Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.
Active in-pixel AMP circuit invented by Peter Noble in 1968

Please see https://en.wikipedia.org/wiki/Photodiode#Pinned_photodiode, which does not tell the real truth about the invention and the historical development efforts of Pinned Photodiode and the in-pixel active image sensors.

This documentation should be corrected and re-worded according to the true facts.

This document do not quote Peter Noble’s 1968 work and Hagiwara’s 1975 and 1978 works.

**The truth is that Peter Noble is the inventor of in-pixel active image sensors in 1968.**

**The truth is that Yoshiaki Hagiwara is the inventor of Pinned Photodiode in 1975.**

Fossum did not invent CMOS process technology.

Fossum did not invent the in-pixel image sensor.

**The truth is that Ando Team at NHK developed the first active in-pixel image sensor in 1987.**

Terniashi did not invent Pinned Photodiode.

Teranishi reported in IEDM1978 Buried Photodiode which is not Pinned Photodiode because The Buried Photodiode reported by Teranishi in IEDM1982 had the serious image lag problem.
CCD does not have any image lag. The N+P floating photodiode had serious image lag.

The pinned photodiode (PPD) has a shallow P+ implant in N type diffusion layer over a P-type epitaxial substrate layer. It is not to be confused with the PIN photodiode. The PPD is used in CMOS active-pixel sensors.[21]

Early charge-coupled device image sensors suffered from shutter lag. This was largely resolved with the invention of the pinned photodiode (PPD).[22] It was invented by Nobukazu Teranishi, Hiromitsu Shiraki and Yasuo Ishihara at NEC in 1980.[23][24] They recognized that lag can be eliminated if the signal carriers could be transferred from the photodiode to the CCD. This led to their invention of the pinned photodiode, a photodetector structure with low lag, low noise, high quantum efficiency and low dark current.[22] It was first publicly reported by Teranishi and Ishihara with A. Kohono, E. Oda and K. Arai in 1982, with the addition of an anti-blooming structure.[22][24] The new photodetector structure invented at NEC was given the name "pinned photodiode" (PPD) by B.C. Burkey at Kodak in 1984. In 1987, the PPD began to be incorporated into most CCD sensors, becoming a fixture in consumer electronic video cameras and then digital still cameras.[22]

In 1994, Eric Fossum, while working at NASA's Jet Propulsion Laboratory (JPL), proposed an improvement to the CMOS sensor: the integration of the pinned photodiode. A CMOS sensor with PPD technology was first fabricated in 1995 by a joint JPL and Kodak team that included Fossum along with P.P.K. Lee, R.C. Gee, R.M. Guidash and T.H. Lee. Since then, the PPD has been used in nearly all CMOS sensors. The CMOS sensor with PPD technology was further advanced and refined by R.M. Guidash in 1997, K. Yonemoto and H. Sumi in 2000, and I. Inoue in 2003. This led to CMOS sensors achieving imaging performance on par with CCD sensors, and later exceeding CCD sensors.[22]

---

21. Difference between Buried Photodiode and Pinned Photodiode. stackexchange.com
Please see https://en.wikipedia.org/wiki/Photodiode#Pinned_photodiode.

Hagiwara at Sony invented Pinned Photodiode in 1975.

The pinned photodiode (PPD) has a shallow P+ implant in N type diffusion layer over a P-type epitaxial substrate layer. It is not to be confused with the PIN photodiode. The PPD is used in CMOS active-pixel sensors.[21]

Early charge-coupled device image sensors suffered from shutter lag. This was largely resolved with the invention of the pinned photodiode (PPD).[22] It was invented by Nobukazu Teranishi, Hiromitsu Shiraki and Yasuo Ishihara at NEC in 1980.[23][24] They recognized that lag can be eliminated if the signal carriers could be transferred from the photodiode to the CCD. This led to their invention of the pinned photodiode, a photodetector structure with low lag, low noise, high quantum efficiency and low dark current.[22] It was first publicly reported by Teranishi and Ishihara with A. Kohono, F. Oda and K. Arai in 1982, with the addition of an anti-blooming structure.[22] The new photodetector structure invented at NEC was given the name "pinned photodiode" (PPD) by B.C. Burkey at Kodak in 1984. In 1987, the PPD began to be incorporated into most CCD sensors, becoming a fixture in consumer electronic video cameras and then digital still cameras.[22]

