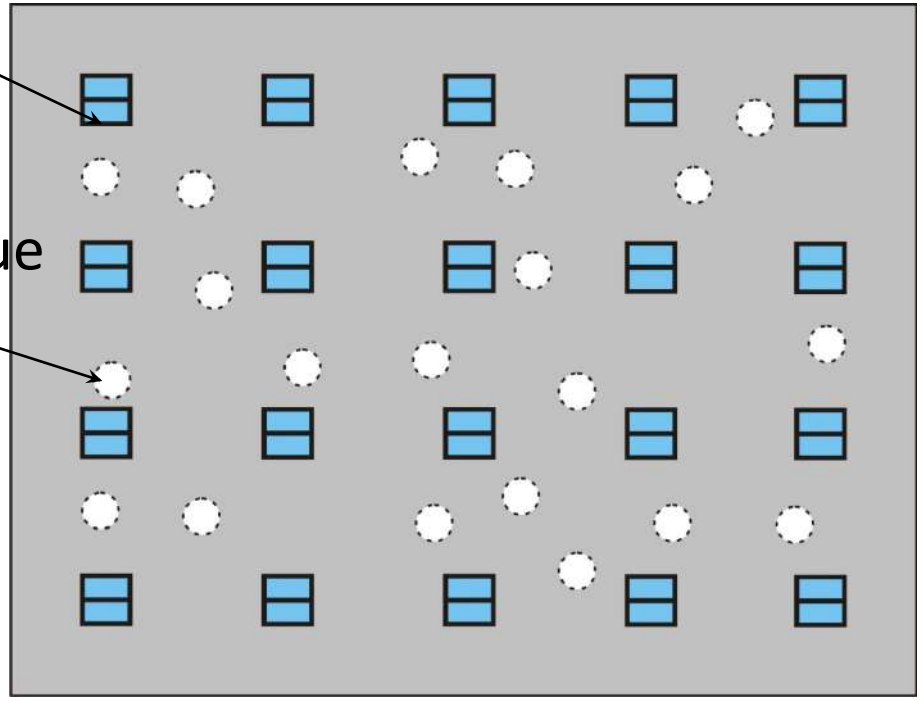
Circles = moving charge carriers due to doping



