Appendix B: A bit more on Semiconductor Device Physics and Avalanche Breakdown

A SPAD uses a reverse biased p-n junction as the photon detector – in this case an LED. At the appropriate bias voltage, no current will flow 'backward' through the LED when no light is incident on the junction, but the absorption of a photon will produce an electron-hole pair that is quickly separated by the large electric field in the junction. The electrons are accelerated by the field and collide with other atoms, which produce additional excited electrons. The process continues (see figure), building up an 'avalanche' of electrons that produces a current/voltage pulse that is large enough to be measured. This process is analogous to the behavior of a Geiger-Müller tube.

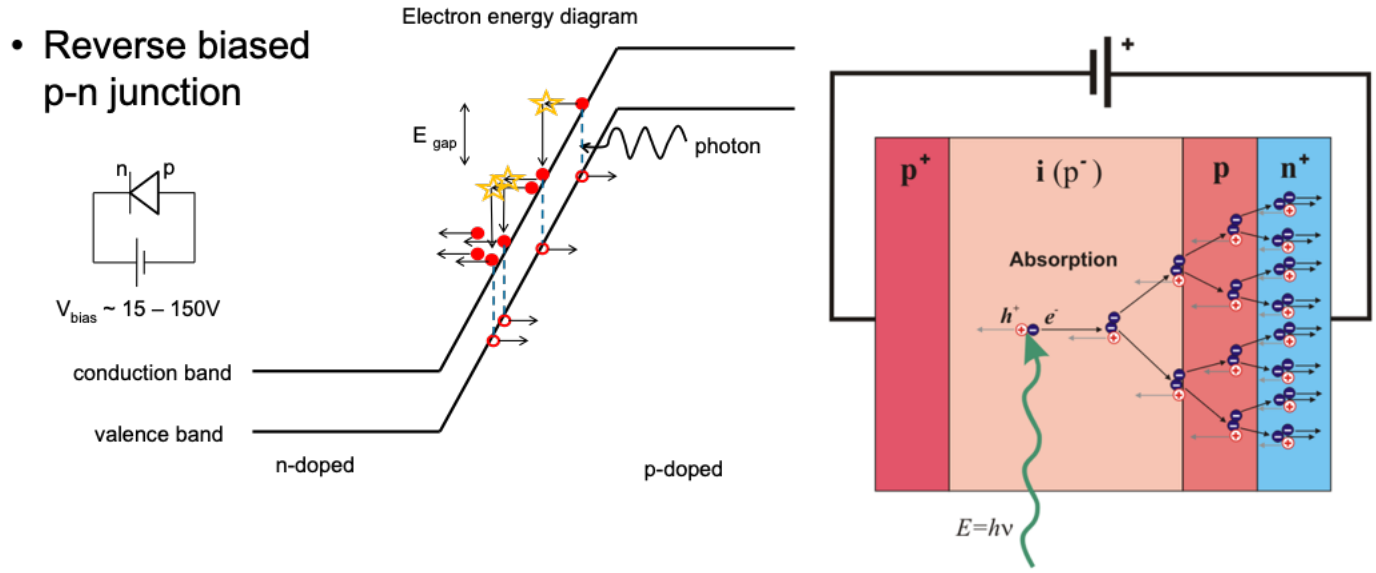

Figure 2. Electron energy diagram in a reverse biased p-n junction. An absorbed photon creates an electron (solid circle) and a hole (empty circle). The large reverse bias voltage produces an electric field in the junction that accelerates the electrons toward the n-doped side. When an electron collides with an atom, its kinetic energy can be used to excite an additional electron into the conduction band. Inset: diagram of a reverse biased p-n junction. Images licensed under Creative Commons Share Alike 3.0.

"Two mechanisms can cause breakdown, namely avalanche multiplication and quantum mechanical tunneling of carriers through the bandgap. Neither of the two breakdown mechanisms is destructive. However heating caused by the large breakdown current and high breakdown voltage causes the diode to be destroyed unless sufficient heat sinking is provided."

"When applying a high electric field, carriers gain kinetic energy and generate additional electron-hole pairs through impact ionization."
http://ecee.colorado.edu/~bart/book/book/chapter4/ch4_5.htm

"Carriers can be generated in semiconductors by illuminating the semiconductor with light. The energy of the incoming photons is used to bring an electron from a lower energy level to a higher energy level. In the case where an electron is removed from the valence band and added to the conduction band, an electron-hole pair is generated. A necessary condition is that the energy of the photon, E_{ph},is larger than the bandgap energy,E_g. As the energy of the photon is given off to the electron, the photon no longer exists." http://ecee.colorado.edu/~bart/book/book/chapter2/ch2_8.htm#2_8_6