

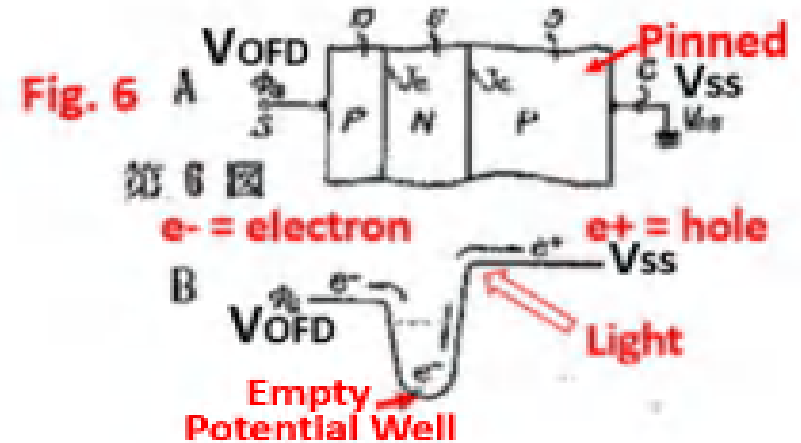
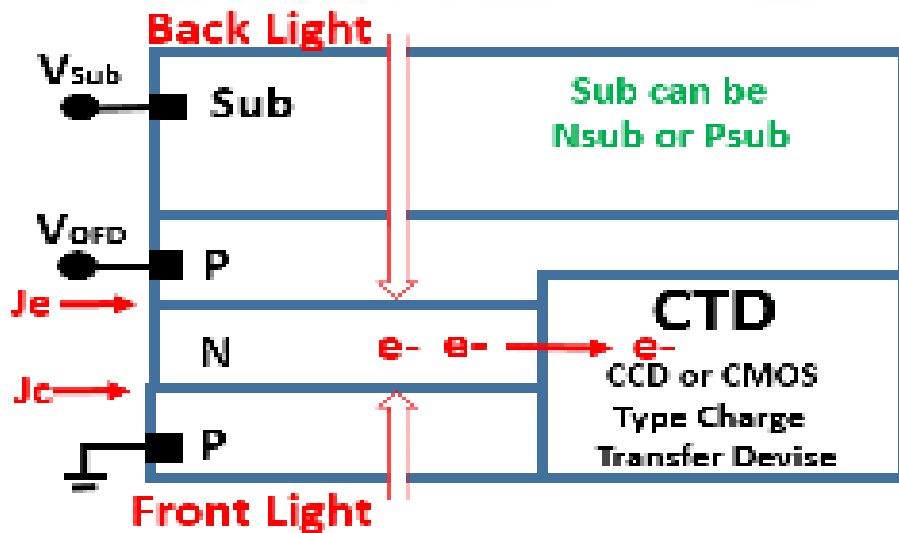
Pinned Photo Diode

Yoshiaki Hagiwara at Sony invented the Pinned Photo Diode in 1975.
Pinned Photo Diode is identical to SONY HAD (Hole Accumulation Diode).
Please Visit <http://www.aiplab.com/>



For the original document, visit and search the Japanese Official Patent Web:
https://www4.j-platpat.inpit.go.jp/eng/tokujitsu/tkbs_en/TKBS_EN_GM101_Top.action
and put documentation numbers 1975-134985, 1975-127647 and 1975-127647.

PNP/Sub Junction type Pinned Photo Diode



English Translation of the Patent Claims

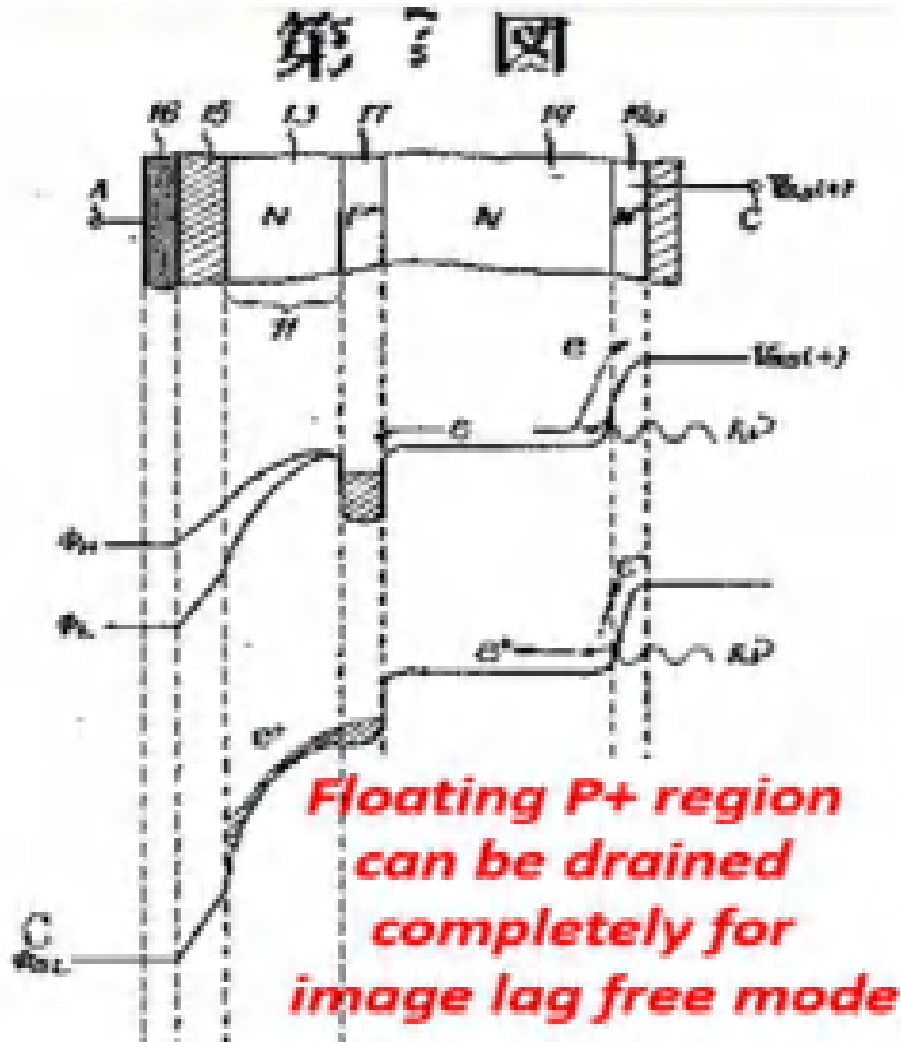
This Japanese Patent 1975-134985 shown here is the evidence to claim that the Pinned Photo Diode with the vertical overflow drain (VOD) function was invented by Yoshiaki Daimon Hagiwara at Sony in 1975.

