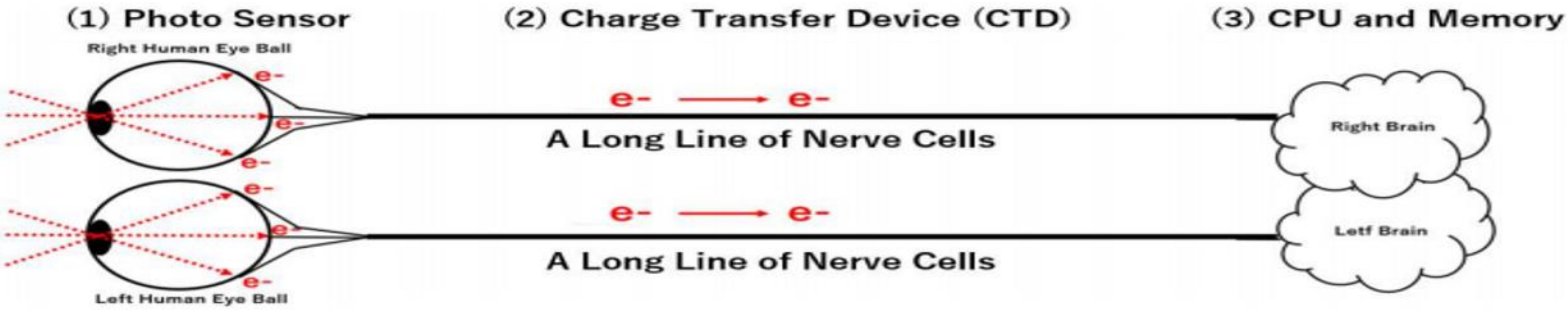
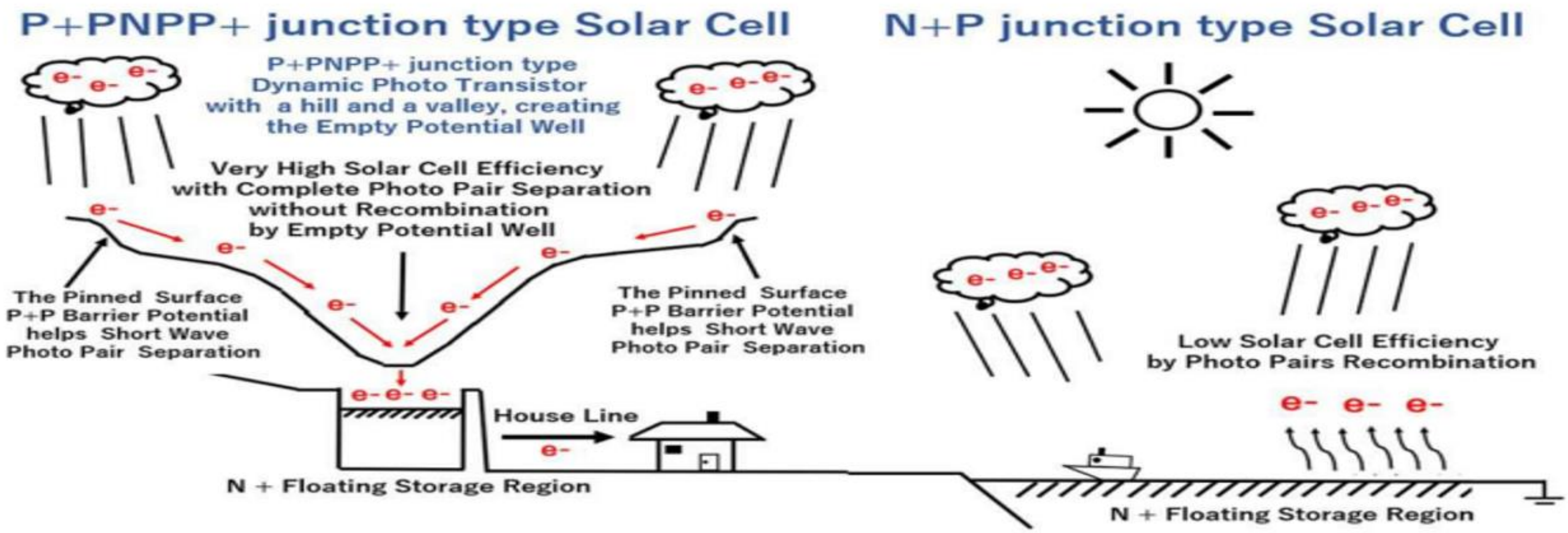
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975

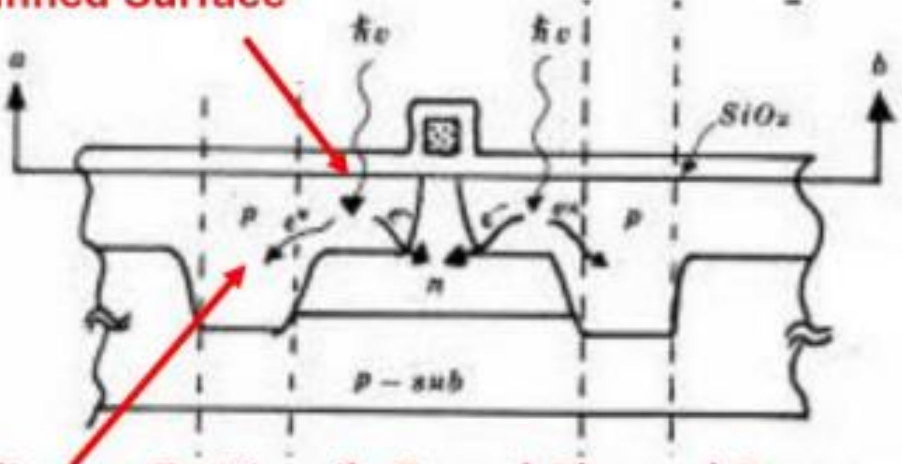




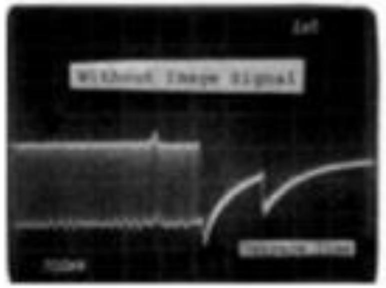
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975