In 1994, Eric Fossum, while working at NASA's Jet Propulsion Laboratory (JPL), proposed an improvement to the CMOS sensor: the integration of the pinned photodiode. A CMOS sensor with PPD technology was first fabricated in 1995 by a joint JPL and Kodak team that included Fossum along with P.P.K. Lee, R.C. Gee, R.M. Guidash and T.H. Lee. Since then, the PPD has been used in nearly all CMOS sensors. The CMOS sensor with PPD technology was further advanced and refined by R.M. Guidash in 1997, K. Yonemoto and H. Sumi in 2000, and I. Inoue in 2003. This led to CMOS sensors achieving imaging performance on par with CCD sensors, and later exceeding CCD sensors.[22]
Hagiwara at Sony invented Pinned Photodiode in 1975 and reported these features in 1978.

The pinned photodiode (PPD) has a shallow P+ implant in N type diffusion layer over a P-type epitaxial substrate layer. It is not to be confused with the PIN photodiode. The PPD is used in CMOS active-pixel sensors.[21]

Early charge-coupled device image sensors suffered from shutter lag. This was largely resolved with the invention of the pinned photodiode (PPD).[22] It was invented by Nobukazu Teranishi, Hiromitsu Shiraki and Yasuo Ishihara at NEC in 1980.[22][23] They recognized that lag can be eliminated if the signal carriers could be transferred from the photodiode to the CCD. This led to their invention of the pinned photodiode, a photodetector structure with low lag, low noise, high quantum efficiency and low dark current.[22] It was first publicly reported by Teranishi and Ishihara with A. Kohono, E. Oda and K. Arai in 1982, with the addition of an anti-blooming structure.[22] The new photodetector structure invented at NEC was given the name "pinned photodiode" (PPD) by B.C. Burkey at Kodak in 1984. In 1987, the PPD began to be incorporated into most CCD sensors, becoming a fixture in consumer electronic video cameras and then digital still cameras.[22]

In 1994, Eric Fossum, while working at NASA's Jet Propulsion Laboratory (JPL), proposed an improvement to the CMOS sensor: the integration of the pinned photodiode. A CMOS sensor with PPD technology was first fabricated in 1995 by a joint JPL and Kodak team that included Fossum along with P.P.K. Lee, R.C. Gee, R.M. Guidash and T.H. Lee. Since then, the PPD has been used in nearly all CMOS sensors. The CMOS sensor with PPD technology was further advanced and refined by R.M. Guidash in 1997, K. Yonemoto and H. Sumi in 2000, and I. Inoue in 2003. This led to CMOS sensors achieve imaging performance on par with CCD sensors, and later exceeding CCD sensors.[22]

---

21. Difference between Buried Photodiode and Pinned Photodiode. stackexchange.com
Hagiwara invented Pinned Photodiode in 1975 with OFD function used in ILT CCD defined in 1975 patents.

The pinned photodiode (PPD) has a shallow P+ implant in N type diffusion layer over a P-type epitaxial substrate layer. It is not to be confused with the PIN photodiode. The PPD is used in CMOS active-pixel sensors.\[21\]

Early charge-coupled device image sensors suffered from shutter lag. This was largely resolved with the invention of the pinned photodiode (PPD).\[22\] It was invented by Nobukazu Teranishi, Hiromitsu Shiraki and Yasuo Ishihara at NEC in 1980.\[22\][\[23\] They recognized that lag can be eliminated if the signal carriers could be transferred from the photodiode to the CCD. This led to their invention of the pinned photodiode, a photodetector structure with low lag, low noise, high quantum efficiency and low dark current.\[22\] It was first publicly reported by Teranishi and Ishihara with A. Kohono, F. Oda and K. Arai in 1982, with the addition of an anti-blooming structure.\[22\][\[24\]

The new photodetector structure invented at NEC was given the name "pinned photodiode" (PPD) by B.C. Burkey at Kodak in 1984. In 1987, the PPD began to be incorporated into most CCD sensors, becoming a fixture in consumer electronic video cameras and then digital still cameras.\[22\]