- (1) In the semiconductor substrate (Sub)
- (2) the first region (P) is formed,
- (3) and the second region (N) is formed upon on the first region (P),
- (4) forming the photo sensing part (NP).
- (5) The charge from this (NP) is transferred to the charge transfer device (CTD),
- (6) which is formed along the front surface of the semiconductor substrate (Sub).
- (7) In the so-defined image sensing device,
- (8) on the second region (N) of the photo sensing part (NP),
- (9) a rectifying junction (PN) is formed.
- (10) Let this junction(PN) be called an emitter junction (Je).
- (11) Let the junction between the first region(N) and the second region (P)
- (12) be called as the collector junction (Jc) forming a transistor (PNP).
- (13) In the second region (N) , which is the base of the said transistor (PNP),
- (14) according to the optical image, the electronic charge (e-) is stored.
- (15) The electronic charge (e-) , stored in here (N) , is transferred to the said CTD.
- (16) the image sensor structure with such a charge transfer operation
- (17) with the features explained above is in the scope of this patent claim.

Pinned Photo Diode (NPN/Sub junction type)

See Japanese Patent 1975-127647 by Hagiwara at Sony in 1975 [Patent Claim in English Translation](#)

Figure 7 of JAP 1975-127647

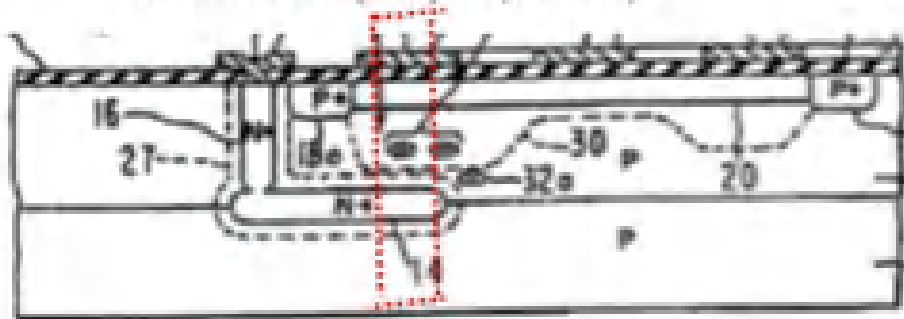


- (1) Along the main surface of the silicon substrate die (Sub),
- (2) the charge transfer gate (CTG) is formed upon the oxide layer (SiO₂).
- (3) whereby the first region (N) is formed for charge transferring area (CTD).
- (4) On the other side of the silicon substrate die (Sub),
- (5) another region (P) is formed nearby the charge transferring area (CTD).
- (6) The region (P) and the nearby first region (N) together
- (7) form a photo sensing area (NPN junction).
- (8) By applying a proper pulse (P1) onto the charge transfer gate (CTG),
- (9) the charge (e⁺) stored in the photo sensing area (PNP junction) is transferred to the charge transfer area (CTD).
- (10) And upon the said transfer gate (CTG),
- (11) a different type of clock pulse (P2) is applied, which is different from the previous pulse (P1).
- (12) Along the main surface of the silicon substrate die (Sub)
- (13) the charge (e⁺) is transferred in this way.
- (14) And so defined solid state image sensor is in the scope of this patent claim.