Pinned Photodiode in SONY SSDM1987 Paper

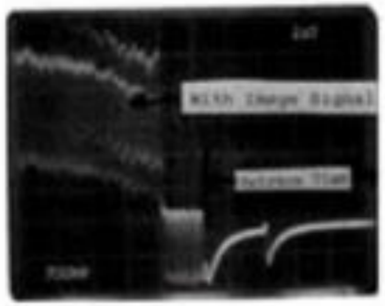
Pinned Surface



Adjacent P+ Heavily Doped Channel Stops

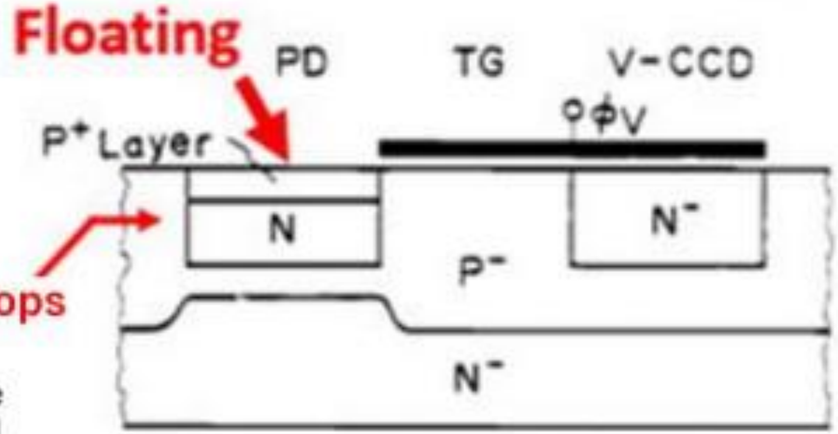


Low Dark Current



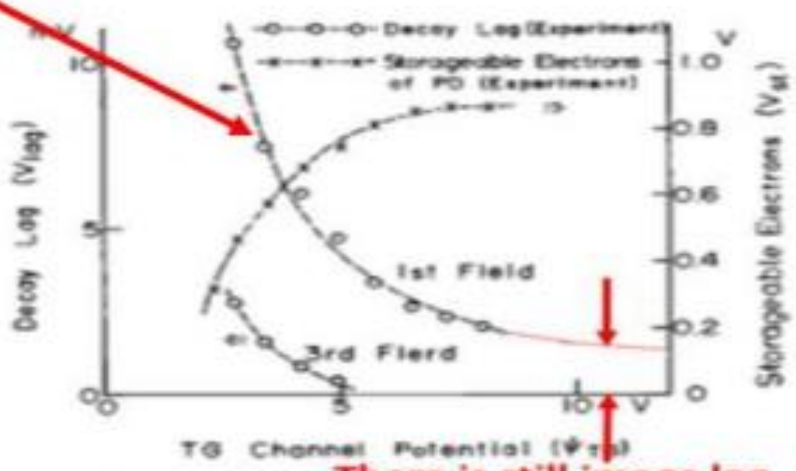
Complete Charge Transfer
No Image Lag

Buried Photodiode in NEC IEDM1982 Paper



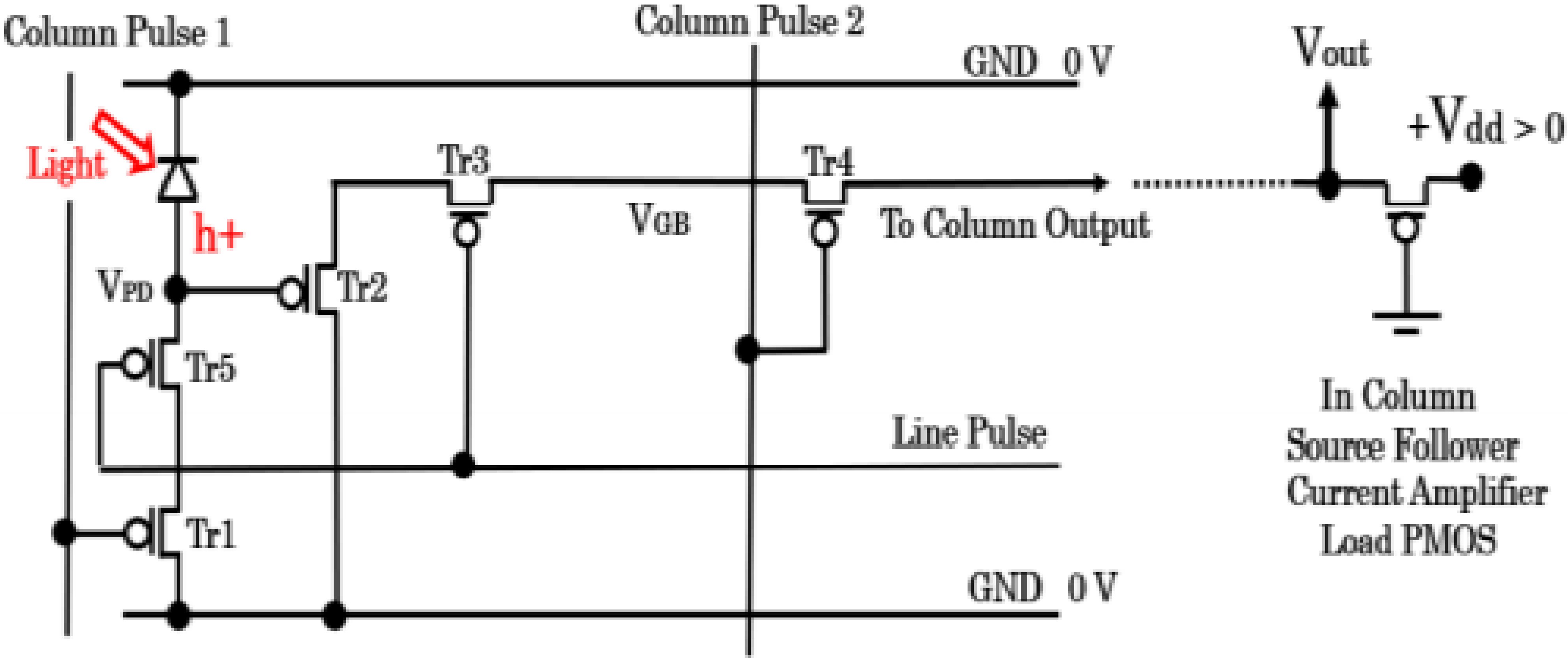
No P+ Channel Stops

The RC delay makes
the floating P+ surface
inducing the undesired
serious image lag,
as reported in Fig. 6
of NEC IEDM1982 paper



There is still image lag
at the CTD gate voltage more than 10 volt.

Active in-pixel AMP circuit invented by Peter Noble in 1968



Peter Nobel, IEEE Tran. of Electron Devices 15-4 (1968) pp. 202-209

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.

Please see https://en.wikipedia.org/wiki/Photodiode#Pinned_photodiode.

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.[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][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 c d e f g h Fossum, Eric R.; Hondongwa, D. B. (2014). "A Review of the Pinned Photodiode for CCD and CMOS Image Sensors". *IEEE Journal of the Electron Devices Society*. **2** (3): 33–43. doi:10.1109/JEDS.2014.2306412.
23. ^ U.S. Patent 4,484,210: Solid-state imaging device having a reduced image lag
24. ^ Teranishi, Nobuzaku; Kohono, A.; Ishihara, Yasuo; Oda, E.; Arai, K. (December 1982). "No image lag photodiode structure in the interline CCD image sensor". *1982 International Electron Devices Meeting*: 324–327. doi:10.1109/IEDM.1982.190285. S2CID 44669969.
25. ^ Gao, Wei (2010). *Precision Nanometrology: Sensors and Measuring Systems for Nanomanufacturing*. Springer. pp. 15–16. ISBN 978-1-84996-253-7.
26. ^ Kozlowski, L. J.; Luo, J.; Kleinhans, W. E.; Liu, T. (14 September 1998). "Comparison of passive and active pixel schemes for CMOS visible imagers". *Infrared Readout Electronics IV*. International Society for Optics and Photonics. **3360**: 101–110. Bibcode:1998SPIE.3360..101K. doi:10.1117/12.584474. S2CID 123351913.
27. ^ a b Fossum, Eric R. (12 July 1993). Blouke, Morley M. (ed.). "Active pixel sensors: are CCDs dinosaurs?". *SPIE Proceedings Vol. 1900: Charge-Coupled Devices and Solid State Optical Sensors III*. International Society for Optics and Photonics. **1900**: 2–14. Bibcode:1993SPIE.1900....2F. CiteSeerX 10.1.1.408.6558. doi:10.1117/12.148585. S2CID 10556755.

Please see https://en.wikipedia.org/wiki/Photodiode#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]

Hagiwara at Sony invented Pinned Photodiode in 1975.

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][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 c d e f g h Fossum, Eric R.; Hondongwa, D. B. (2014). "A Review of the Pinned Photodiode for CCD and CMOS Image Sensors". *IEEE Journal of the Electron Devices Society*. **2** (3): 33–43. doi:10.1109/JEDS.2014.2306412.
23. ^ U.S. Patent 4,484,210: Solid-state imaging device having a reduced image lag
24. ^ Teranishi, Nobuzaku; Kohono, A.; Ishihara, Yasuo; Oda, E.; Arai, K. (December 1982). "No image lag photodiode structure in the interline CCD image sensor". *1982 International Electron Devices Meeting*: 324–327. doi:10.1109/IEDM.1982.190285. S2CID 44669969.
25. ^ Gao, Wei (2010). *Precision Nanometrology: Sensors and Measuring Systems for Nanomanufacturing*. Springer. pp. 15–16. ISBN 978-1-84996-253-7.
26. ^ Kozlowski, L. J.; Luo, J.; Kleinhans, W. E.; Liu, T. (14 September 1998). "Comparison of passive and active pixel schemes for CMOS visible imagers". *Infrared Readout Electronics IV*. International Society for Optics and Photonics. **3360**: 101–110. Bibcode:1998SPIE.3360..101K. doi:10.1117/12.584474. S2CID 123351913.
27. ^ a b Fossum, Eric R. (12 July 1993). Blouke, Morley M. (ed.). "Active pixel sensors: are CCDs dinosaurs?". *SPIE Proceedings Vol. 1900: Charge-Coupled Devices and Solid State Optical Sensors III*. International Society for Optics and Photonics. **1900**: 2–14. Bibcode:1993SPIE.1900....2F. CiteSeerX 10.1.1.408.6558. doi:10.1117/12.148585. S2CID 10556755.

Please see https://en.wikipedia.org/wiki/Photodiode#Pinned_photodiode.

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][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 c d e f g h Fossum, Eric R.; Hondongwa, D. B. (2014). "A Review of the Pinned Photodiode for CCD and CMOS Image Sensors". *IEEE Journal of the Electron Devices Society*. **2** (3): 33–43. doi:10.1109/JEDS.2014.2306412.
23. ^ U.S. Patent 4,484,210: Solid-state imaging device having a reduced image lag
24. ^ Teranishi, Nobuzaku; Kohono, A.; Ishihara, Yasuo; Oda, E.; Arai, K. (December 1982). "No image lag photodiode structure in the interline CCD image sensor". *1982 International Electron Devices Meeting*: 324–327. doi:10.1109/IEDM.1982.190285. S2CID 44669969.
25. ^ Gao, Wei (2010). *Precision Nanometrology: Sensors and Measuring Systems for Nanomanufacturing*. Springer. pp. 15–16. ISBN 978-1-84996-253-7.
26. ^ Kozlowski, L. J.; Luo, J.; Kleinhans, W. E.; Liu, T. (14 September 1998). "Comparison of passive and active pixel schemes for CMOS visible imagers". *Infrared Readout Electronics IV*. International Society for Optics and Photonics. **3360**: 101–110. Bibcode:1998SPIE.3360..101K. doi:10.1117/12.584474. S2CID 123351913.
27. ^ a b Fossum, Eric R. (12 July 1993). Blouke, Morley M. (ed.). "Active pixel sensors: are CCDs dinosaurs?". *SPIE Proceedings Vol. 1900: Charge-Coupled Devices and Solid State Optical Sensors III*. International Society for Optics and Photonics. **1900**: 2–14. Bibcode:1993SPIE.1900....2F. CiteSeerX 10.1.1.408.6558. doi:10.1117/12.148585. S2CID 10556755.

Please see https://en.wikipedia.org/wiki/Photodiode#Pinned_photodiode.

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, 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 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 c d e f g h Fossum, Eric R.; Hondongwa, D. B. (2014). "A Review of the Pinned Photodiode for CCD and CMOS Image Sensors". *IEEE Journal of the Electron Devices Society*. **2** (3): 33–43. doi:10.1109/JEDS.2014.2306412.
23. ^ U.S. Patent 4,484,210: Solid-state imaging device having a reduced image lag
24. ^ Teranishi, Nobuzaku; Kohono, A.; Ishihara, Yasuo; Oda, E.; Arai, K. (December 1982). "No image lag photodiode structure in the interline CCD image sensor". *1982 International Electron Devices Meeting*: 324–327. doi:10.1109/IEDM.1982.190285. S2CID 44669969.
25. ^ Gao, Wei (2010). *Precision Nanometrology: Sensors and Measuring Systems for Nanomanufacturing*. Springer. pp. 15–16. ISBN 978-1-84996-253-7.
26. ^ Kozlowski, L. J.; Luo, J.; Kleinhans, W. E.; Liu, T. (14 September 1998). "Comparison of passive and active pixel schemes for CMOS visible imagers". *Infrared Readout Electronics IV*. International Society for Optics and Photonics. **3360**: 101–110. Bibcode:1998SPIE.3360..101K. doi:10.1117/12.584474. S2CID 123351913.
27. ^ a b Fossum, Eric R. (12 July 1993). Blouke, Morley M. (ed.). "Active pixel sensors: are CCDs dinosaurs?". *SPIE Proceedings Vol. 1900: Charge-Coupled Devices and Solid State Optical Sensors III*. International Society for Optics and Photonics. **1900**: 2–14. Bibcode:1993SPIE.1900....2F. CiteSeerX 10.1.1.408.6558. doi:10.1117/12.148585. S2CID 10556755.