In 1994, Eric Fossum, while working at NASA’s Jet Propulsion Laboratory (JPL), proposed an improvement to the CMOS sensor: the integration of the pinned photodiode. A CMOS sensor with PPD technology was first fabricated in 1995 by a joint JPL and Kodak team that included Fossum along with P.P.K. Lee, R.C. Gee, R.M. Guidash and T.H. Lee. Since then, the PPD has been used in nearly all CMOS sensors. The CMOS sensor with PPD technology was further advanced and refined by R.M. Guidash in 1997, K. Yonemoto and H. Sumi in 2000, and I. Inoue in 2003. This led to CMOS sensors achieve imaging performance on par with CCD sensors, and later exceeding CCD sensors.\[22\]

21. Difference between Buried Photodiode and Pinned Photodiode
stackexchange.com

22. a b

23. U.S. Patent 4,484,210: Solid-state imaging device having a reduced image lag


Please see https://en.wikipedia.org/wiki/Photodiode#Pinned_photodiode. The photodiode with the serious image lag data reported by Teranishi in 1982 was NOT Pinned Photodiode.

The pinned photodiode (PPD) has a shallow P+ implant in N type diffusion layer over a P-type epitaxial substrate layer. It is not to be confused with the PIN photodiode. The PPD is used in CMOS active-pixel sensors.[21] Early charge-coupled device image sensors suffered from shutter lag. This was largely resolved with the invention of the pinned photodiode (PPD).[22] It was invented by Nobukazu Teranishi, Hiromitsu Shiraki and Yasuo Ishihara at NEC in 1980.[23][24] They recognized that lag can be eliminated if the signal carriers could be transferred from the photodiode to the CCD. This led to their invention of the pinned photodiode, a photodetector structure with low lag, low noise, high quantum efficiency and low dark current.[22] It was first publicly reported by Teranishi and Ishihara with A. Kohono, F. Oda and K. Arai in 1982, with the addition of an anti-blooming structure.[22][24] The new photodetector structure invented at NEC was given the name "pinned photodiode" (PPD) by B.C. Burkey at Kodak in 1984. In 1987, the PPD began to be incorporated into most CCD sensors, becoming a fixture in consumer electronic video cameras and then digital still cameras.[22]

In 1994, Eric Fossum, while working at NASA’s Jet Propulsion Laboratory (JPL), proposed an improvement to the CMOS sensor: the integration of the pinned photodiode. A CMOS sensor with PPD technology was first fabricated in 1995 by a joint JPL and Kodak team that included Fossum along with P.P.K. Lee, R.C. Gee, R.M. Guidash and T.H. Lee. Since then, the PPD has been used in nearly all CMOS sensors. The CMOS sensor with PPD technology was further advanced and refined by R.M. Guidash in 1997, K. Yonemoto and H. Sumi in 2000, and I. Inoue in 2003. This led to CMOS sensors achieve imaging performance on par with CCD sensors, and later exceeding CCD sensors.[22]
Please see https://en.wikipedia.org/wiki/Photodiode#Pinned_photodiode.

Sony in 1987 developed First Pinned Photodiode with the no-image-lag feature and the electric shutter function.

The pinned photodiode (PPD) has a shallow P+ implant in N type diffusion layer over a P-type epitaxial substrate layer. It is not to be confused with the PIN photodiode. The PPD is used in CMOS active-pixel sensors.[21]

Early charge-coupled device image sensors suffered from shutter lag. This was largely resolved with the invention of the pinned photodiode (PPD).[22] It was invented by Nobukazu Teranishi, Hiromitsu Shiraki and Yasuo Ishihara at NEC in 1980.[23][24] They recognized that lag can be eliminated if the signal carriers could be transferred from the photodiode to the CCD. This led to their invention of the pinned photodiode, a photodetector structure with low lag, low noise, high quantum efficiency and low dark current.[22] It was first publicly reported by Teranishi and Ishihara with A. Kohono, E. Oda and K. Arai in 1982, with the addition of an anti-blooming structure.[23][24] The new photodetector structure invented at NEC was given the name "pinned photodiode" (PPD) by B.C. Burkey at Kodak in 1984. In 1987, the PPD began to be incorporated into most CCD sensors, becoming a fixture in consumer electronic video cameras and then digital still cameras.[22]

