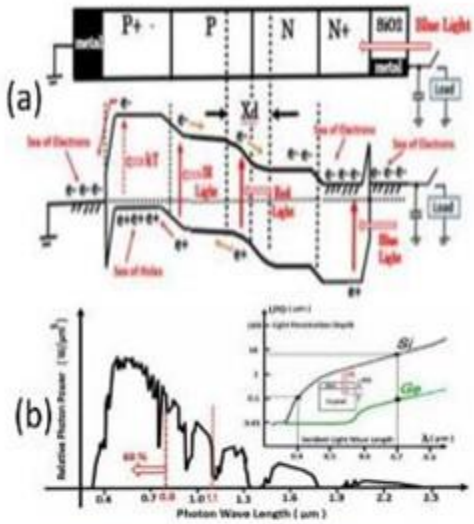

Fig. 19 (a) Single Junction type Solar Cell and (b) Sun Light Spectrum

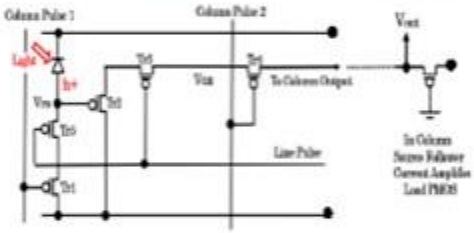

Fig. 20 Active In-pixel source-follower type (APS) PMOS imager invented by Peter Noble in 1968. PMOS transistors were too laerge in early 1970s, now small enough, thanks to the modern advancement of CMOS process scalings.

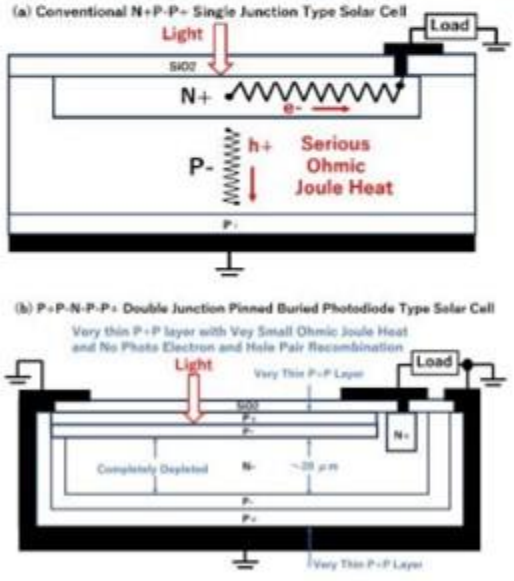

Fig.21 (a) Single Junction Solar Cell and (b) Double Junction Solar Cell.

VI. SILIOCN-BASED PINNED PHOTODIOE TYPE SOLAR CELL

Before CCD image sensor was invented in 1969, the N+P single junction type photodiode, shown in Fig.19a, was used widely both in MOS image sensors and also in ILT CCD image sensors. The single junction type photodiode is still now widely used for low-cost solar cell applications with very low quantum efficiency of less than 20%. In the presence of electric filed, electons and holes can be separeated easily. But ther is no electric filed at the N+ floating silicon surface for the N+P single junction solar cells. The photo electron and hole pairs at the silicon surface stay where they are and eventually sooner or later they all recombine each other and wasted into heat. The sun light contains a plenty of high energy photons of the short-wave blue-light spectrum as shown in Fig.19b. Sun light gives a plenty of the high-energy photons of the short-wave. But they were all wasted because the blue light that cannot penetrate in the deep bulk silicon crystal since the high energy photons cannot penetrate deep into the bulk silicon crystal. They are all recombined at the silicon surface into heat.

VII. ACTIVE IN-PIXEL CURREENT SOURCE AMPLIFER (APS)

Sensitivity of video cameras is defined as the signal to noise (S/N) ratio. Charge Coupled Device (CCD) invented in 1969 and the active pixel sensor (APS) source-follower circuit [25] originally invented by Peter Noble in 1968 both contribute to minimizing the signal noise (N). On the other hand, Pinned Buried Photodiode originally invented in 1975 by Hagiwara at Sony [8-10] has been continuously contributing to maximize the signal (S), since the beginning of development efforts [11-13] by Sony till present. Both CCD and CMOS video cameras are continuously using the triple junction type Pinned Buried Photodiode [8-16] , originally invented by Hagiwara at Sony in 1975, in order to maximize the video cameras signal output (S), since the first development and the production in 1978 by Sony, with the perfect mechanical-parts free electronic shutter function [20-21].

CCD was considered as a super star in the image sensor world till 2000s. Buried Channel type CCD imagers invented in early 1970s showed the excellent 99.999% charge efficiency and achieved the good picture quality in the analog TV era. However, now the typical resolution of a digital high definition (HD) TV picture is about 6000H x 4000V or more. There are more than 10,000 times of the charge transfer steps are required. Consequently the total charge loss for each pixel is more than 10% . Buried Channel CCD loses 0.001 % of the photo-charge per each charge transfer step, 10,000 charge transfer times 0.001 % gives 10% total charge loss, which is too large. Human eyes cannot recognize any noise less than 3% , the 10% noise is too large. CCD became useless in the modern digital HDTV era. A new hero is now on the high-light stage of the image sensor world. As shown in Fig. 20, an active-pixel sensor (APS) has a source-follower type current-amplifier output circuit, which was originally invented by Peter J.W. Noble in 1968 [25] but was never used till recently because the MOS transistor size was much larger than one pixel size in 1970s till early 2000s. In Fig.21, a conversional flat-floating-surface NPP+ single junction type low-QE solar cell structure (a) is compared with a P+PNP-PP+ double junction Pinned Buried Photodiode type (b). The diffrence in the quantum efficiency (QE) between the two photodiode strucutures is very important data to be measured. The double junction Pinned Buried Photodiode type solar cell has the buried N- region being completely depleted of majrity carrier photo electons, being removed swifly and no space for photo electons to be recombined, resulting high QE.