p-type

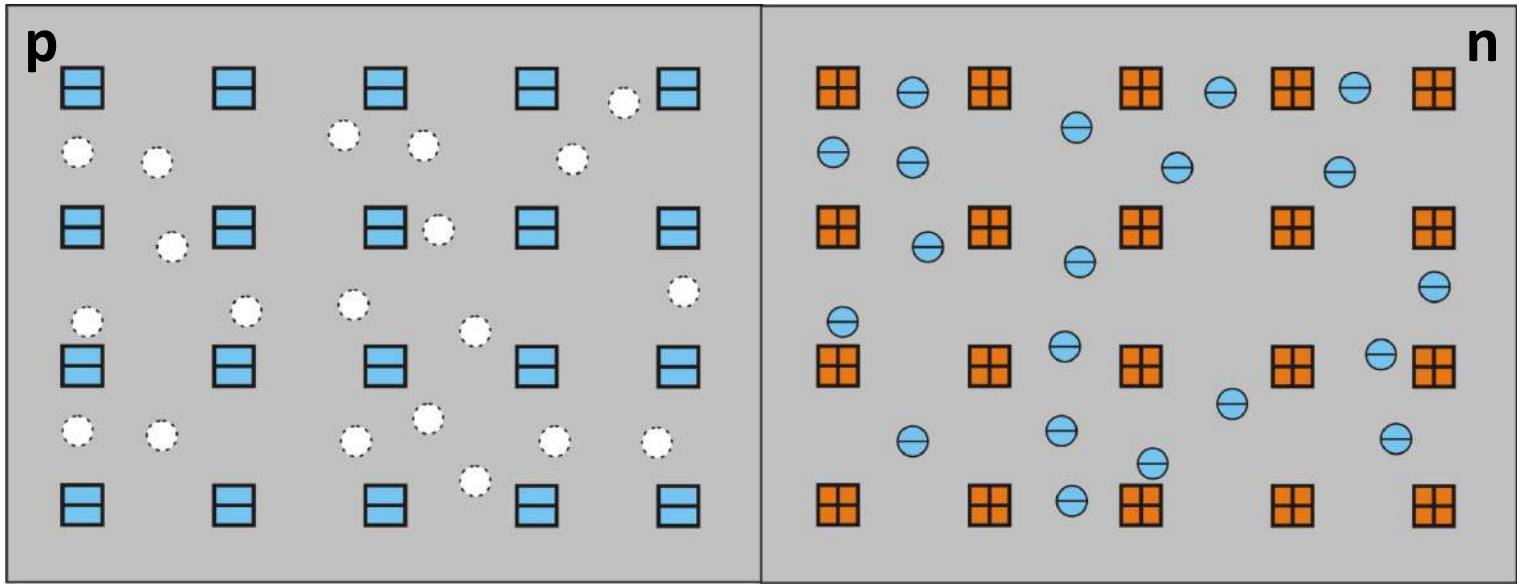
Squares = fixed ions

Circles = moving charge carriers due to doping

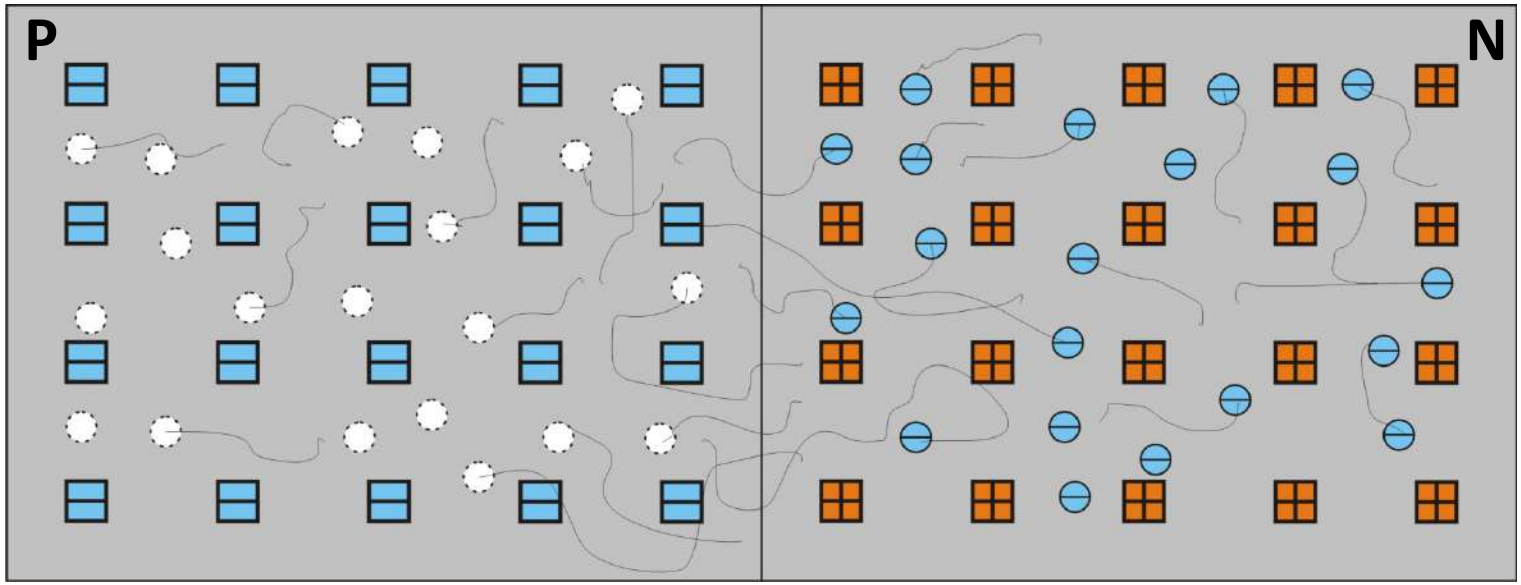


pn-junction

(right after we join both parts)