In 1994, Eric Fossum, while working at NASA's Jet Propulsion Laboratory (JPL), proposed an improvement to the CMOS sensor: the integration of the pinned photodiode. A CMOS sensor with PPD technology was first fabricated in 1995 by a joint JPL and Kodak team that included Fossum along with P.P.K. Lee, R.C. Gee, R.M. Guidash and T.H. Lee. Since then, the PPD has been used in nearly all CMOS sensors. The CMOS sensor with PPD technology was further advanced and refined by R.M. Guidash in 1997, K. Yonemoto and H. Sumi in 2000, and I. Inoue in 2003. This led to CMOS sensors achieve imaging performance on par with CCD sensors, and later exceeding CCD sensors.[22]
Please see https://en.wikipedia.org/wiki/Photodiode#Pinned_photodiode, which does not tell the real truth about the invention and the historical development efforts of Pinned Photodiode and the in-pixel active image sensors.

This documentation should be corrected and re-worded according to the true facts.

This document do not quote Peter Noble’s 1968 work and Hagiwara’s 1975 and 1978 works.

The truth is that Peter Noble is the inventor of in-pixel active image sensors in 1968.

The truth is that Yoshiaki Hagiwara is the inventor of Pinned Photodiode in 1975.

Fossum did not invent CMOS process technology.

Fossum did not invent the in-pixel image sensor.

The truth is that Ando Team at NHK developed the first active in-pixel image sensor in 1987.

Terniashi did not invent Pinned Photodiode.
Teranishi reported in IEDM1978 Buried Photodiode which is not Pinned Photodiode because The Buried Photodiode reported by Teranishi in IEDM1982 had the serious image lag problem.
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.
What is NPN Double Junction type Static Photo Transistor?


It is light-sensitive transistor and is similar to an ordinary bipolar junction transistor (BJT) except that it has no connection to the base terminal. Its operation is based on the photodiode that exists at the CB junction. Instead of the base current, the input to the transistor is provided in the form of light as shown in the schematic symbol.

https://www.electronics-notes.com/articles/electronic_components/transistor/what-is-a-phototransistor-tutorial.php
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.

In 1975 the first PPD was invented by Hagiwara at Sony and used in ILT CCD PDs by Hamazaki at Sony in 1987.

PPD must have the P+ channel stops nearby to pin the surface P+ layer.
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.

The original 1975 invention of N+PNP junction type photodiode as sketched in the Sony Yokohama Research Cente Lab Note by Yoshiaki Hagiwara is the evidence that Hagiwara is the inventor of the Pinned Photodiode with the vertical overflow drain function with the lightly doped n base region by the thyristor punch thru action mode.
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.

(a) Pinned Photodiode defined in Fig. 7 of JPA1975-127647

(b) Pinned Photodiode defined in Fig. 5 and 6 of JPA1975-134985

Fig. 7A

Fig. 7B

Fig. 7C

Fig. 5

Fig. 6A

Fig. 6B

Metal Contact is optional

Complete Charge Transfer with no Image Lag

Empty Potential Well

Light
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.

Four Types of Basic Photo Sensor Structures

(A) Classical N+P Single Junction type Photodiode with the floating surface N storage region

(B) Double Junction PNP type Buried Photodiode with the floating surface P region and the floating buried N storage region

(C) Double Junction P+NP type Buried Photodiode with the floating surface P+ hole accumulation region and the floating N Storage Region.

(D) Double Junction P+NP type Pinned Photodiode with the pinned surface P+ hole accumulation region and the pinned N Storage Region.
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.

Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.


PNP Double Junction type Buried Channel Pinned Photodiode
with MOS Capacitor Buffer Memory for Built-in Global Shutter Function

An example of Actual Numerical Calculation

\[ V_{bar} = kT \ln \left( \frac{N_{a+}}{N_a} \right) = 0.119274 \text{ V} \]

<table>
<thead>
<tr>
<th>V_G</th>
<th>Metal SiO_2</th>
<th>P</th>
<th>N</th>
<th>P</th>
<th>P+ Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>a</td>
<td>b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When \( V_{GG} = 0 \text{ V}, V_s = 0 \text{ V} \):
- Both have the same curve from Point b.

