Comments on Photoconductive Detectors - 9/11/03 Version

Photoconductivity was first reported in 1873 by W. Smith [J. Soc. Telegraph Eng., Vol. 2 (1873) p. 31], making it one of the first properties of semiconductors to be studied and exploited. At the same time, some of the newest, fastest, most sophisticated, and most complex photodetectors are based on the phenomenon of photoconductivity. The world's fasted electrical pulses are made using photoconductive switches fabricated in gallium arsenide with a very short minority carrier lifetime. Many night vision and thermal imaging systems use extrinsically-doped silicon photoconductor arrays to take infrared pictures, and still others use quantum well infrared photodetector (QWIP) arrays.

The images in the video shown in lecture were made with a camera that can be viewed as being very similar functionally to the silicon vidicon that goes into a home video camera, the difference being that the QWIP "vidicons" are sensitive in the infrared region of the spectrum rather than in the visible region. The images shown in the video were made using a camera containing a 256 by 256 pixel array of QWIP cells that were sensitive to "light" at 8 - 10 μm; it had to be cooled and was operated at under 150 K (-123˚C). Today's devices have pixel arrays as large as 1024 by 1024, or more.

Other infrared detector arrays for these applications can be made from silicon doped with "deep" donors for which the energy required to ionize the donor corresponds to that of the infrared light of interest. Unlike the column V donors we discussed in class, these donors are not normally ionized at room temperature; it is the incident light that ionizes them, leading to an increased conductivity, i.e., photoconductivity. These detectors are called extrinsically-doped silicon photoconductors.

An interesting question to consider is how one can make a photoconductor detector which gives a large signal, and yet is linear, meaning it still operates under low level conditions. Low level injection means the optically generated carriers are far less numerous than the majority carriers, so it seems that the change in conductivity can never be a very big fraction of the total conductivity. The way engineers have gotten around this problem is by looking for materials in which the majority carrier mobility is much, much smaller than the minority carrier mobility. Usually the two mobilities are comparable, so finding such a material is not easy, unless one uses a trick. The trick is to photoexcite the carriers not from lattice bonds, but instead from deep donors, as is done in the extrinsic silicon photoconductors mentioned above. The ionized donors correspond mathematically to the majority carriers, but they can not move and thus have effectively zero mobility.

Returning to the QWIP devices, they are made using layers of different semiconductors whose thicknesses and compositions are chosed to create electrons localized in space much like those associated with a deep donor ion

(except that they are localized in planes, not about points in space like donor ions). They are structurally much more complex than a traditional photoconductor, but in exchange for the increased complexity one gains much more flexibility in designing the performance and spectral response characteristics of the devices.

Note to students: You are not responsible for this material on problem sets and quizzes. It is solely intended to be for your intellectual stimulation and enlightment.