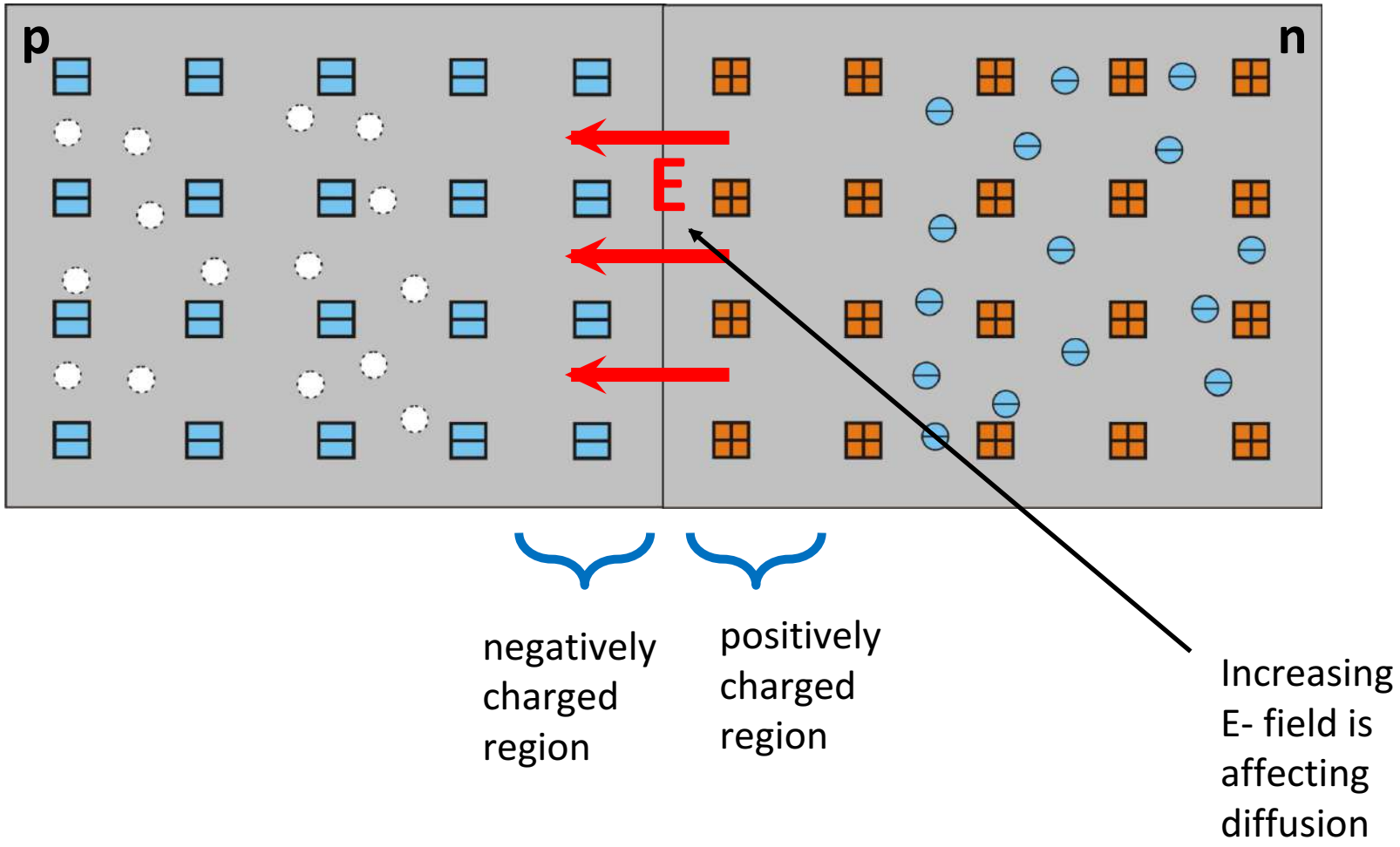


Electrons and holes diffuse due to the difference in concentration (random motion)