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.[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][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 c d e f g h Fossum, Eric R.; Hondongwa, D. B. (2014). "A Review of the Pinned Photodiode for CCD and CMOS Image Sensors". *IEEE Journal of the Electron Devices Society*. **2** (3): 33–43. doi:10.1109/JEDS.2014.2306412.
23. ^ U.S. Patent 4,484,210: Solid-state imaging device having a reduced image lag
24. ^ Teranishi, Nobuzaku; Kohono, A.; Ishihara, Yasuo; Oda, E.; Arai, K. (December 1982). "No image lag photodiode structure in the interline CCD image sensor". *1982 International Electron Devices Meeting*: 324–327. doi:10.1109/IEDM.1982.190285. S2CID 44669969.
25. ^ Gao, Wei (2010). *Precision Nanometrology: Sensors and Measuring Systems for Nanomanufacturing*. Springer. pp. 15–16. ISBN 978-1-84996-253-7.
26. ^ Kozlowski, L. J.; Luo, J.; Kleinhans, W. E.; Liu, T. (14 September 1998). "Comparison of passive and active pixel schemes for CMOS visible imagers". *Infrared Readout Electronics IV*. International Society for Optics and Photonics. **3360**: 101–110. Bibcode:1998SPIE.3360..101K. doi:10.1117/12.584474. S2CID 123351913.
27. ^ a b Fossum, Eric R. (12 July 1993). Blouke, Morley M. (ed.). "Active pixel sensors: are CCDs dinosaurs?". *SPIE Proceedings Vol. 1900: Charge-Coupled Devices and Solid State Optical Sensors III*. International Society for Optics and Photonics. **1900**: 2–14. Bibcode:1993SPIE.1900....2F. CiteSeerX 10.1.1.408.6558. doi:10.1117/12.148585. S2CID 10556755.

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.[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][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 c d e f g h Fossum, Eric R.; Hondongwa, D. B. (2014). "A Review of the Pinned Photodiode for CCD and CMOS Image Sensors". *IEEE Journal of the Electron Devices Society*. **2** (3): 33–43. doi:10.1109/JEDS.2014.2306412.
23. ^ U.S. Patent 4,484,210: Solid-state imaging device having a reduced image lag
24. ^ Teranishi, Nobuzaku; Kohono, A.; Ishihara, Yasuo; Oda, E.; Arai, K. (December 1982). "No image lag photodiode structure in the interline CCD image sensor". *1982 International Electron Devices Meeting*: 324–327. doi:10.1109/IEDM.1982.190285. S2CID 44669969.
25. ^ Gao, Wei (2010). *Precision Nanometrology: Sensors and Measuring Systems for Nanomanufacturing*. Springer. pp. 15–16. ISBN 978-1-84996-253-7.
26. ^ Kozlowski, L. J.; Luo, J.; Kleinhans, W. E.; Liu, T. (14 September 1998). "Comparison of passive and active pixel schemes for CMOS visible imagers". *Infrared Readout Electronics IV*. International Society for Optics and Photonics. **3360**: 101–110. Bibcode:1998SPIE.3360..101K. doi:10.1117/12.584474. S2CID 123351913.
27. ^ a b Fossum, Eric R. (12 July 1993). Blouke, Morley M. (ed.). "Active pixel sensors: are CCDs dinosaurs?". *SPIE Proceedings Vol. 1900: Charge-Coupled Devices and Solid State Optical Sensors III*. International Society for Optics and Photonics. **1900**: 2–14. Bibcode:1993SPIE.1900....2F. CiteSeerX 10.1.1.408.6558. doi:10.1117/12.148585. S2CID 10556755.

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.

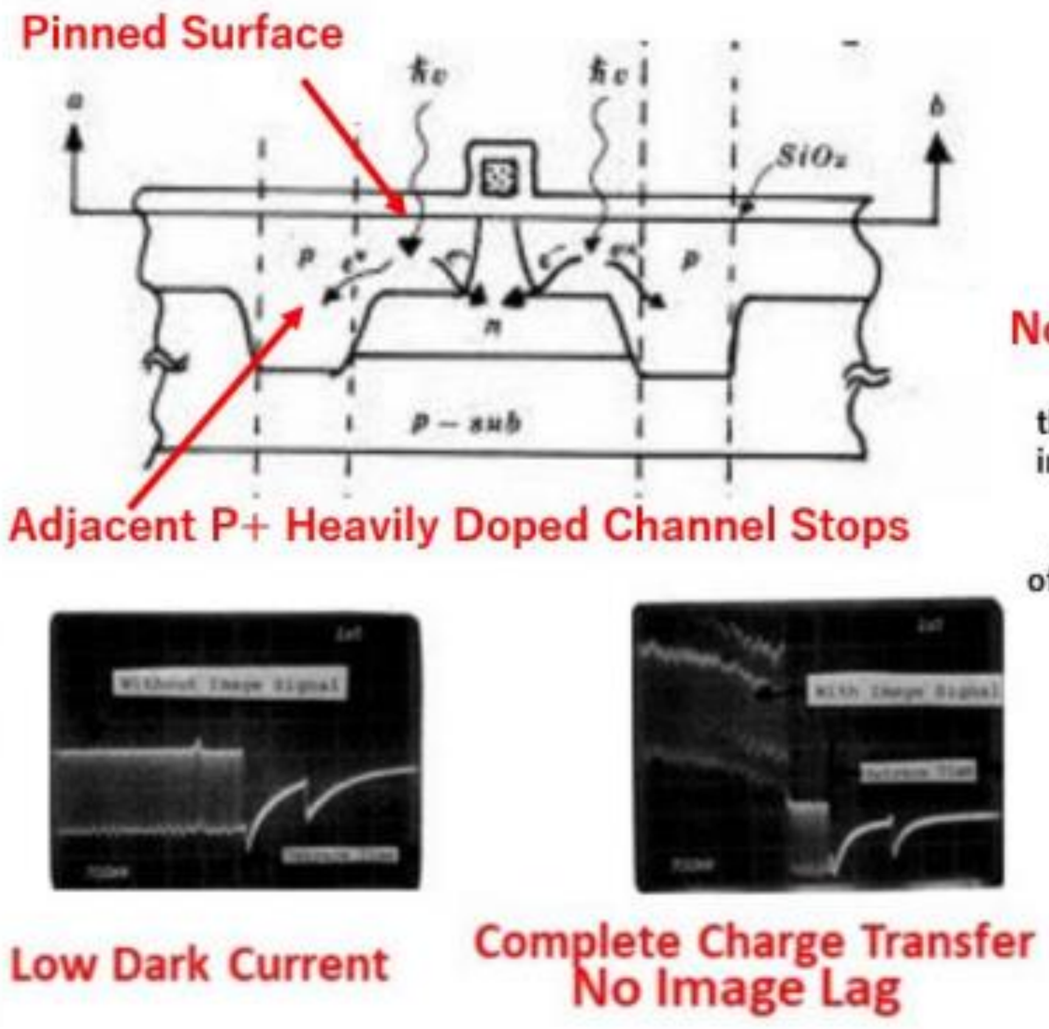
Fossum did not invent the in-pixel image sensor.

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

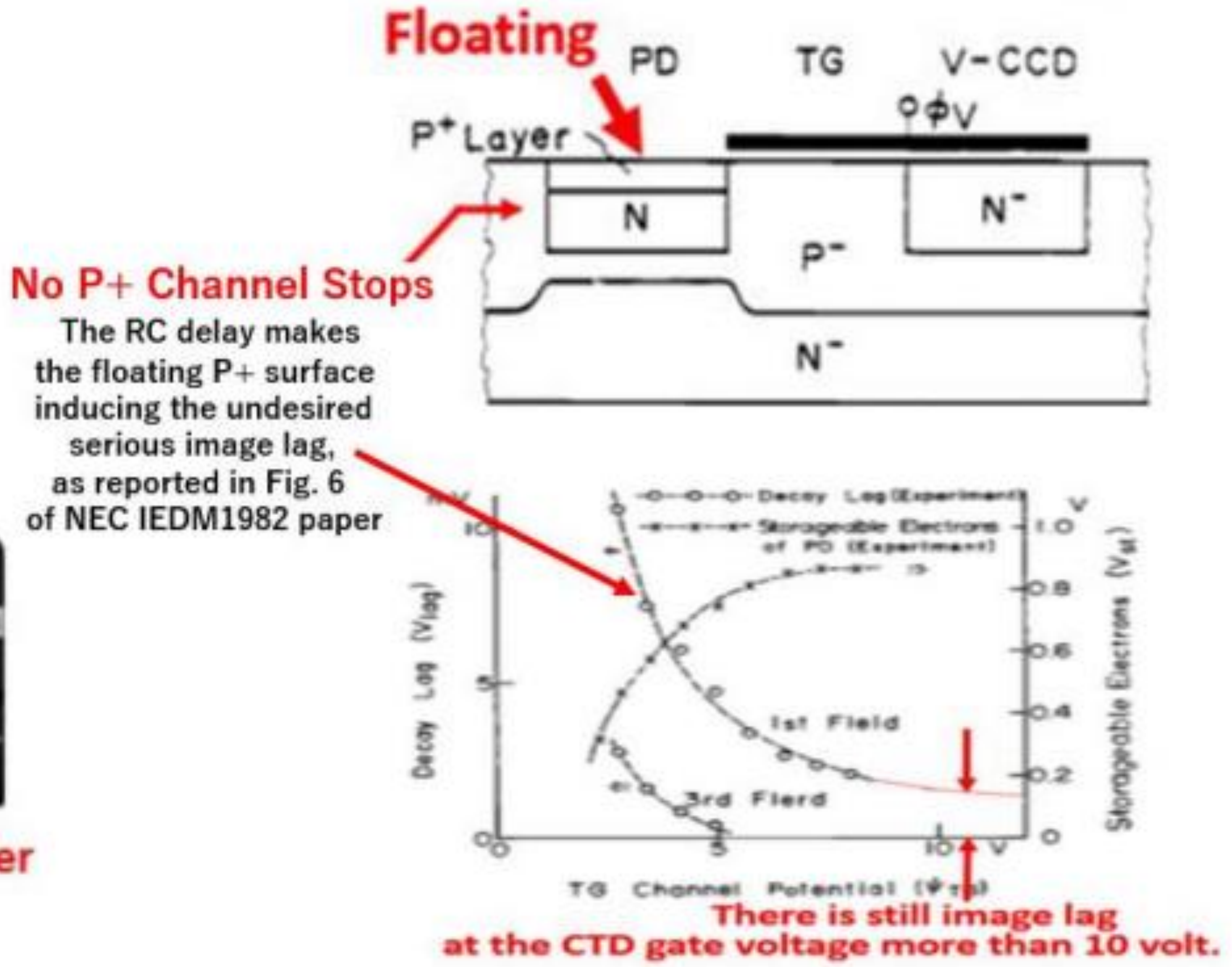
Terniashi did not invent Pinned Photodiode.
Teranish reported in IEDM1978 Buried Photodiode which is not Pinned Photodiode because
The Buried Photodiode reported by Teranishi in IEDM1982 had the serious image lag problem.