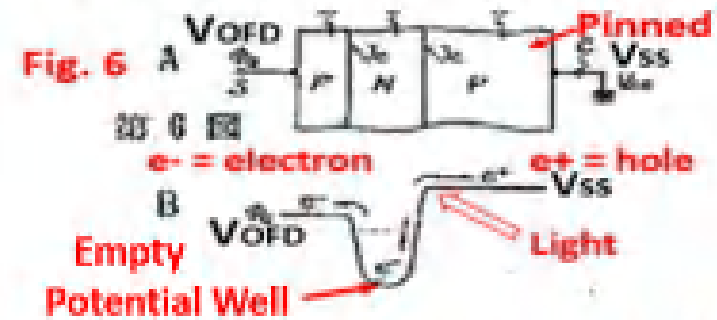
SONY- Fairchild Patent War (1991-2001) on Pinned Photo Diode with Vertical OFD

Fairchild Early Patent on CCD sensor with vertical OFD protection
 USP3896485 (July 22, 1975)

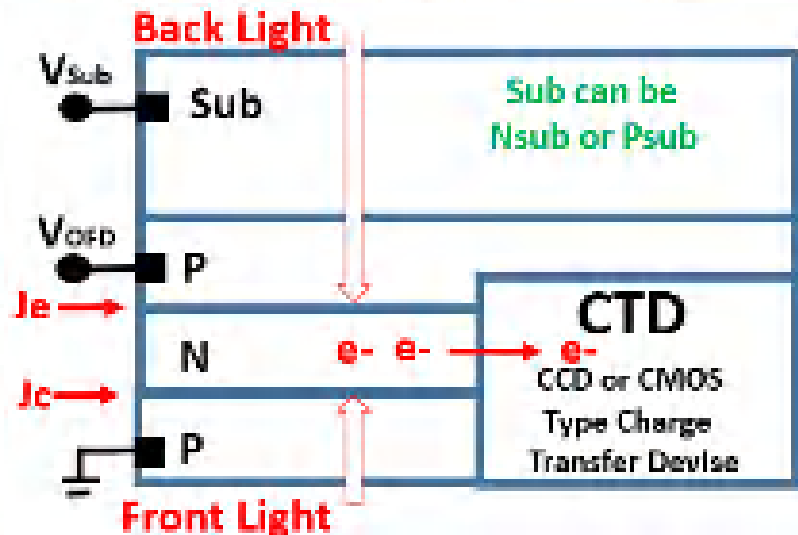
Sony Hagiwara Patent on Pinned Photo Diode with P+NPNsub Thyristor type vertical OFD protection
 JAP 1975-134985 (November 10, 1975)



Fairchild Early Patent, filed on July 22, 1975, applied on the surface CCD type MOS capacitance with poor blue sensitivity while Sony Hagiwara Patent, filed on Nov. 10, 1975, applied on the Pinned Photo Diode, with good blue sensitivity and low dark current also with the built-in vertical overflow drain function, which was well known as the P+NPNsub Thyristor Punch-Thru action. Sony took more than ten years in this Patent War to challenge to explain the differences on the two image sensor structures and the two vertical overflow drain structures to the authorities who did not have any backgrounds on the semiconductor device physics.



Structure defined for Upside-Down Wafer

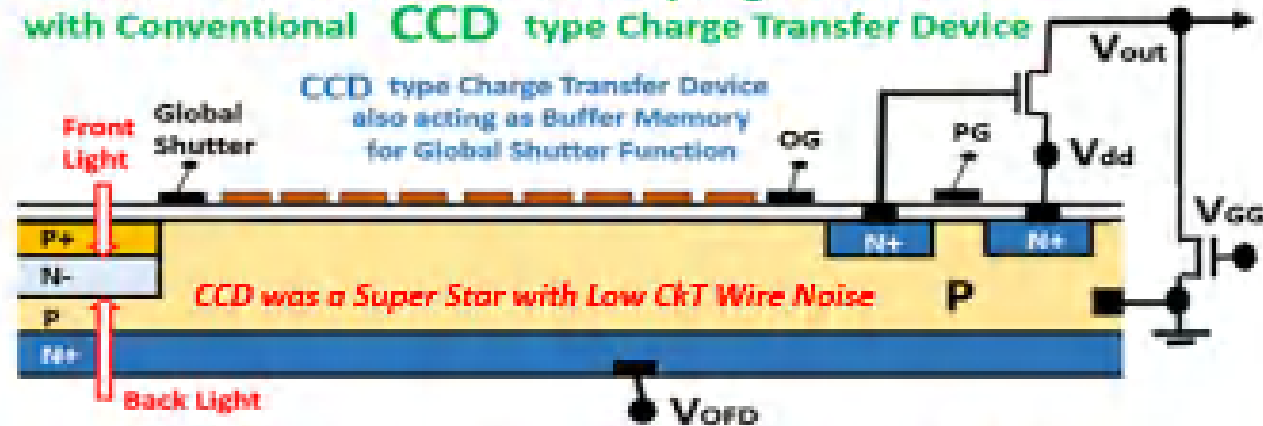


See Hagiwara Japanese Patent Application (JAP 1975-134985)