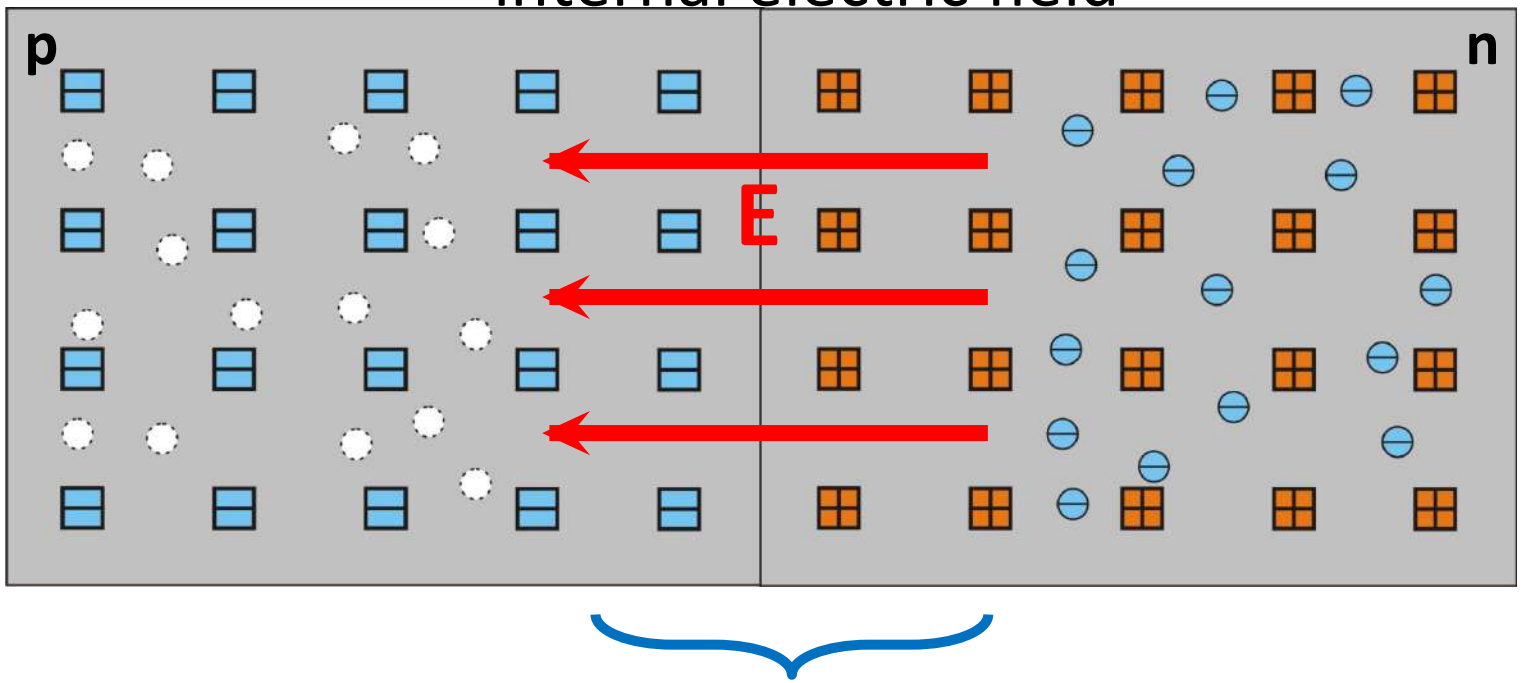
If an electron and a hole meet, they recombine (dissapear and change into a photon or vibration of the lattice)

As electrons and holes recombine, the part of the material near the junction becomes charged



pn-junction

After a short time the equilibrium is reached: the diffusion is stopped by the internal electric field