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

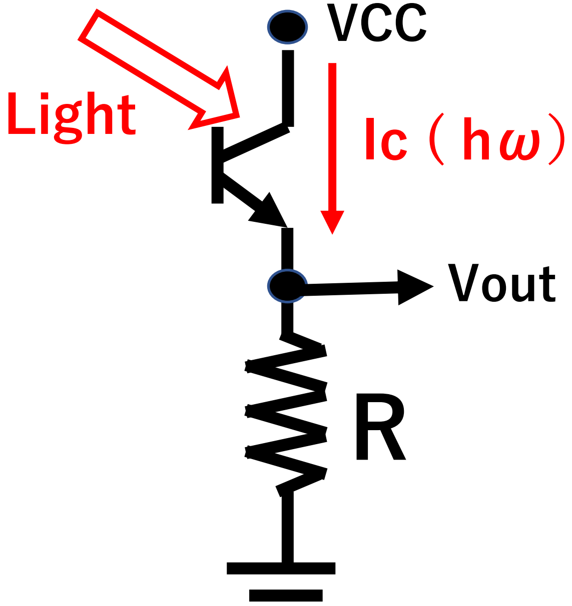
Pinned Photodiode in SONY SSDM1987 Paper

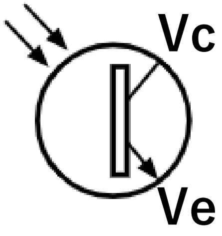


Buried Photodiode in NEC IEDM1982 Paper

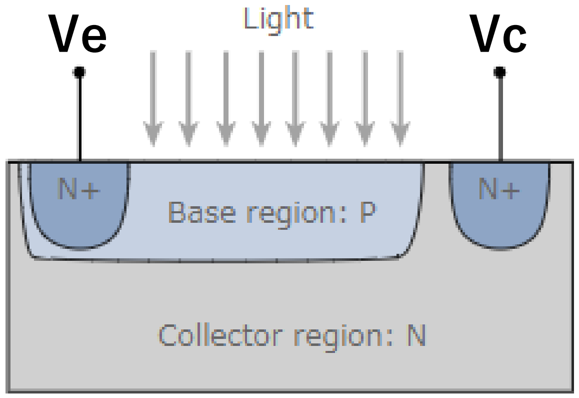


What is NPN Double Junction type Static Photo Transistor ?



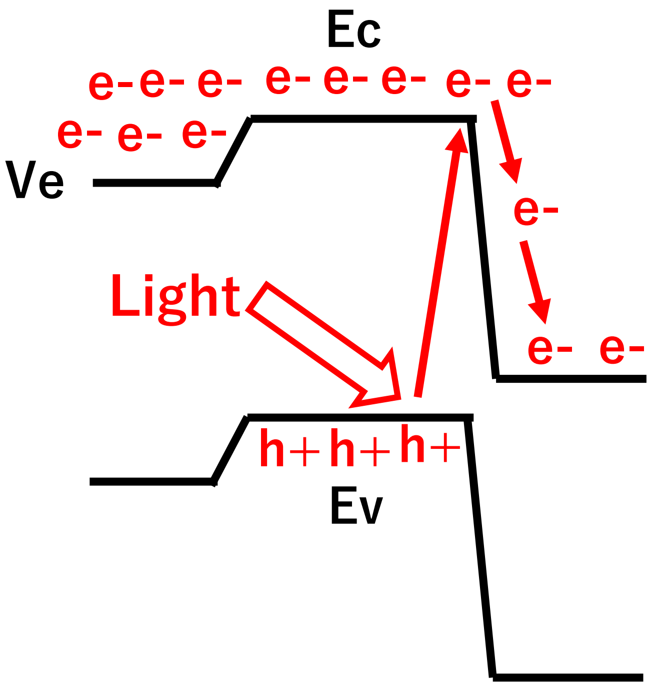


Phototransistor circuit symbol (for a device based around an NPN transistor)



Homojunction planar phototransistor structure

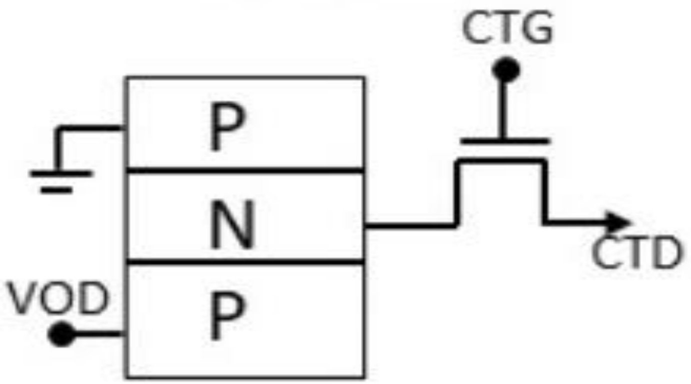
https://www.physlab.org/wp-content/uploads/2016/03/Photodiode_circuit.pdf



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.

https://electronics.stackexchange.com/questions/83018/difference-between-buried-photodiode-and-pinned-photodiode

This is a commonly misunderstood misused set of terminologies.

First off these are not PIN Photodiodes - which stands for P - Intrinsic- N. These have large depletion regions for higher internal QE (Quantum Efficiency) and faster response. You can't make an array with this design though.

Pinning, refers to fermi-level pinning or pinning to a certain voltage level. Or also the forcing or prevention of the fermi-level/voltage from moving in energy space.

You can get surface state pinning from the dangling Si/SiO2 bonds providing trapping centers. A buried PD (Photodiode) has a shallow implant that forces the charge carriers away from these surface traps. The Si/SiO2 surface contributes to increased leakage (dark current) and noise (particularly 1/f noise from trapping/de-trapping). So confusingly a buried PD avoids pinning of the fermi-level at the surface.

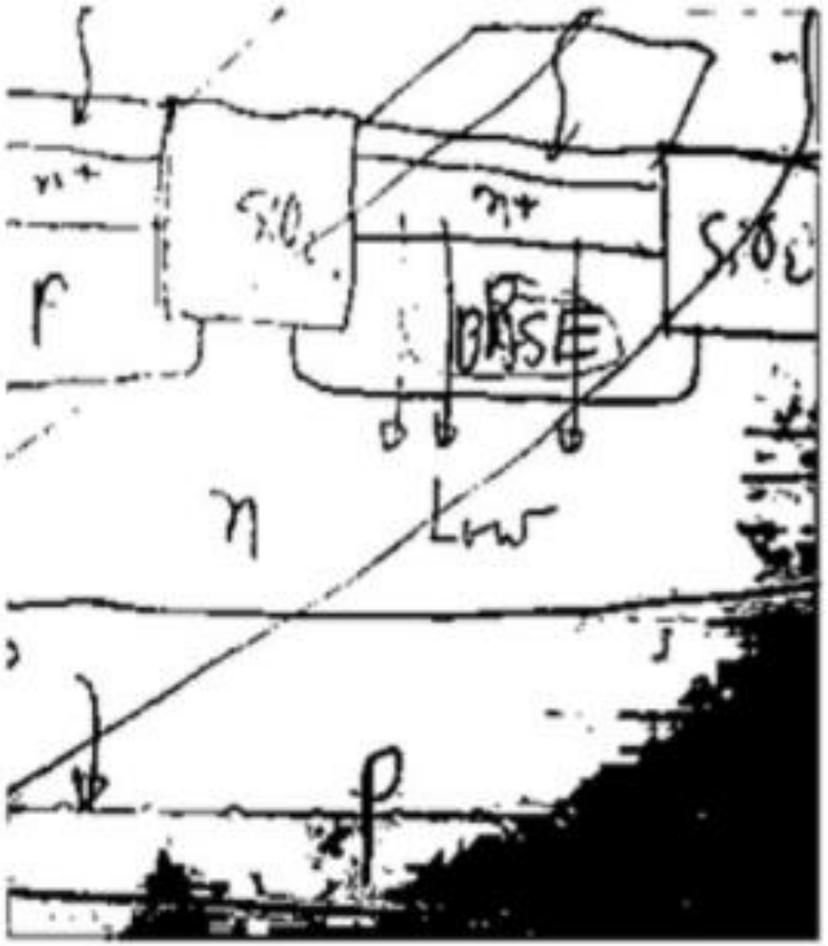
A pinned PD is by necessity a buried PD, but not all buried PD's are pinned. The first Pinned PD was invented by Hagiwara at Sony and is used in ILT CCD PD's, these same PD's and the principles behind this complete transfer of charge are used in most CMOS imagers built today.