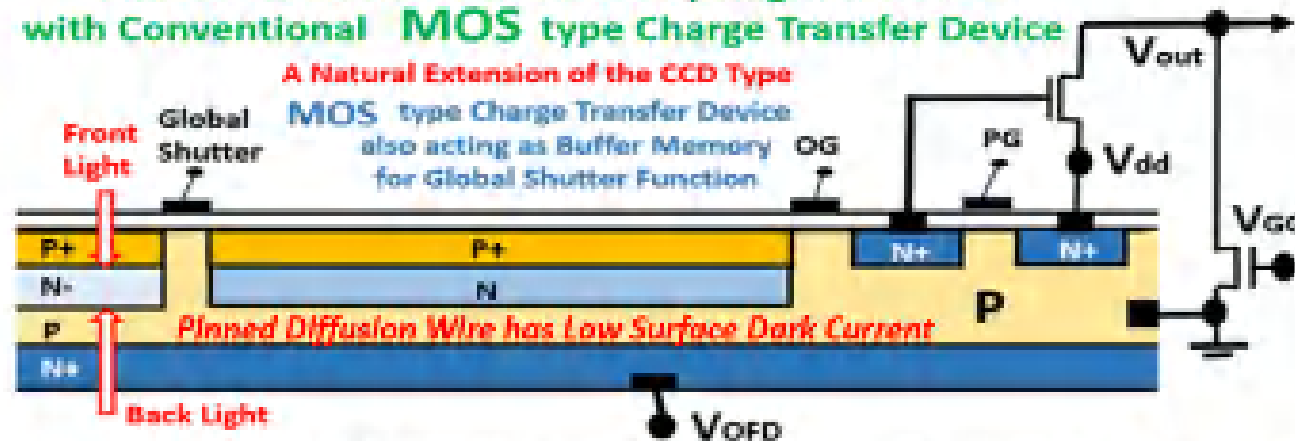
P+NPNsub junction Pinned Photo Diode invented by Hagiwara 1975 with Conventional CCD and MOS type Charge Transfer Devices

See JAP 1975-134985 and USP 4851887

Pinned Photo Diode invented by Hagiwara 1975 with Conventional CCD type Charge Transfer Device



Pinned Photo Diode invented by Hagiwara 1975 with Conventional MOS type Charge Transfer Device



In 1970s, we could not put the active source follower amplifier circuits in each small pixel. Image sensor engineers all knew that we had to wait until MOS process scaling down gets farther down. Until then, we needed the CCD type charge transfer device as the Super Star.

Origin of no-image-lag pinned photo diode invented by Hagiwara at SONY in 1975

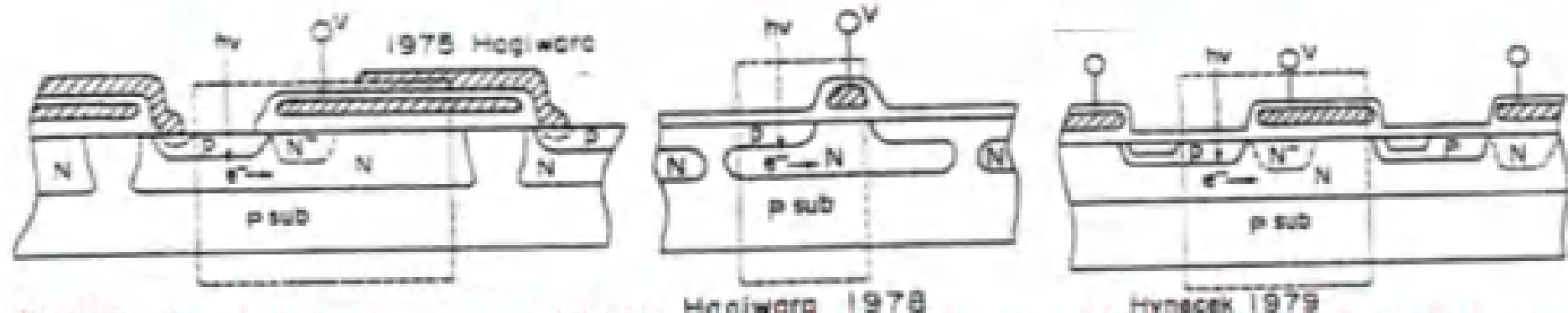
High-Density and High-Quality Frame Transfer
CCD Imager with Very Low Smear, Low Dark
Current, and Very High Blue Sensitivity

Yoshiaki Hagiwara, Member, IEEE

(1) an ITL CCD imager application,
an example case shown in 1975 patent

(2) SONY 1978 FT CCD imager application
with original pinned photo diode

(3) Henecek 1979 invention
of virtual phase CCD imager



(1) 1975 pinned photo diode sensor (2) 1978 pinned photo diode sensor (3) 1979 pinned photo diode sensor

Fig.9. Three image sensors, Hagiwara 1975/1978, and Hyneczek 1979, are compared. The boxed regions in the three sensors operate in the same charge transfer mechanism, which was later named by Hyneczek, who applied this structure to realize, a virtual phase transfer CCD imager. The three sensors perform complete charge transfer. And no image lag is possible.