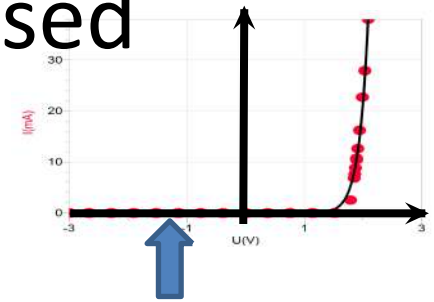


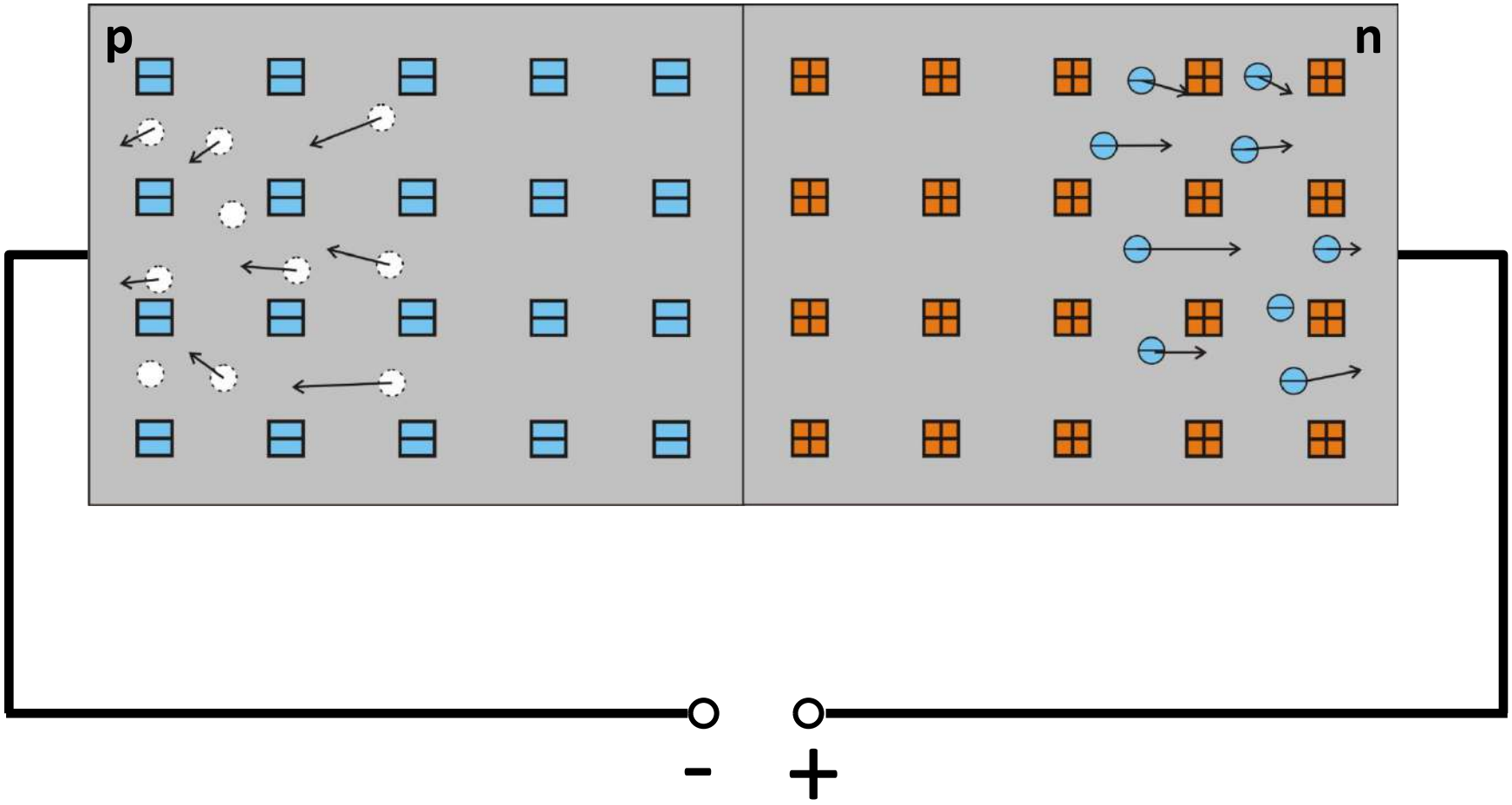
No moving charges

Depletion region

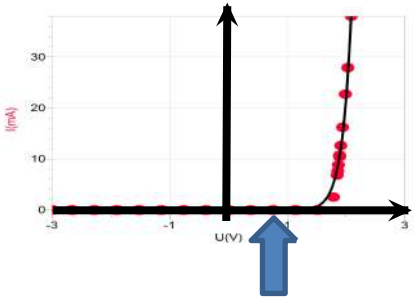
This is the situation in any diode before we connect it to a voltage source