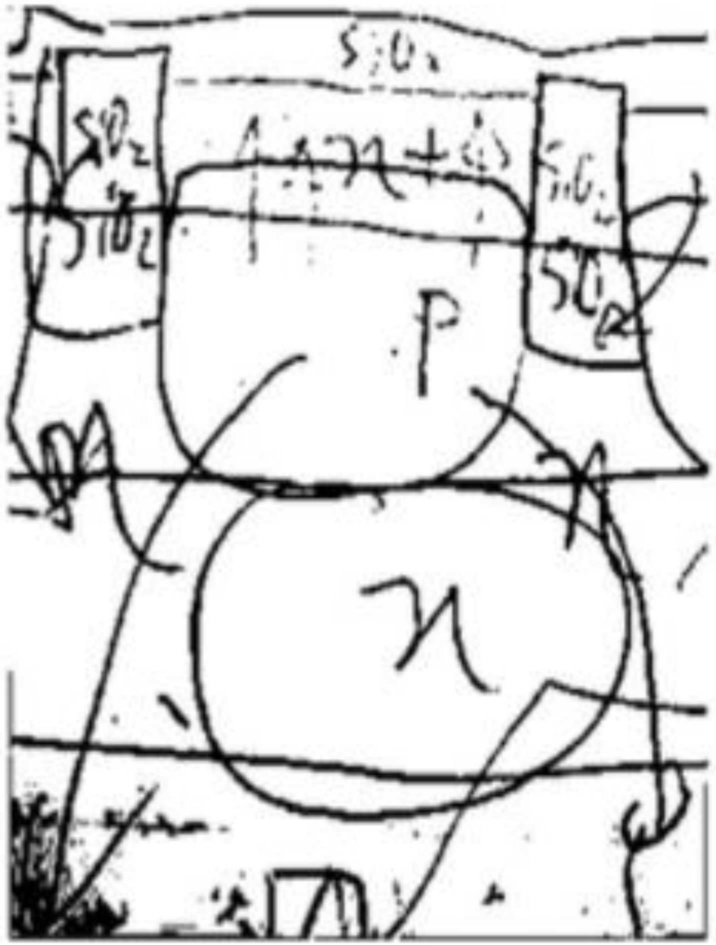
A pinned PD is designed to have the collection region deplete out when reset. AS the PD depletes it becomes disconnected from the readout circuit and if designed properly will drain all charge out of the collection region (accomplishing complete charge transfer). An interesting side effect is that the capacitance of the PD drops to effectively zero and therefore the KTC noise $q_n = sqrt(KTC)$ also goes to zero. When you design the depletion of the PD to deplete at a certain voltage you are pinning that PD to that voltage. That is where the term comes from.

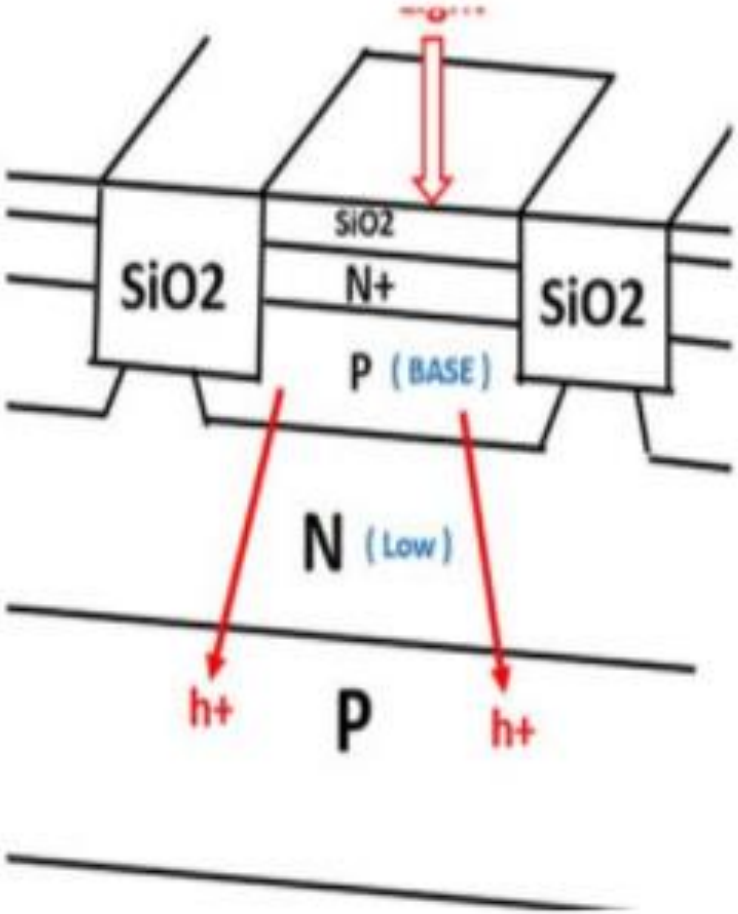
I've edited this Answer to acknowledge Hagiwara-san's contribution. It has long been incorrectly attributed to Teranishi and to Fossum (in CMOS image sensors)

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

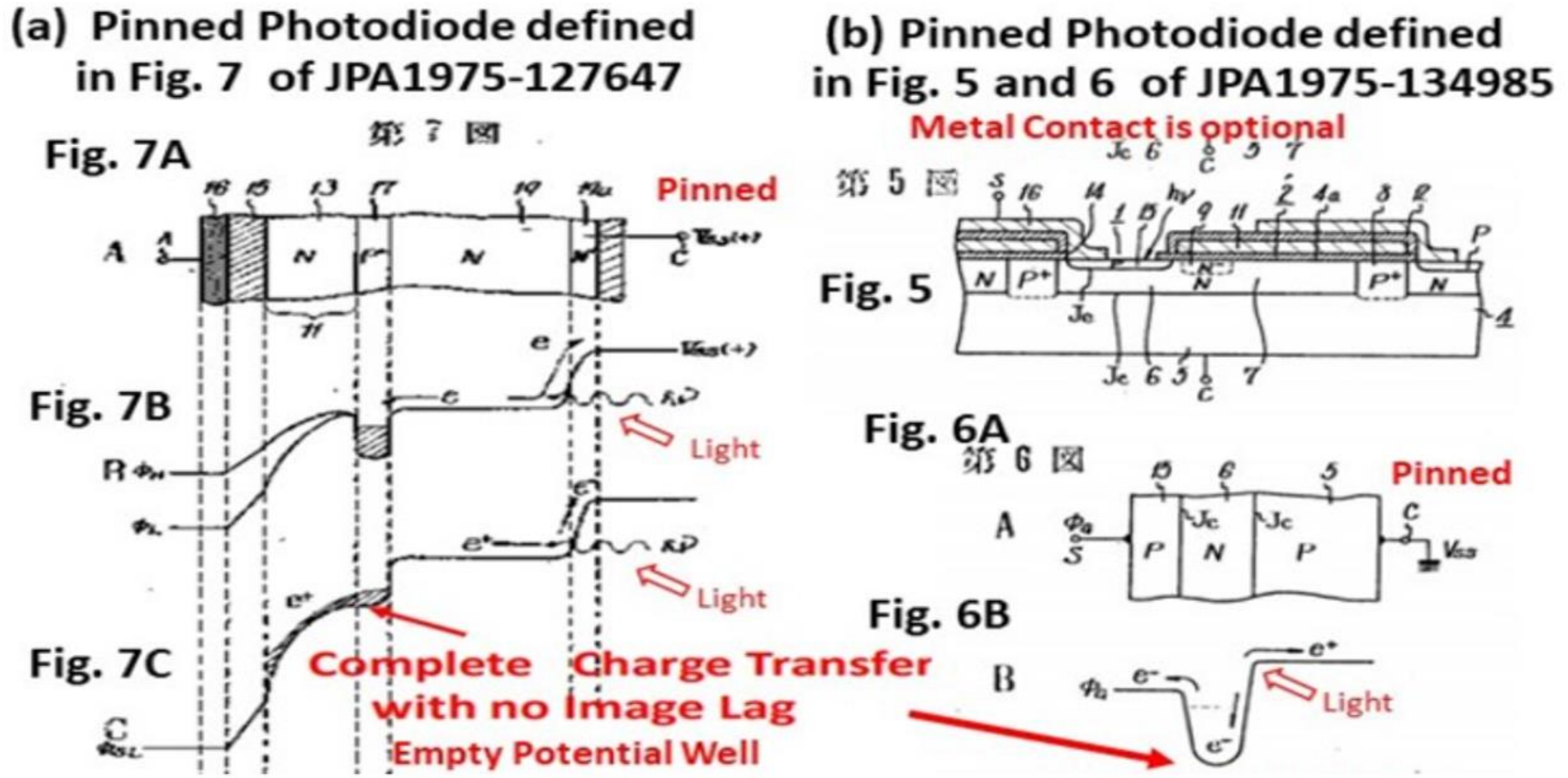
The original 1975 invention of N+PNP junction type photodiode as sketched in the Sony Yokohama Research Cente Lab Note by Yoshiaki Hagiwara is the evidence that Hagiwara is the inventor of the Pinned Photodiode with the vertical overflow drain function with the lightly doped n base region by the thyristor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





