

Fig. 7 Spectral Response (a) and output waves showing complete charge transfer of no image lag feature (b) and the very low surface dark current characteristics with out illumination(c) and with illumination(d).

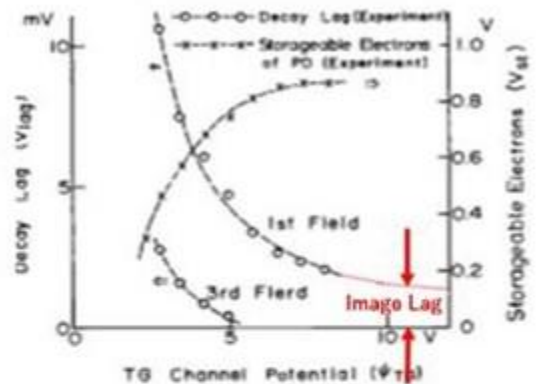


Fig.11 Image Lag reportd by NEC in IEDM1982 Buried Photodiode Paper

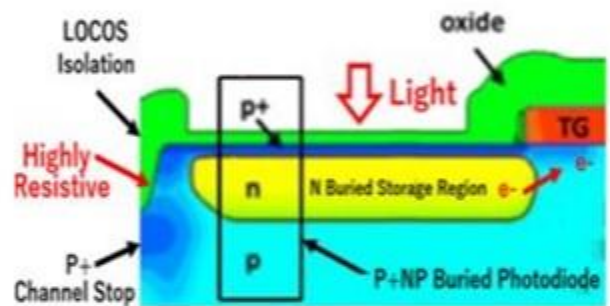


Fig.12 Kodak 1984 Pinned Buried Photodiode with LOCOS P+ channel stop

Sony developed PNP double junction type Pinned Buried Photodiode for the first time in the world in 1977 and 1978, and reported at the SSDM1977 and the SSDM1978 conferences at Tokyo. Complete charge transfer capability of the no image lag and the very low surface dark current were reported. See Fig. 7.

A unique lamp anneal method was invented and developed by Kazuo Nishiyama at Sony [14] and was used in the formation of the perfectly pinned P+ adjacent channel stop with the ideal zero RC delay time constant. Only high energy ion implantation was used in Sony process, without LOCOS isolation nor Shallow Trench isolation. See Fig. 8. Sony also developed Interline Transfer (ILT) CCD image sensor with a thin-polysilicon gate CCD/MOS photo capacitor [15] with the no image lag feature and the clocked OFD electronic shutter scheme [16]. See Fig. 9.

In 1982, NEC developed Buried Photodiode and reported in the IEDM1982 conference [17-18] with image-lag data. NEC used Buried Photodiode in ILT CCD image sensor for the first time in the world. See Fig.10. However, in the NEC Buried Photodiode, serious image lag was observed. See Fig.11. Both Philips and NEC Buried Photodiode are similar. But they both were not Pinned Buried Photodiodes since the surface P+ has a RC time delay and become floating in high frequency operations.

At the IEDM1984 conference, KODAK used P+NP double junction type Pinned Buried Photodiode for the first time in ILT CCD image sensor. KODAK Pinned Buried Photodiode has the P+ surface region connected directly, within some distance in depth, to the adjacent P+ channel stop formed under LOCOS isolation [19]. See Fig.12. KODAK named the device as Pinned Photodiode. NEC reported the serious image lag data while KODAK reported the no image lag feature.

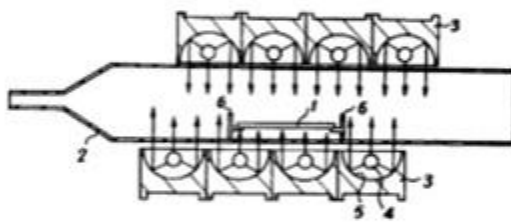


Fig. 8 Unique Lamp Anneal method invented by Nishiyama at Sony in 1981

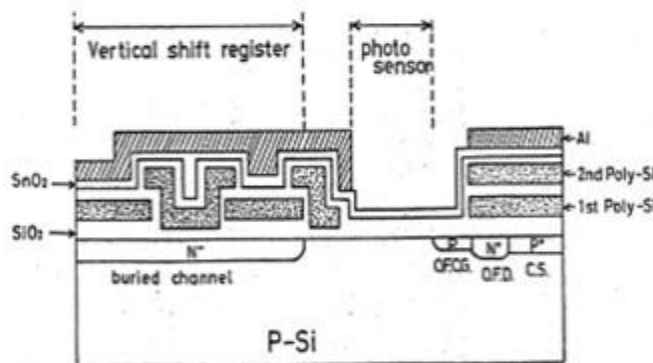


Fig. 9 ILT CCD image sensor with CCD/MOS photo capacitor

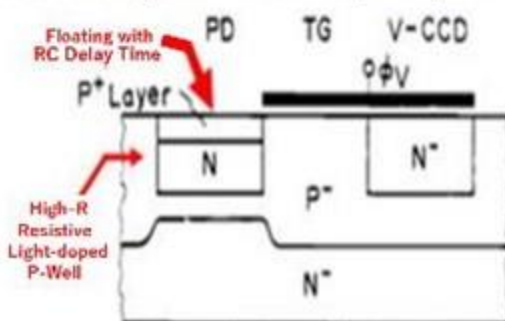


Fig.10 NEC IEDM1982 Buried Photodiode with RC delay