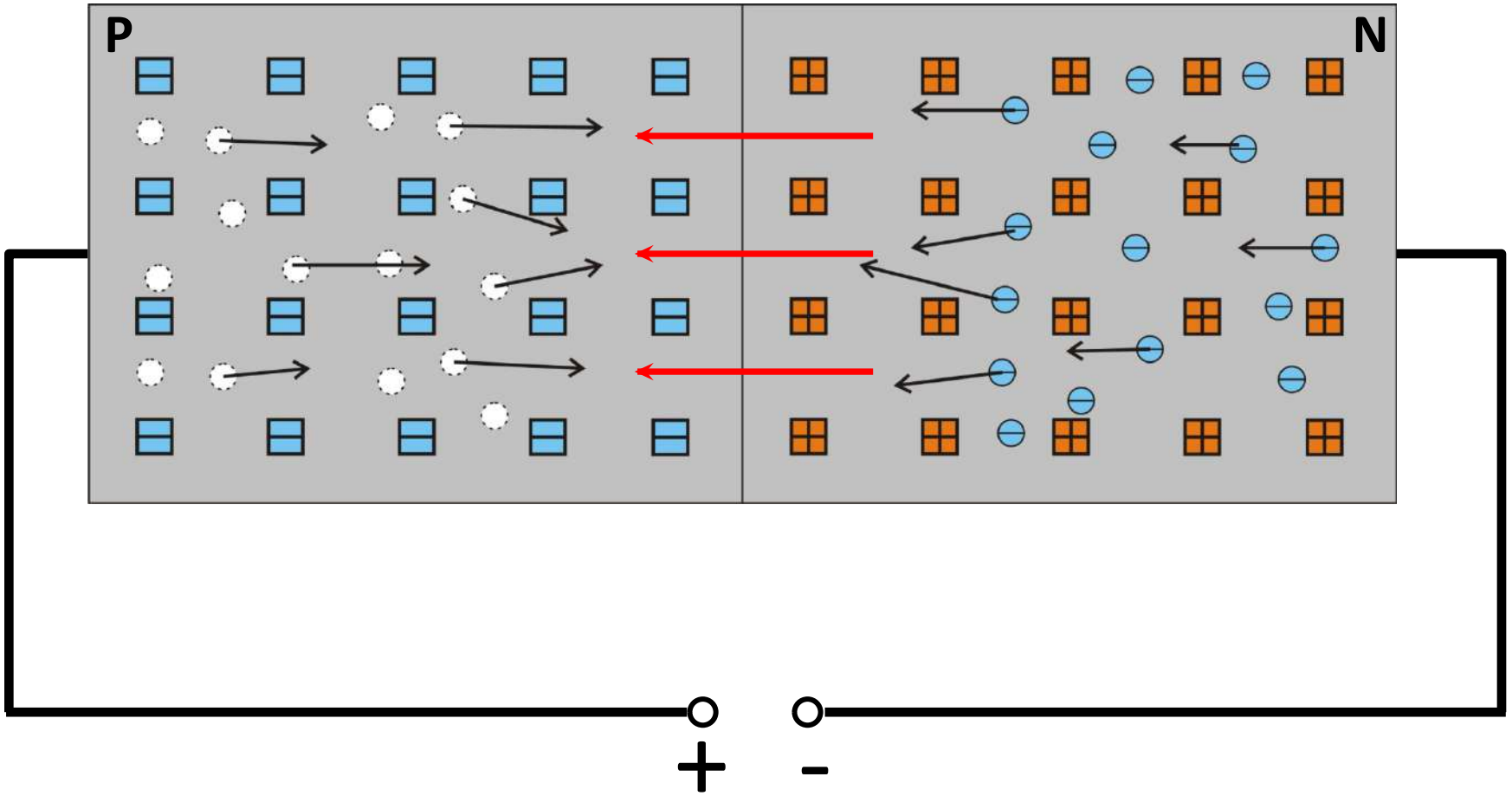
LED connected in the reversed direction





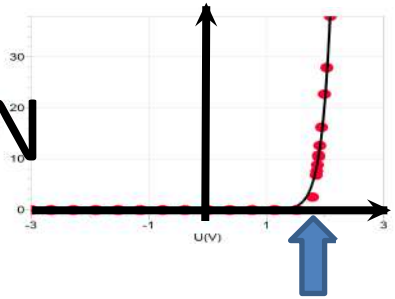
LED is connected in the forward direction but is not glowing yet