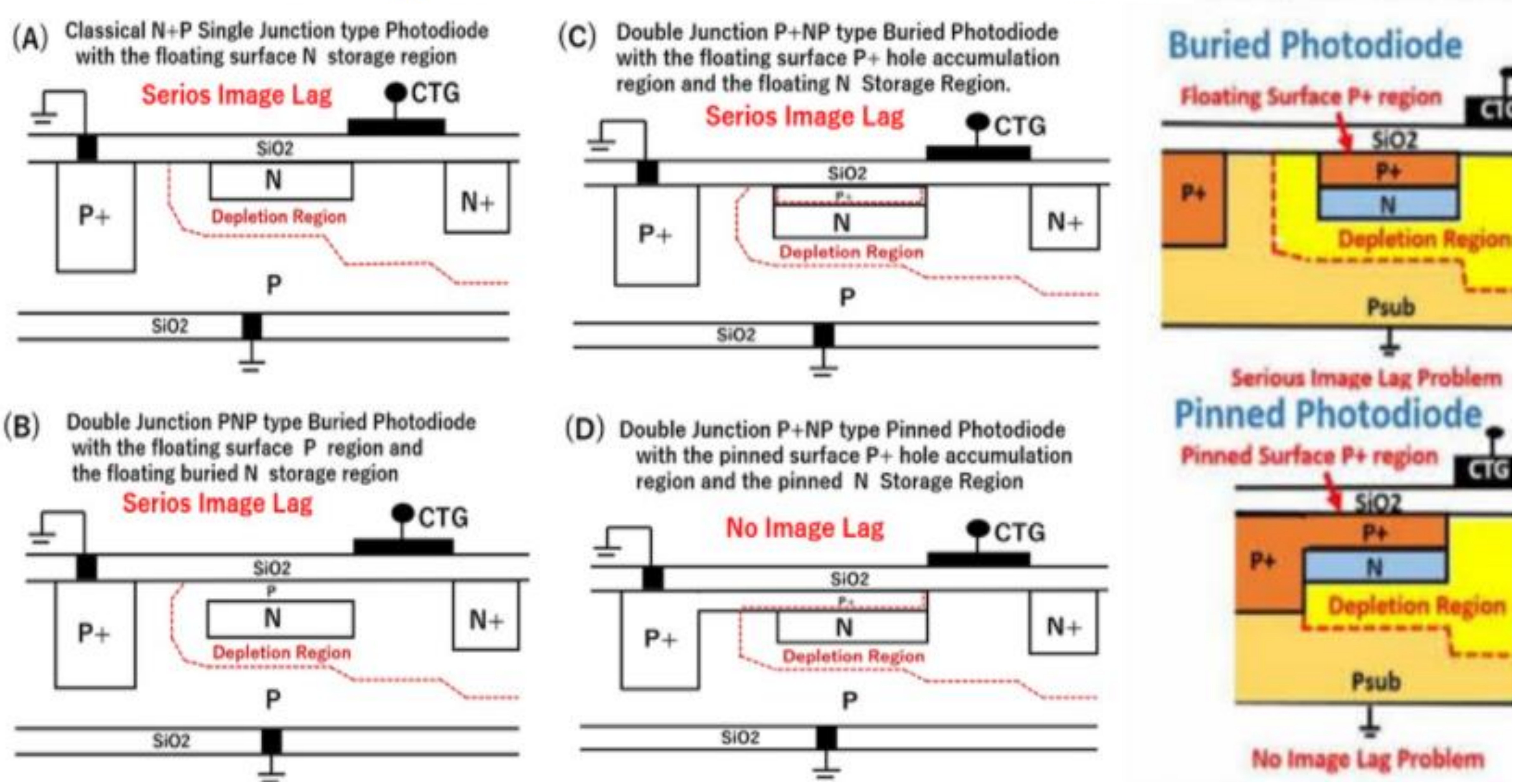


Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.



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

Four Types of Basic Photo Sensor Structures

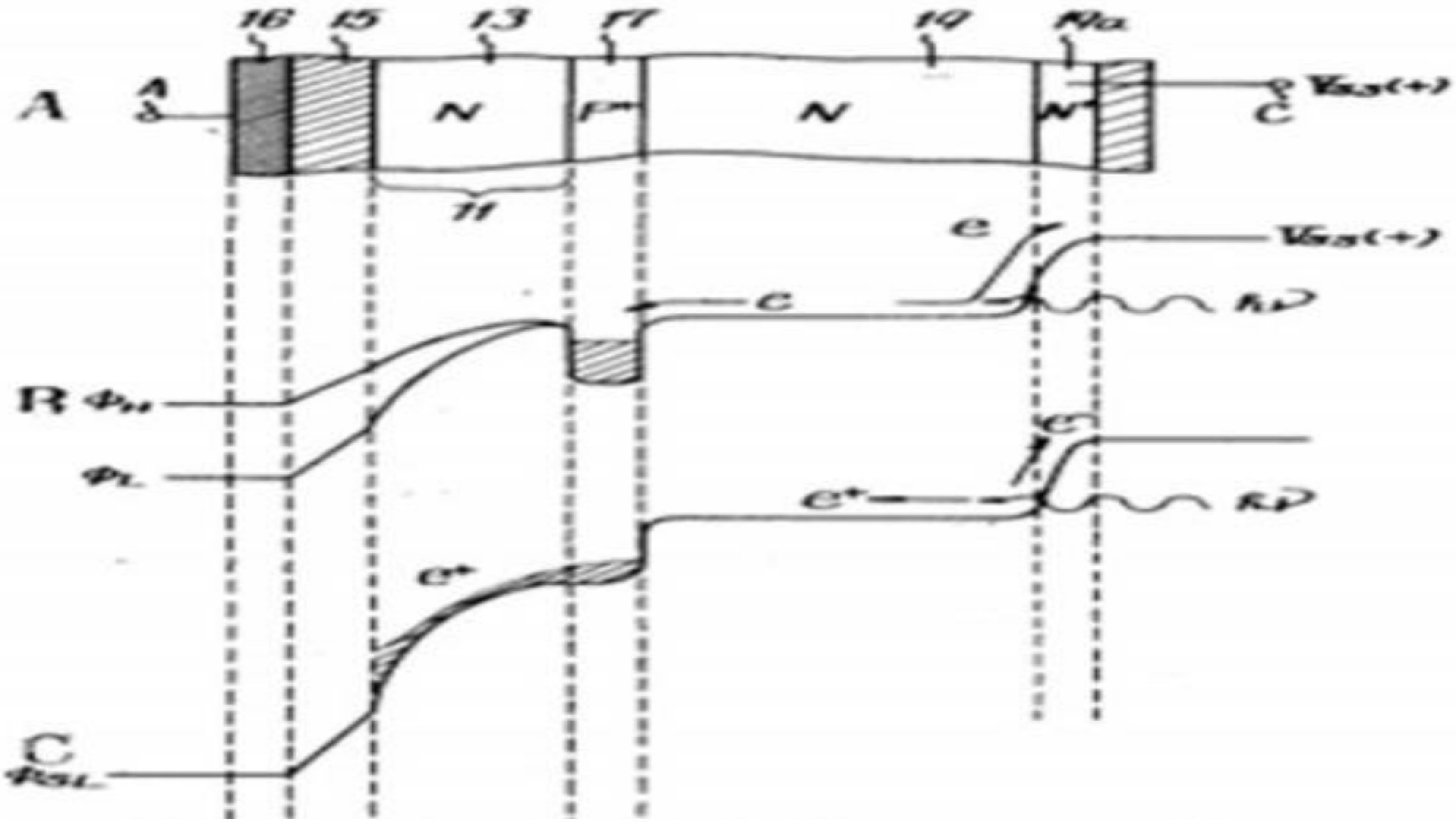


Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.

Figure 7 of Japanese Patent Application 1975-127647, applied Oct 23, 1975,

Public April 26, 1977 (Patent No. S52-51816)

第7図



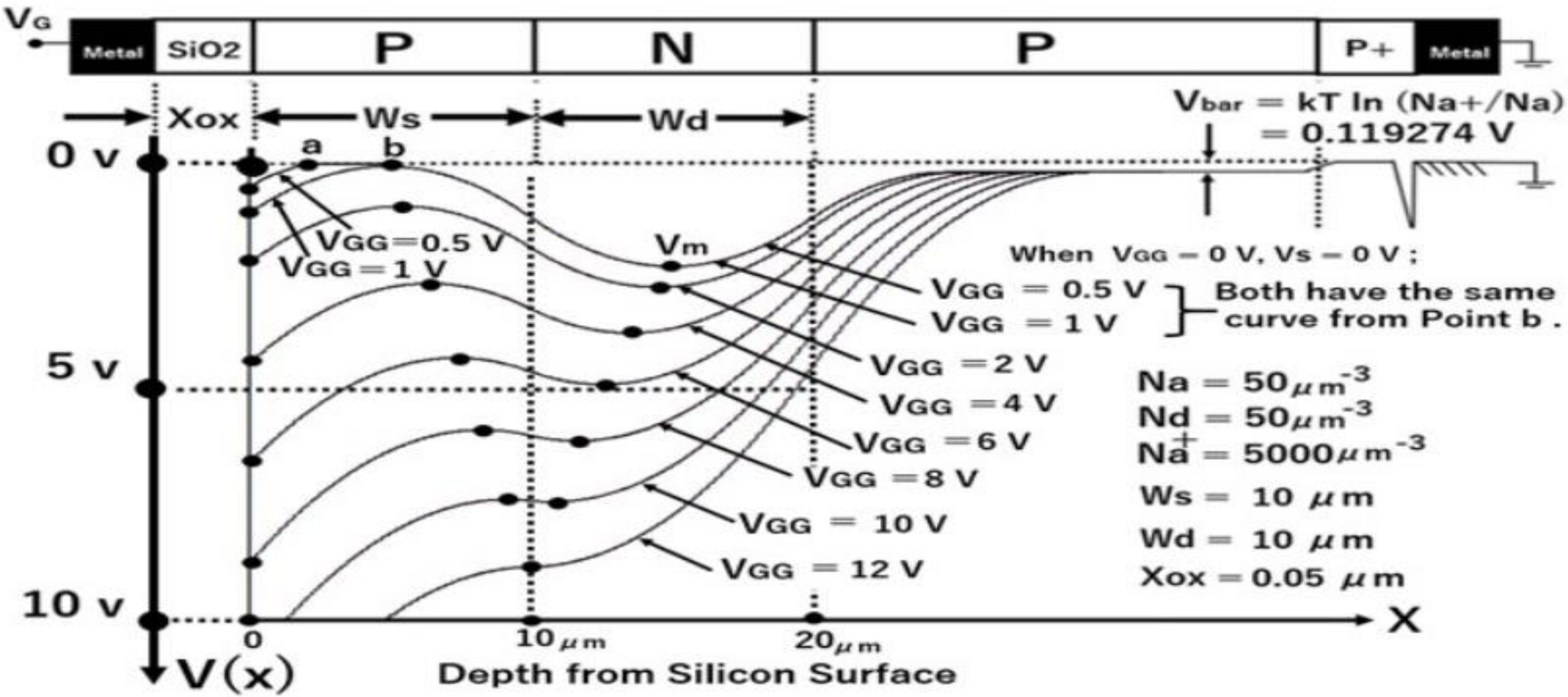
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.

Yoshiaki Hagiwara invented it and applied for Japanese Patent on Oct 23, 1975.