See Japanese Patent App 50-134978 by Yoshiaki Hagiwara at Sony, 1975

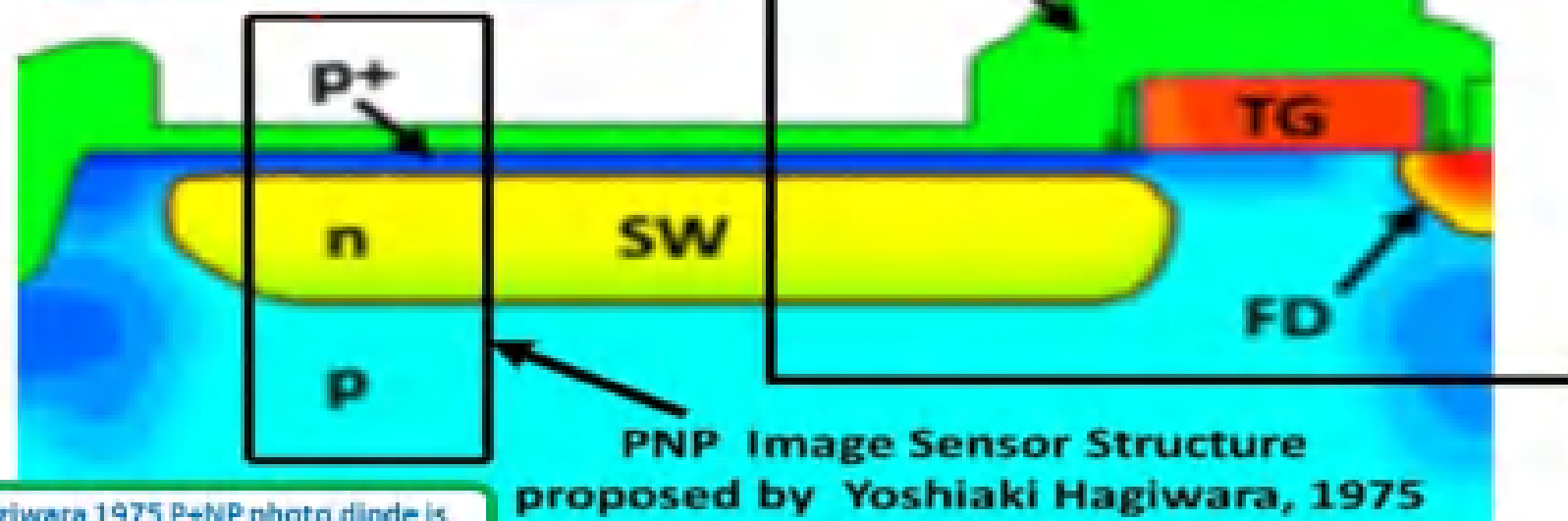
See Hagiwara Japanese Patent Application (1975-134985)

Teranish did not invent the pinned photo diode: Hagiwara at Sony did.

The pinned photo diode seen in Fossum 2014 paper, which is shown below, is the same as the SONY original HAD sensor invented by Yoshiaki Hagiwara at Sony in his 1975 patent.

Hagiwara invented the pinned photo diode in 1975.

Teranishi IEDM 1983 photo diode is a copy of Hagiwara 1975 invention



Hagiwara 1975 P+NP photo diode is now called as the pinned photo diode

See <http://www.aiplab.com/> for details.

A Pinned Photo Diode of the P+N-PNsub junction (thyristor) type

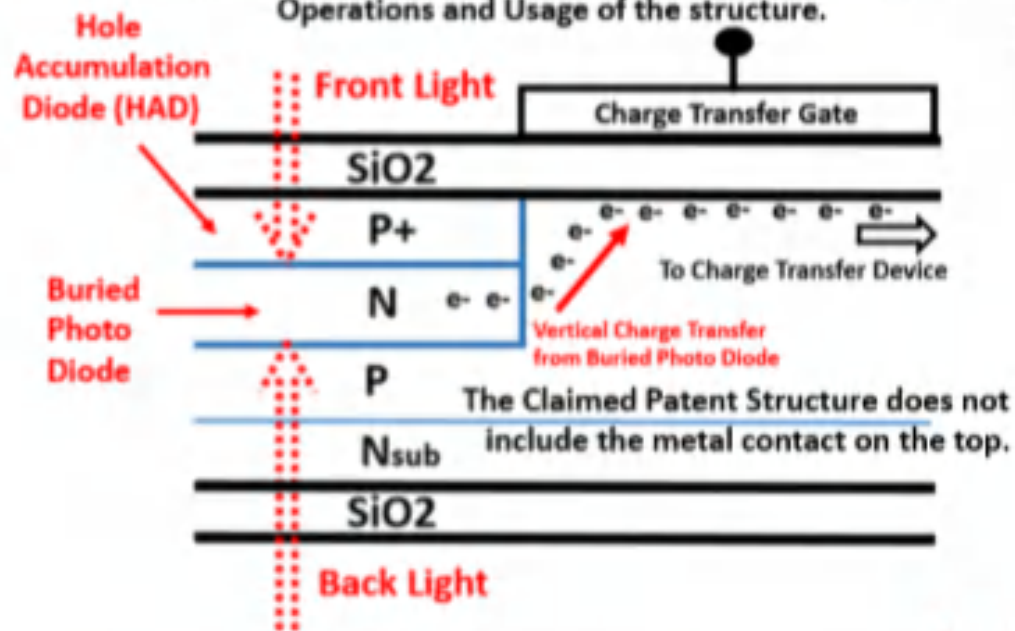
with vertical overflow drain function invented by Hagiwara 1975

See Japanese Patent Document Number (1975-134985)

File	1975-134985	Filed	1975/11/10
Public	1975-058414	Public	1977/05/13
		Grant	1983/10/19