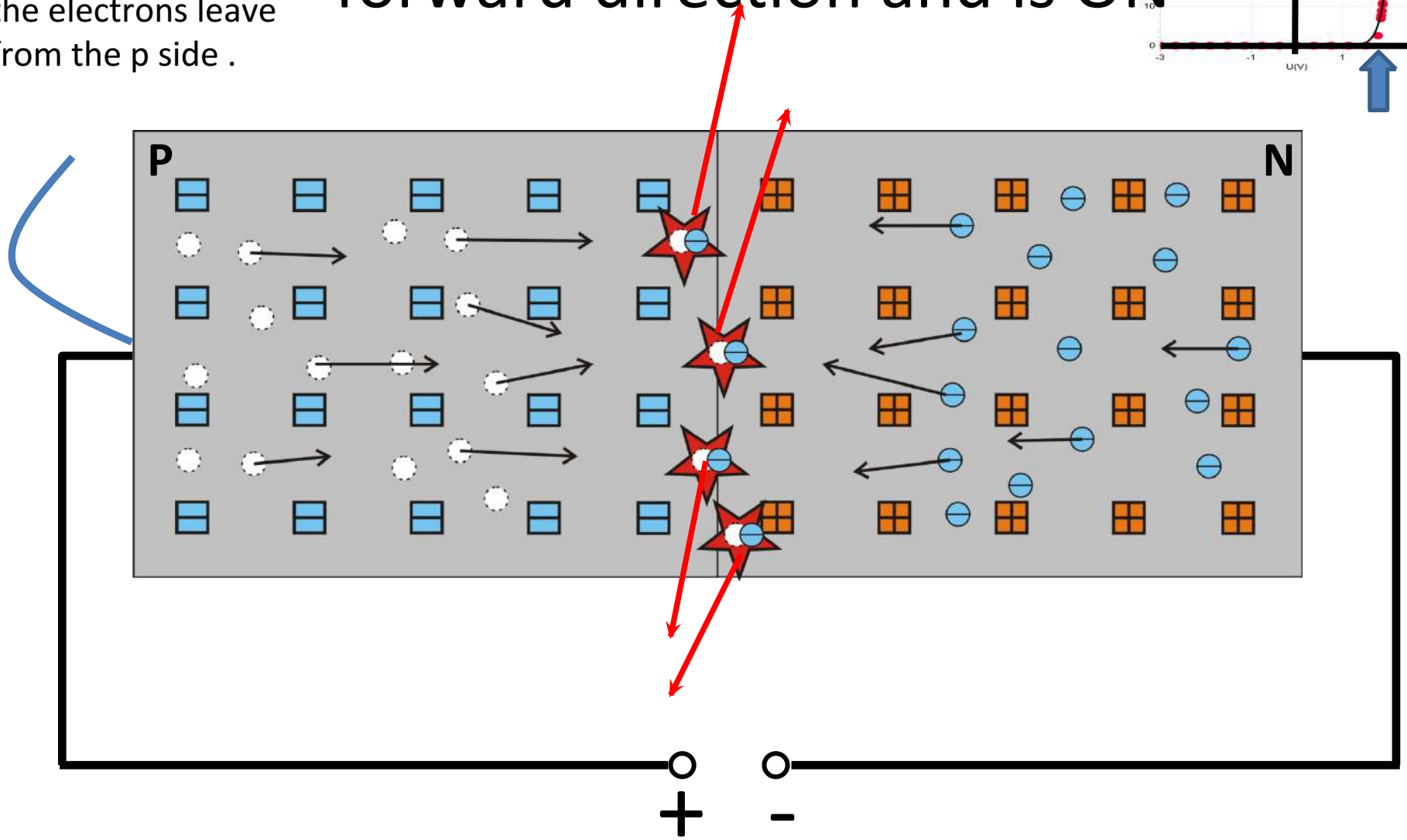




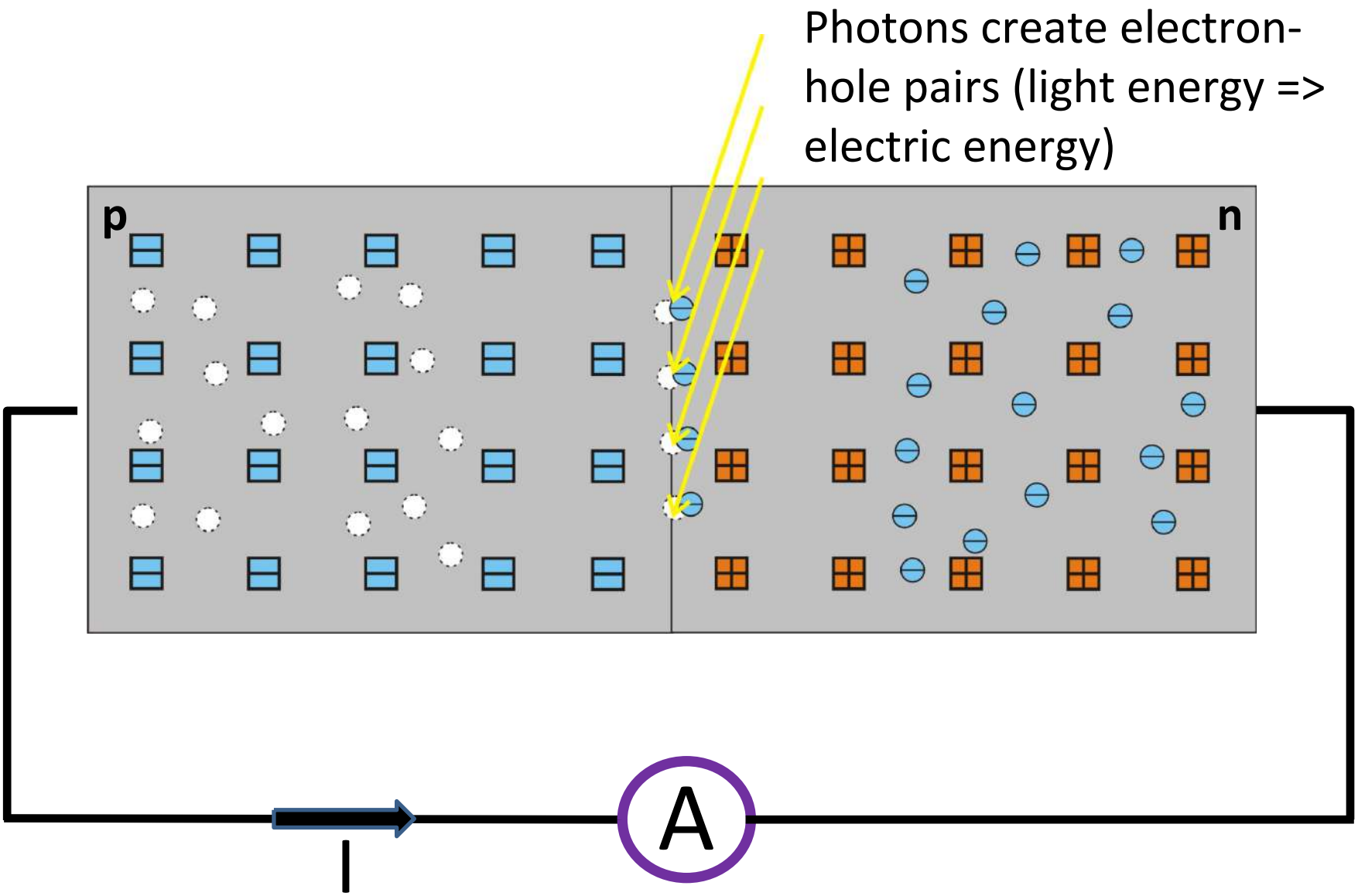
LED is connected in the forward direction and is ON

Holes are created as the electrons leave from the p side .





LED as a solar cell



LED as a solar cell

Internal E field pulls electrons and holes apart
(preventing them from recombining)