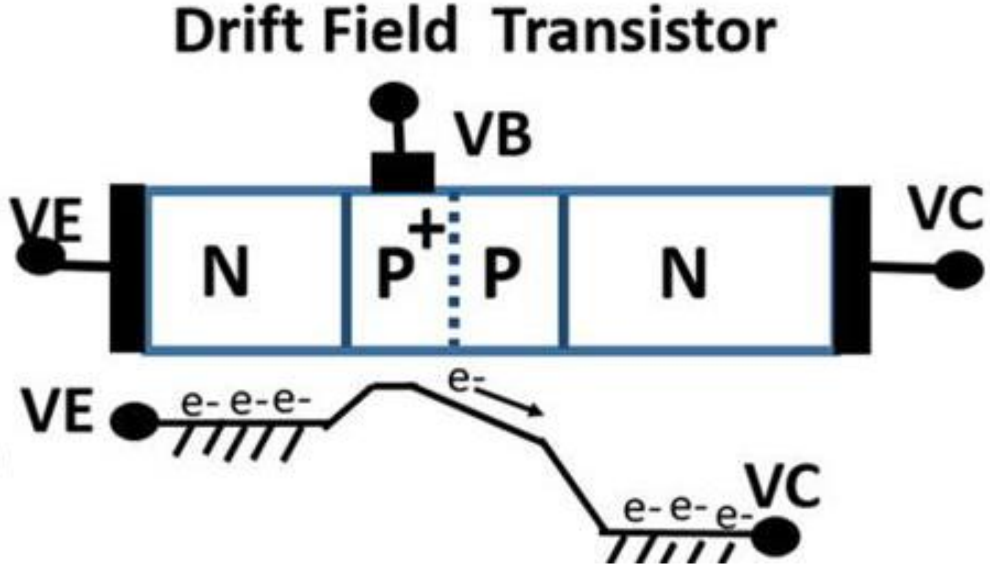
PNP Double Junction type Buried Channel Pinned Photodiode

with MOS Capacitor Buffer Memory for Built-in Global Shutter Function

An example of Actual Numerical Calculation



What is Drift Field Transistor ?



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

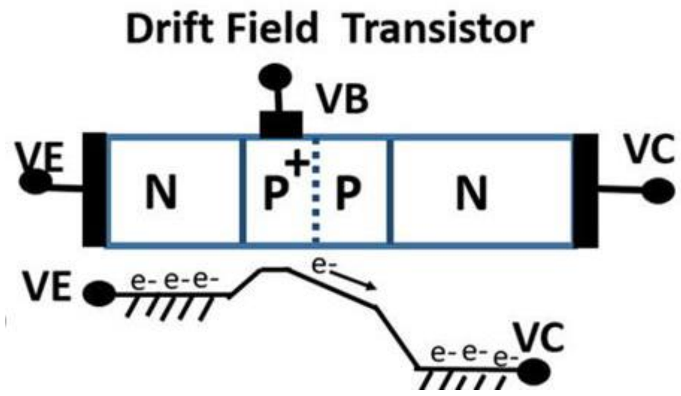
Invented by Herbert Kroemer at the Central Bureau of Telecommunications Technology
of the German Postal Service, in 1953.

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
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.




Herbert Kroemer in 2008

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

Born	August 25, 1928 (age 92) Weimar, Germany
Nationality	Germany United States
Alma mater	University of Jena University of Göttingen
Known for	Drift-field transistor Double-heterostructure laser Heterojunction bipolar transistor
Awards	J J Ebers Award (1973) Humboldt Research Award (1994) Nobel Prize in Physics (2000) IEEE Medal of Honor[1](2002)
Scientific career	
Fields	Electrical Engineering, Applied Physics

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.

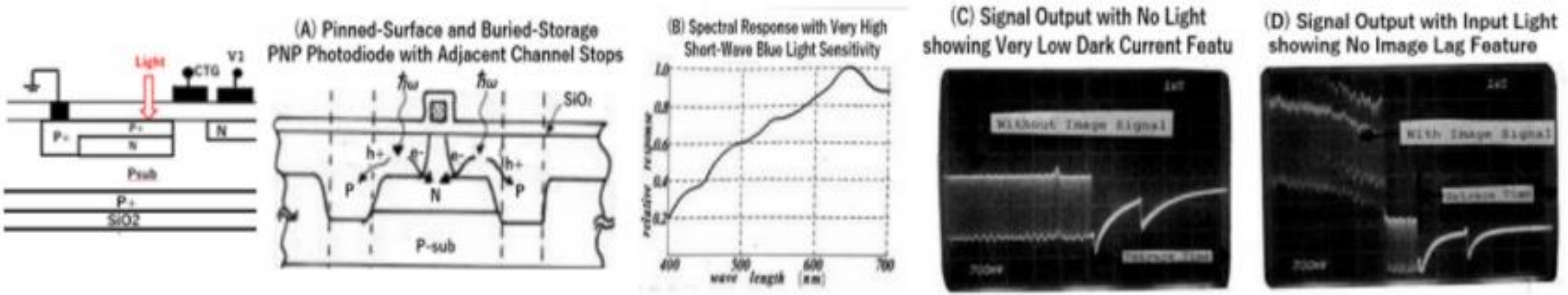
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975.

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/cm^2. And the dark current level was less than 3 % of the maximum signal level at room temperature of 20 ℃. Very low surface dark current was observed since there is no electric field in the Pinned P+ surface region,

Yoshiaki Hagiwara, SSDM1978 `Paper and Japanese Patent No. 1215101 (Japanese Patent Application JPA 1975-134985)

Yoshiaki Hagiwara, Motoaki Abe and Chikara Okada, “A 380H x 488V CCD Imager with Narrow Channel Transfer Gates”. Proceeding of the 10th Conference on Solid State Devices, Tokyo 1978; Japanese Journal of Applied Physics, Volume 18(1979) Supplement 18-1, pp. 335-340.



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.


SONY

2000年度

発明考案実施褒賞

1 級

萩原 良昭 殿

特許第1215101号

固体撮像装置

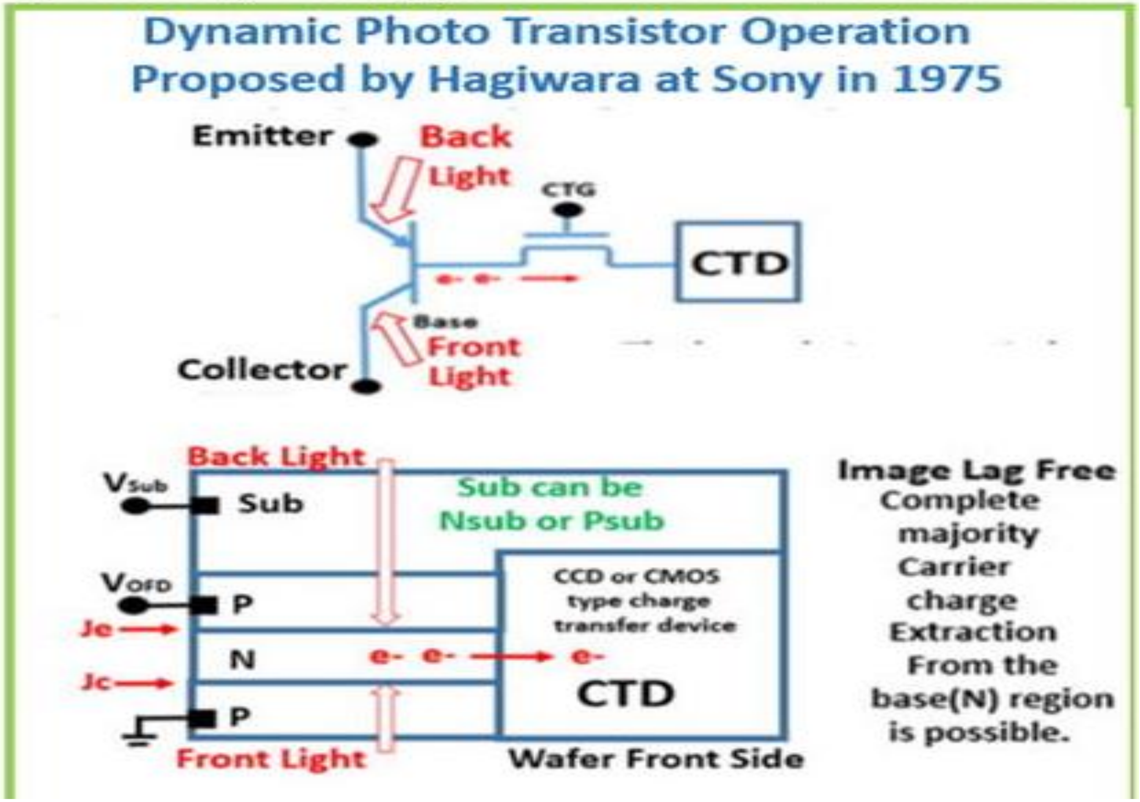
貴発明は卓越した創造性および先見性により
会社に対し顕著な貢献がありましたので
発明考案規定に基づき
ここに本賞を贈りこれを賞します

2001年4月26日

ソニー株式会社
社長

安藤国威

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.

Japanese Patent Application JPA 1975-134985

applied by Yoshiaki Hagiwara at Sony on November 10, 1975

Patent Claim in Original Japanese

1) 半導体基体(N)に、
第１導電型の第１半導体領域（P)と、
之の上に形成された第２導電型の
第２半導体領域（N)とが形成されて

2) 光感知部(NP)と之よりの電荷を転送
する電荷転送部（CTD)とが上記半導
体基体の主面に沿う如く配置されて
成る個体撮像装置に於いて

3) 上記光感知部(NP)の上記第２半導体
領域（N)に整流性接合が形成され、
該接合をエミッタ接合(Je)とし、

4) 上記第１及び第２半導体領域間の接合
をコレクタ接合(Jc)とするトランジ
スタ(PNP)を形成し、

5) 該トランジスタ(PNP)のベースとなる
上記第２半導体領域(N)に光学像に応
じた電荷を蓄積し

6) ここ(N) に蓄積された電荷を上記転送
部に移行させて、その転送を行うよう
にしたことを特徴とする個体撮像装置

Patent Claim in English Translation

1) In the semiconductor basic body (N), the first region (P) of the first impurity is formed, and on which the second region (N) of the second impurity type is formed.

2) On The photo sensor (NP) so defined as a solid state image sensor with Charge Transfer Device (CTD) placed along the surface of the semiconductor basic body,

3) a rectifying emitter junction (Je) is formed on the photo sensor (NP).

