Radiation damage in Si detectors –ST62

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Radiation damage in Silicon devices:

- Ionization damage:

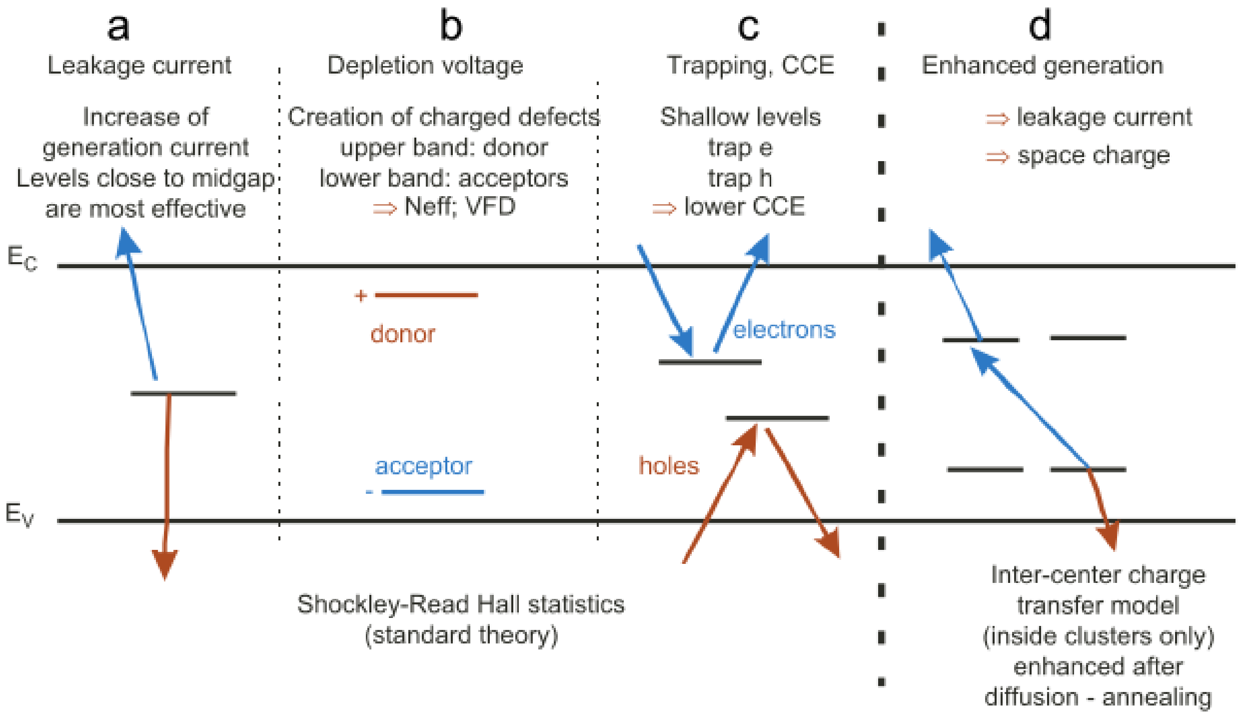
Ionization creates charge carriers that cannot be removed, since the oxide (usually SiO_2) is an insulator, and form local charge concentrations: these charges can be fixed, trapped or mobile.
Affect: Increase noise, modify the electric field and increase of the surface leakage current

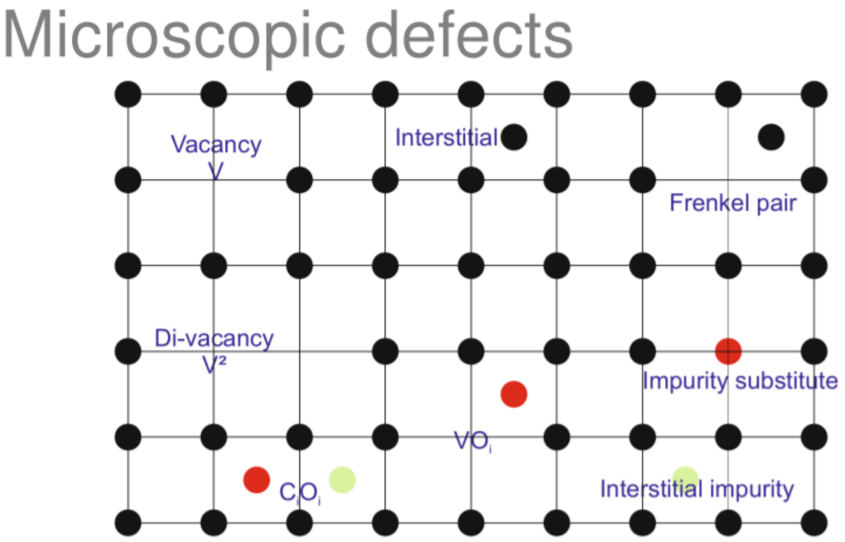
- Displacement damage: (related to not-ionizing energy loss)

The damage is caused by hadrons or high-energy leptons. The minimum energy needed to remove an atom from the Si lattice .The displacement energy is Ed ~25eV. If the energy released by the impinging particle is lower than Ed, only lattice oscillations occur with no damage; if, in turn, the released energy is greater than Ed, an atom is displaced by its original position and becomes an interstitial, leaving in its former position a vacancy.
Affect: Points defects and clusters defects. Alter sensors electrical properties.

The most important radiation damage is displacement damage:

- 1.Defects created in the bulk form energy levels in the band gap: releasing electrons in the conduction band or trapping those from the valence band.
  2. Defects-related energy level in the forbidden band increases the generation/recombination rate, thus increasing the leakage current as well.





The most important radiation damage is displacement damage:

- Modification of the effective bulk doping: change depletion voltage and increase leakage current.

The microscopic origin of the initial acceptor removal has not been fully understood yet, but experimental observations suggest the creation of acceptors ion complexes that result in the de-activation of doping elements, which are removed from the lattice by interstitials.

- Reduction of the charge collection efficiency: increase of defects-related trapping centers.

Hence the longer the drift time, the higher is the probability that a carrier has to be trapped.

In LGAD: This effect of initial acceptor removal not been understood yet.

One Possible explanation:

In irradiated Silicon with a fluence-dependent concentration that forms with Boron B-I complexes which are electrically inert. These complexes make Boron atoms inactive.

To overcome this issue two researches came out:

1. The first one is to reduce the concentration of interstitials available for capturing B atoms by using Carbon-enriched Si wafers where the interstitials get filled with C instead of with B.
2. The second one is to reduce the formation of the acceptor-interstitial complex by replacing Boron with Gallium.

Thank you