A Pinned Photo Diode defined in the Patent Claims

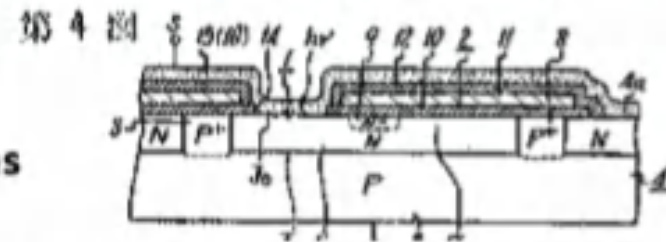
The Scope of Patent Right is extended over all kinds of Operations and Usage of the structure.



in case of Thinned Silicon Die

SONY HAD and PPD are the same thing !

One Schottky Barrier Image Sensor Application



One Pinned Photo Diode Image Sensor Application

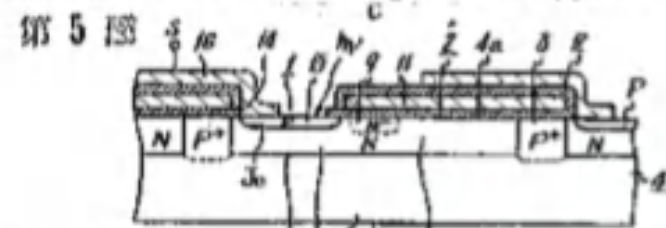
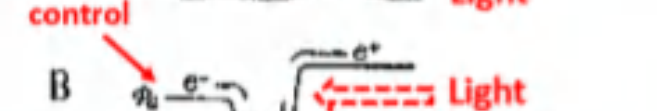
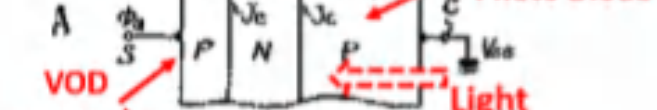


Diagram A: Pinned Photo Diode



Empty Potential Well with no charge

No Image Lag

PPD in Complete Charge Transfer Mode

< The origin of Sony's HAD sensor is Hagiwara's idea in 1978 >

What is the Difference ?

- Extended channel stop :
two-phase (Sony) and
light sensitivity (Philips),

Hagiwara 1975 invention
See JAP 1975-134985

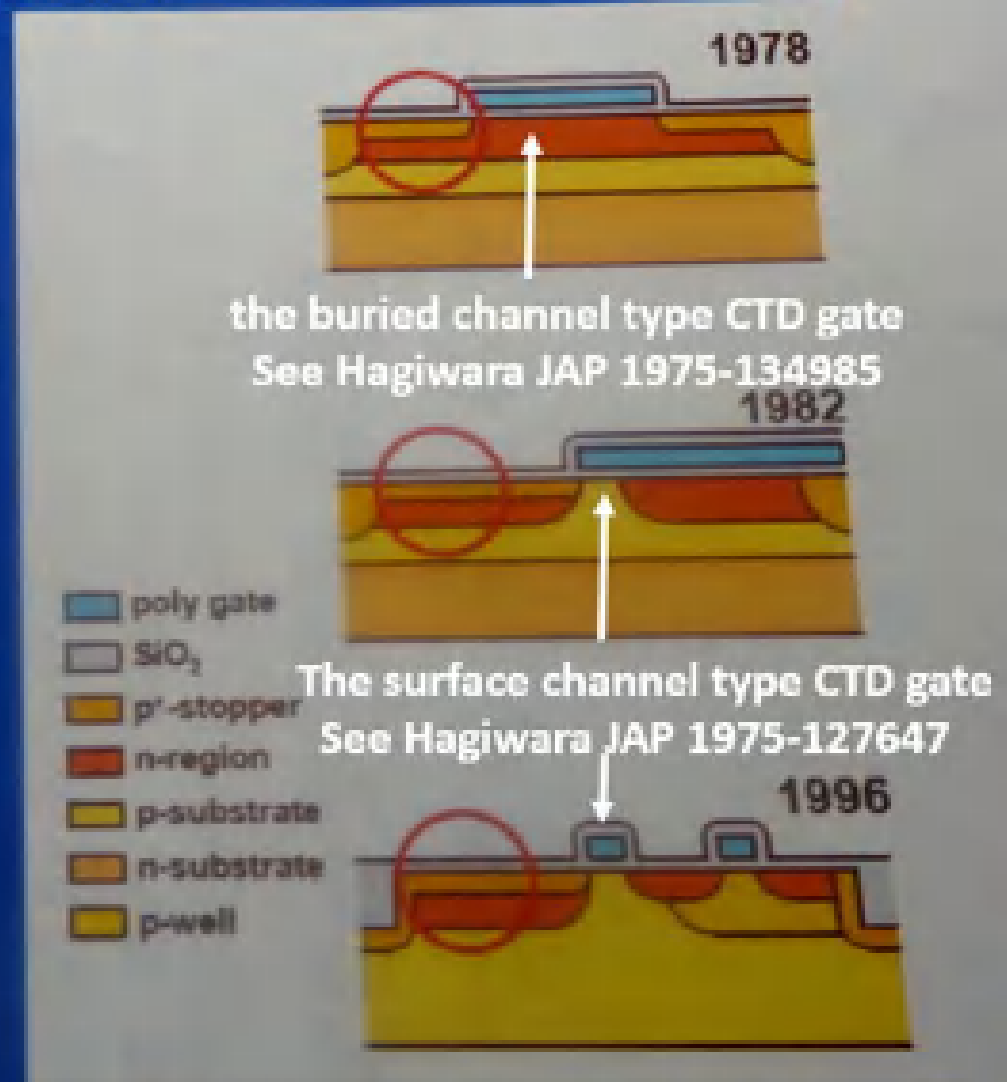
- Pinned-photodiodes in
CCD (NEC)

