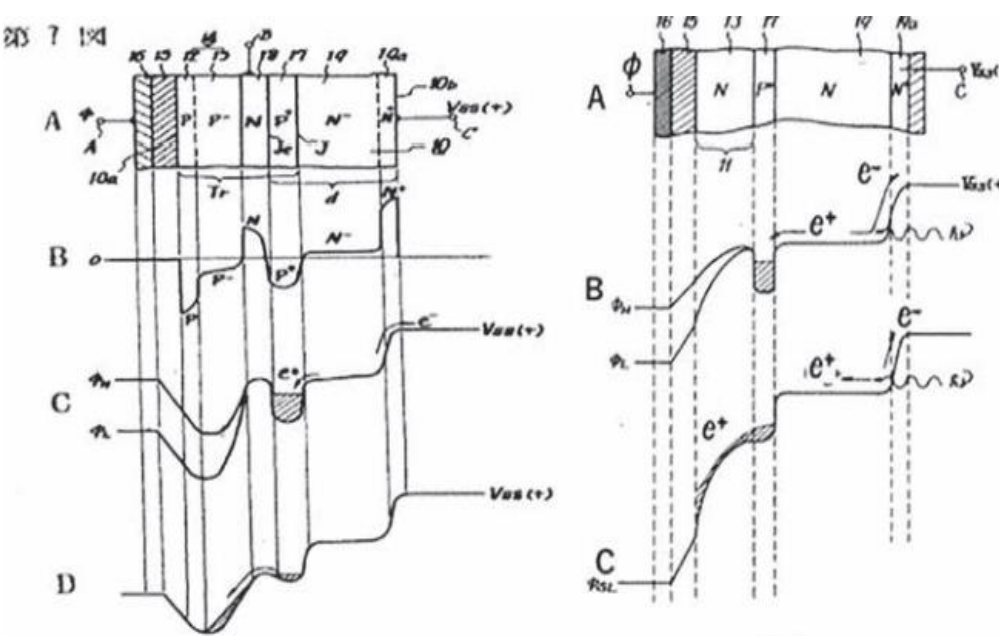
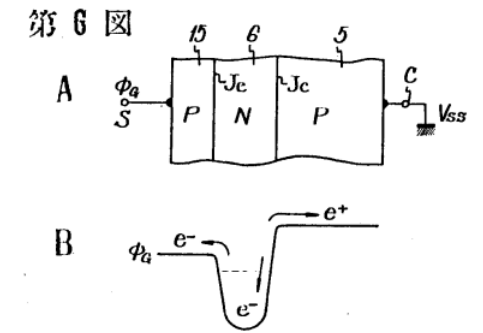
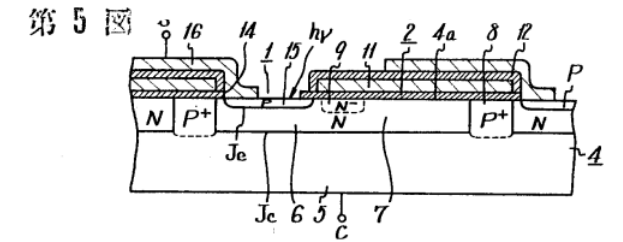


Hagiwara invented the N+NPNP triple junction ( JPA1975-127646 ) and the N+NPN double junction Pinned Photodiode ( JPA1975-127646 ) in Oct 23, 1975 with the metal wire contact on the light-lit surface as an option. However, the size of the metal contact and the MOS transistor were too large to be included in the pixel size. Hagiwara invented the adjacent P+ channel stop region for pinning the light-lit P surface region and developed the surface metal wire contact-less light-lit PNP junction type pinned buried photodiode in the frame transfer (FT) image sensor in 1978. In 1982, Teranishi team at NEC developed the PNP double junction type buried photodiode, but with some serious RC delay time constant problem to the substrate, NEC reported the serious image lag data in IEDM1982 paper. Kodak recognized the importance of pinning the light-lit surface, and KODAK named it as Pinned Photodiode. Kodak used the adjacent LOCOS isolation for pinning the light-lit surface while Hagiwara used the heavily doped P+ channel stops formed by the high energy ion implantation and the rapid lamp anneal method developed by Kazuo Nishiyama at Sony.



Hagiwara at Sony invented and reported in 1978 Surface Metal Contact-less Pinned Photodiode With adjacent P+ channel stops, formed by high energy ion implantation without using the conventional LOCOS isolation.

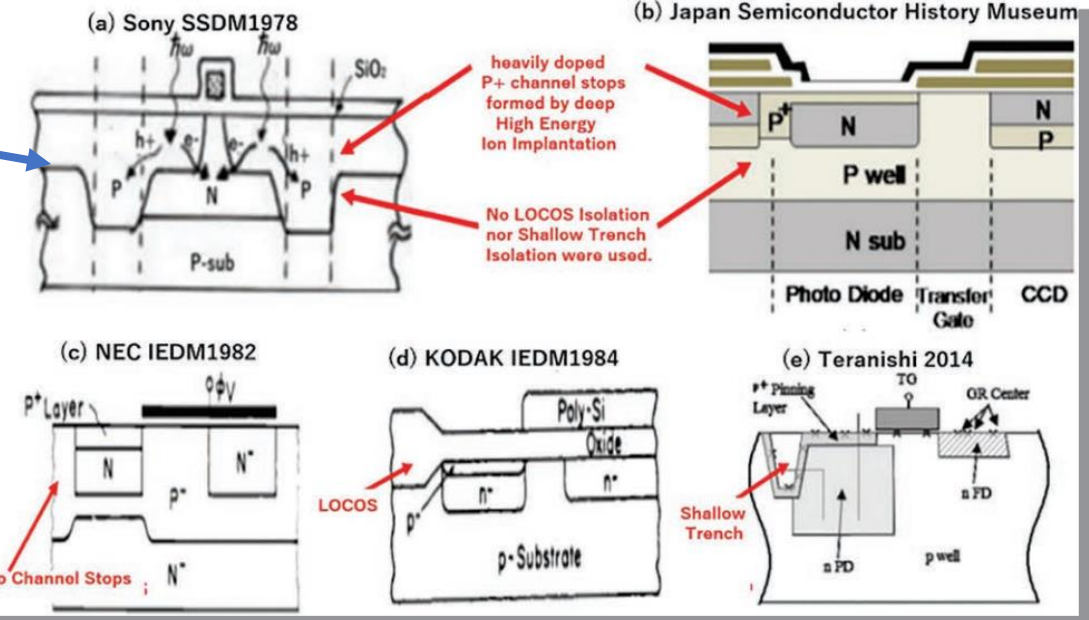


Figure 5. (a) PNP double junction PPD developed by Hagiwara team at Sony in 1978; (b) PPD defined and shown by Semiconductor History Museum of Japan, (c) NEC buried photodiode [17], (d) Kodak PPD [18], (e) PPD reported by Teranishi [25,26]

Fig. 6 of JPA1975-127646 and Fig. 6 of 1975-127647