- \( \text{Na} = 50 \mu m^{-3} \)
- \( \text{Nd} = 50 \mu m^{-3} \)
- \( \text{Na}^+ = 5000 \mu m^{-3} \)
- \( W_s = 10 \mu m \)
- \( W_d = 10 \mu m \)
- \( X_{ox} = 0.05 \mu m \)

V(x) vs. Depth from Silicon Surface
What is Drift Field Transistor?

The drift-field transistor, also called the drift transistor or graded base transistor, is a type of high-speed bipolar junction transistor having a doping-engineered electric field in the base to reduce the charge carrier base transit time.

Invented by Herbert Kroemer at the Central Bureau of Telecommunications Technology of the German Postal Service, in 1953.

It continues to influence the design of modern high-speed bipolar junction transistors.

Early drift transistors were made by diffusing the base dopant in a way that caused a higher doping concentration near the emitter reducing towards the collector.

Who invented the drift field Transistor?

Herbert Kroemer invented the drift field Transistor.

https://en.wikipedia.org/wiki/Herbert_Kroemer

Herbert Kroemer (born August 25, 1928) is a German-American physicist who, along with Zhores Alferov, received the Nobel Prize in Physics in 2000 for "developing semiconductor heterostructures used in high-speed- and opto-electronics". Kroemer is professor emeritus of electrical and computer engineering at the University of California, Santa Barbara, having received his Ph.D. in theoretical physics in 1952 from the University of Göttingen, Germany, with a dissertation on hot electron effects in the then-new transistor. His research into transistors was a stepping stone to the later development of mobile phone technologies.
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.

Sony developed in 1978 the P+NP double junction type Pinned Photodiode with the complete charge transfer capability to realize the excellent feature of no image lag for fast action pictures. The pinned surface P+ hole accumulation region was formed by self-aligned ion implantation. Total dark current was measured to be less than 5 nA/cm². And the dark current level was less than 3% of the maximum signal level at room temperature of 20°C. Very low surface dark current was observed since there is no electric field in the Pinned P+ surface region,


Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.

Finally the Sony-Fairchild Patent Wat(1991-2000) ended over the Sony HAD Sensor which is identical to the P+NPNSub junction type Pinned Photodiode with Vertical Overflow Drain, originally invented by Hagiwara at Sony in 1975. And finally Hagiwara received for his 1975-134985 Japanese Patent officially, the First Patent Award from Mr. Ando, Sony president in April, 2001 after more 26 years of struggles since his invention.
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.
Please see https://en.wikipedia.org/wiki/Photodiode#Pinned_photodiode, which does not tell the real truth about the invention and the historical development efforts of Pinned Photodiode and the in-pixel active image sensors.

This documentation should be corrected and re-worded according to the true facts.

This document do not quote Peter Noble’s 1968 work and Hagiwara’s 1975 and 1978 works.

**The truth is that Peter Noble is the inventor of in-pixel active image sensors in 1968.**

**The truth is that Yoshiaki Hagiwara is the inventor of Pinned Photodiode in 1975.**

Fossum did not invent CMOS process technology.

Fossum did not invent the in-pixel image sensor.

**The truth is that Ando Team at NHK developed the first active in-pixel image sensor in 1987.**

Terniashi did not invent Pinned Photodiode.

Teranish reported in IEDM1978 Buried Photodiode which is not Pinned Photodiode because The Buried Photodiode reported by Teranishi in IEDM1982 had the serious image lag problem.
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.
Active in-pixel AMP circuit invented by Peter Noble in 1968

Please see https://en.wikipedia.org/wiki/Photodiode#Pinned_photodiode, which does not tell the real truth about the invention and the historical development efforts of Pinned Photodiode and the in-pixel active image sensors.

This documentation should be corrected and re-worded according to the true facts.

This document do not quote Peter Noble’s 1968 work and Hagiwara’s 1975 and 1978 works.

**The truth is that Peter Noble is the inventor of in-pixel active image sensors in 1968.**

**The truth is that Yoshiaki Hagiwara is the inventor of Pinned Photodiode in 1975.**

Fossum did not invent CMOS process technology.

Fossum did not invent the in-pixel image sensor.

**The truth is that Ando Team at NHK developed the first active in-pixel image sensor in 1987.**

Terniashi did not invent Pinned Photodiode.
Teranish reported in IEDM1978 Buried Photodiode which is not Pinned Photodiode because The Buried Photodiode reported by Teranishi in IEDM1982 had the serious image lag problem.