Hagiwara 1975 invention
See JAP 1975-127647

- Pinned-photodiodes in
CMOS (Kodak)

Sony original HAD and the PPD
are the same thing, both are

Hagiwara 1975 inventions.



Hagiwara was working on the buried channel type CCD charge transfer analysis, using IBM360 computers for his device simulation, which was published in ISSCC1974 in Philadelphia.



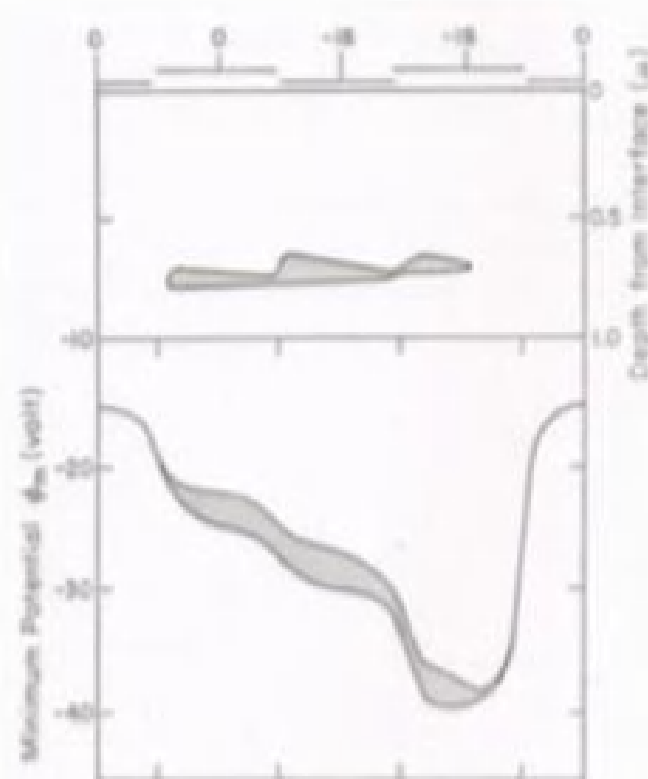
Charge-Coupled Devices and Applications

Chairman
Lewis M. Terman

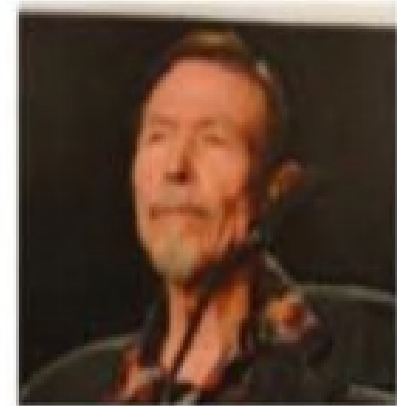
Technical to the importance of the charge-coupled phenomena is attested to by the works of S. Leiberman and the David A. Brackbill awards this year to the originators of the charge-coupled and bucket brigade devices, respectively. The papers in this volume are presented as follows:

Charge-coupled devices are unique among semiconductor devices in that when their applications into circuits, charge is transported and extracted and then used to charge a capacitor or control through a resistor to yield one to many a signal output. It

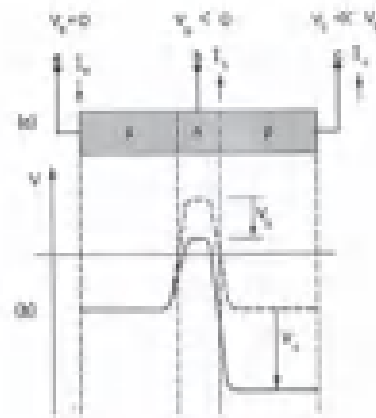
My PhD thesis paper
on buried channel CCD
at ISSCC1974, in Philadelphia, USA