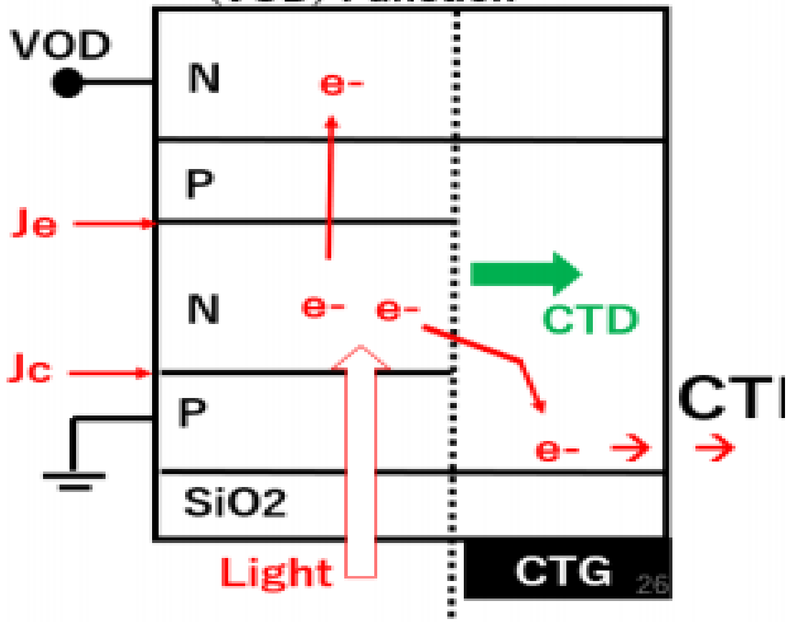
4) The junction between the first region (P) and the second region (N). being as the collector junction (Jc) of the transistor (PNP),

5) the second region (N)becomes the base region of the transistor (PNP) which stores the photo charge according to the photo image.

6) And the charge stored in this region (N) is transferred to the Charge Transfer Device (CTD).

File 1975-134985 Filed 1975/11/1(
Public 1977-058414 on 1977/05/1:

Buried Pinned Photodiode Patent
the PNP Double Junction type
Dynamic Photo Transistor
with the Vertical Overflow Drain
(VOD) Function



Patent Claim of JPA1975-134985 on the PNPN Pinned Photodiode

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.

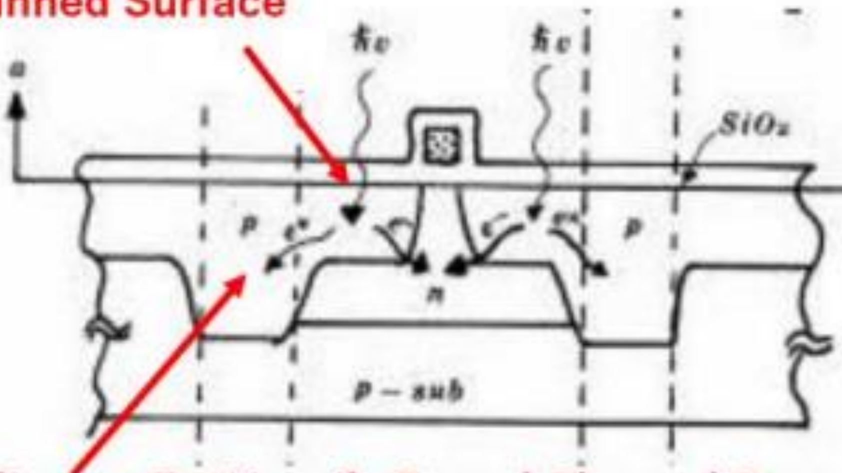
The truth is that Ando Team at NHK developed the first active in-pixel image sensor in 1987.

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.

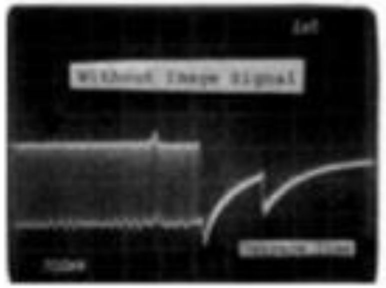
Double Junction Dynamic type Photo Transistor was invented by Hagiwara in 1975

Pinned Photodiode in SONY SSDM1987 Paper

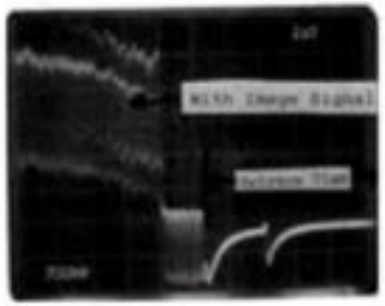
Pinned Surface



Adjacent P+ Heavily Doped Channel Stops



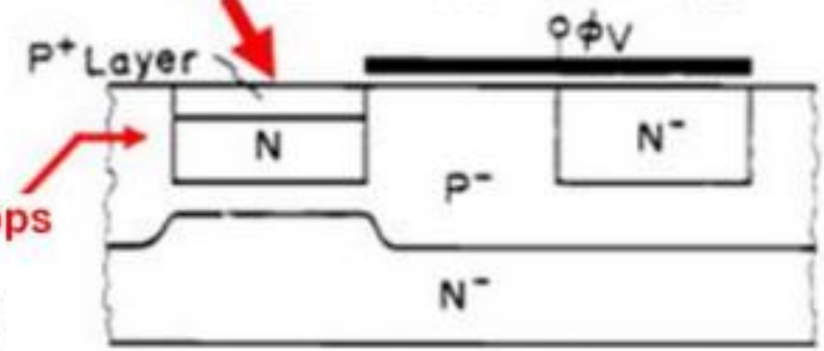
Low Dark Current



Complete Charge Transfer
No Image Lag

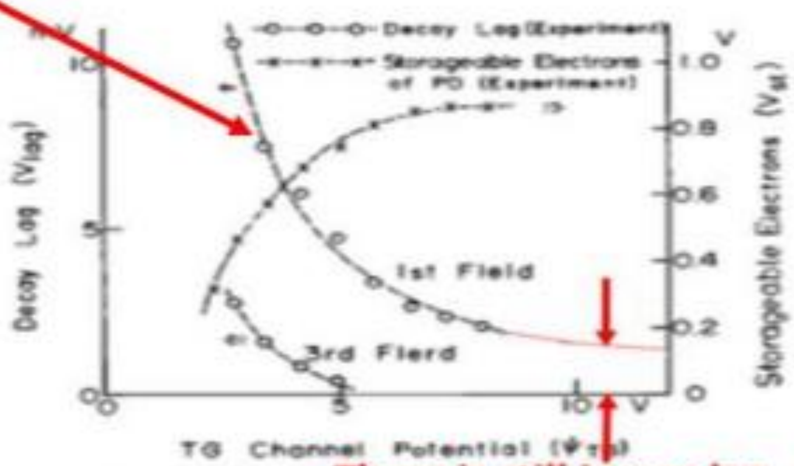
Buried Photodiode in NEC IEDM1982 Paper

Floating



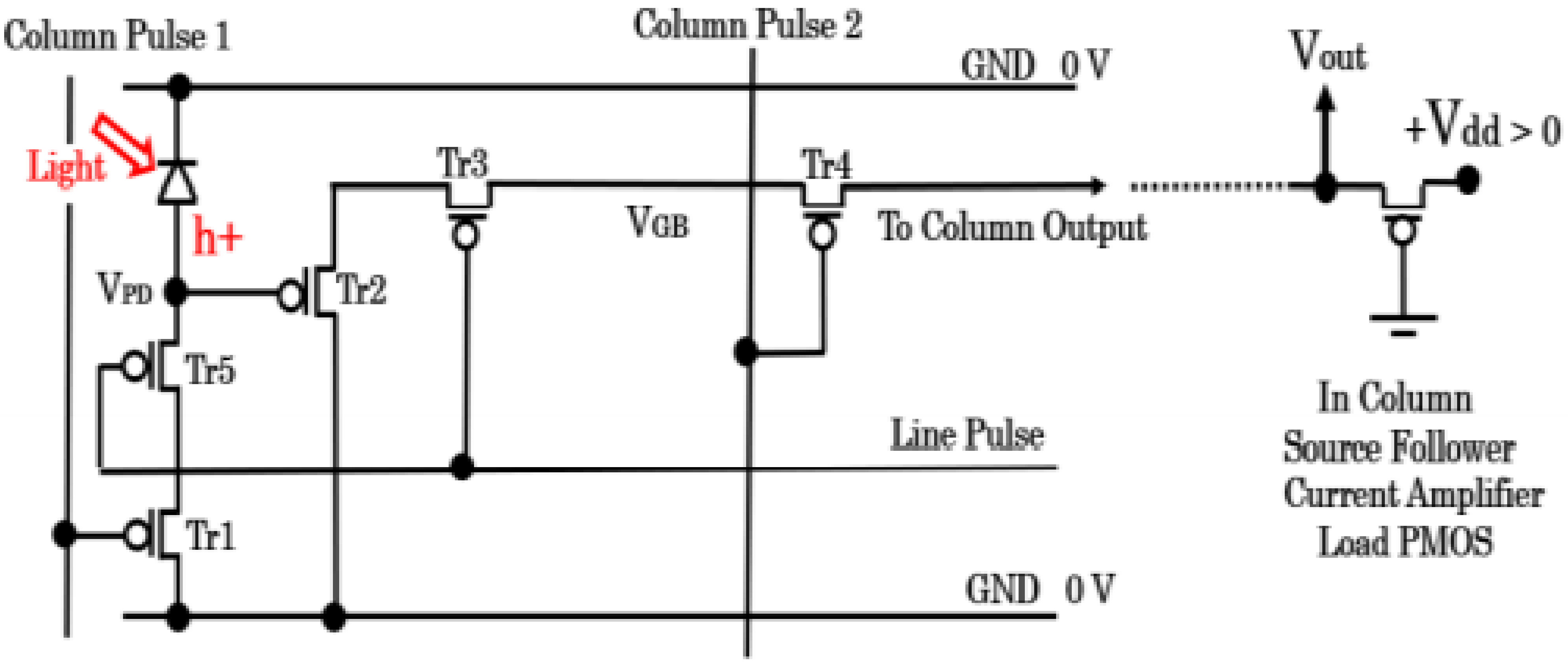
No P+ Channel Stops

The RC delay makes
the floating P+ surface
inducing the undesired
serious image lag,
as reported in Fig. 6
of NEC IEDM1982 paper



There is still image lag
at the CTD gate voltage more than 10 volt.

Active in-pixel AMP circuit invented by Peter Noble in 1968



Peter Nobel, IEEE Tran. of Electron Devices 15-4 (1968) pp. 202-209

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.