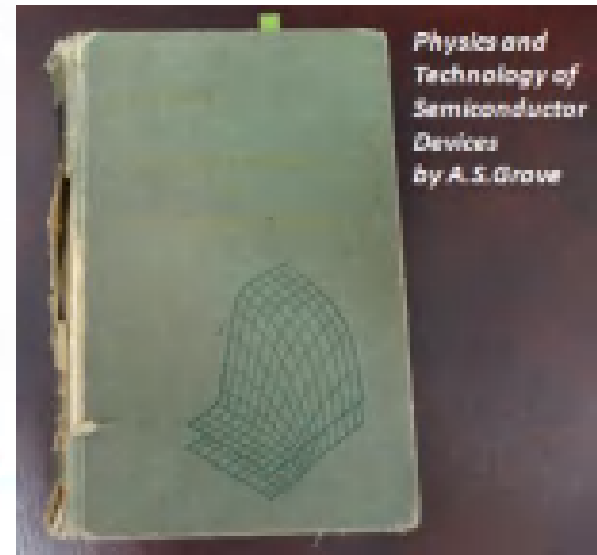
Prof. T. C. McGill



Prof. C. A. Mead



Bipolar Transistor
Feynman: Physics Volume III
p.14-11 Fig.14-12



Prof. T. G. McGill

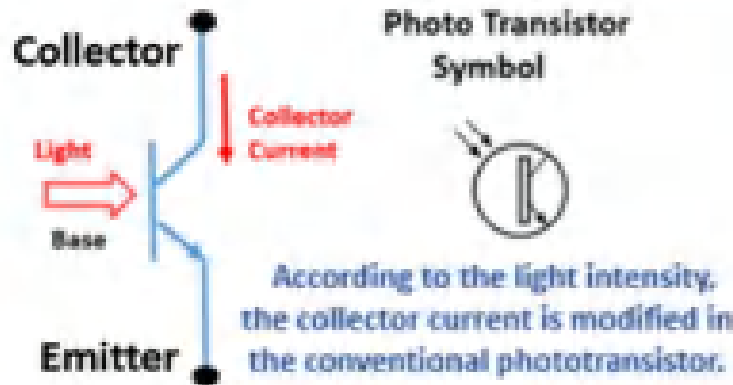


Prof. James McCaldin

Pinned Photo Diode (PNP/Sub junction type)

See Japanese Patent 1975-134985 by Hagiwara at Sony in 1975

Conventional Static Photo Transistor of PNP junction type



Dynamic Photo Transistor Operation proposed by Hagiwara Sony in 1975

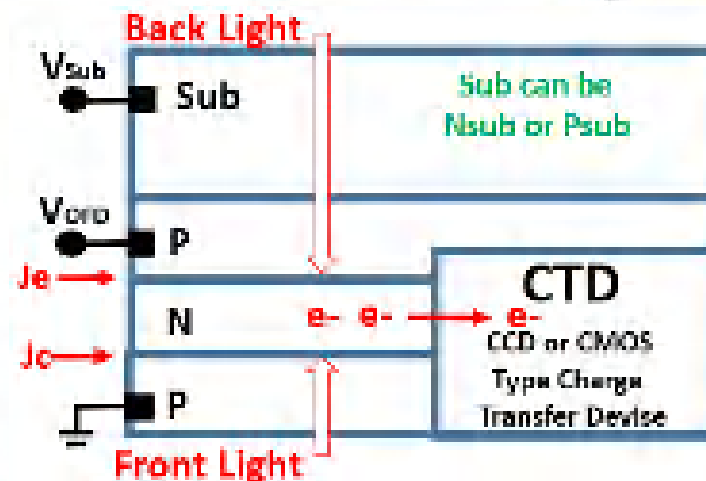
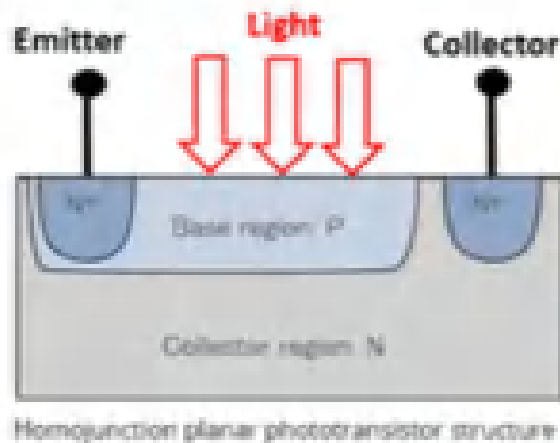
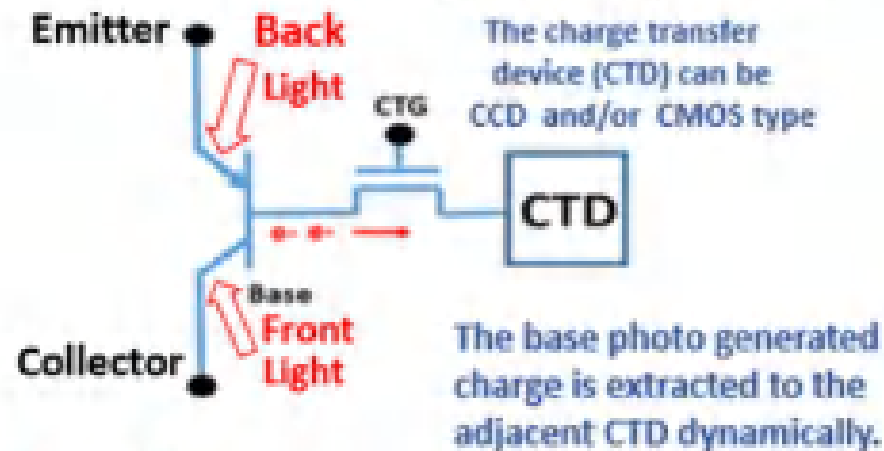


Image Lag Free Complete majority Carrier charge Extraction From the base(N) region is possible.

PNP/Sub junction type Pinned Photo Diode