

Sony's Representative Inventions Supporting Stacked Multi-Functional CMOS Image Sensors

Sony Corporation
Sony Semiconductor Solutions Corporation

Taku Umabayashi, an employee of Sony, was awarded the Purple Ribbon Medal in the 2020 Spring Conferment of Medals of Honor. The Purple Ribbon Medals honor influential characters with their outstanding achievement in inventions and discoveries in the field of science and technology, and in the academic, sports, and arts and cultural fields. The medal was awarded to Mr. Umabayashi in appreciation to his achievement in the development of stacked multi-functional CMOS image sensors. His achievement in research and development had already received the Prime Minister Award of the National Commendation for Invention in 2016, and also with recommendation from the Japan Institute of Invention and Innovation ("JIII"), he received the Awards for Science and Technology (Development Category) of the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology in 2018. JIII had also recommended Mr. Umabayashi for the Purple Ribbon Medals.

Provided below are explanations of stacked multi-functional CMOS image sensors and Sony's notable inventions which support them.

Pinned Photodiode Adopted for Back-Illuminated CMOS Image Sensors

The history of Sony's inventions of image sensors goes back to the CCD era. Above all, Pinned Photodiode is a technology that contributes to improving the performance of back-illuminated CMOS image sensors, and the history of inventions and product development are as below.

In 1975, Sony invented a CCD image sensor that adopted a back-illuminated N+NP+N junction type and an N+NP+NP junction type Pinned Photodiode (PPD) (Japanese patent application number 1975-127646, 1975-127647 Yoshiaki Hagiwara). In the same year, inspired by such structure, Sony invented a PNP junction type PPD with VOD (vertical overflow drain) function (Japanese Patent No. 1215101 Yoshiaki Hagiwara). After that, Sony succeeded in making a principle prototype of a frame transfer CCD image sensor that adopted the PNP junction type PPD technology, having a high-impurity-concentration P+ channel stop region formed near a light receiving section by ion implantation technology for the first time in the world, and its technical paper was presented at the academic conference, SSDM 1978 (Y. Hagiwara, M. Abe, and C. Okada, "A 380H x 488V CCD imager with narrow channel transfer gates", Proc. The 10th Conference on Solid State Devices, Tokyo, (1978)). In 1980, Sony succeeded in making a camera integrated VTR which incorporated a one-chip frame transfer CCD image sensor that adopted the PNP junction type PPD. President Iwama in Tokyo, Chairperson Morita in New York, at the time held a press conference respectively on the same day, which surprised the world. In 1987, Sony succeeded in developing a 8 mm video camcorder that adopted, for the first time in the world, the interline transfer CCD image sensor, which incorporated "PPD having a high-impurity-concentration P+ channel stop region formed near the light receiving section by ion implantation technology" with VOD function, and became the pioneer of the video camera market. The PPD technology that has been nurtured through such a long history is still used in back-illuminated CMOS image sensors.

https://eds.ieee.org/images/files/newsletters/Newsletter_Jan23.pdf

CHRONOLOGY OF SILICON-BASED IMAGE SENSOR DEVELOPMENT

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The first PNP Double Junction Photodiode invented by Philips on March 9, 1975, with an image lag problem, caused by a RC delay time between the floating surface and the high-resistivity pinned back substrate.

The first Pinned-surface PNP Double Junction type and the first Pinned-surface Triple Junction type Photodiodes, both invented by Sony (Hagiwara) on Oct 23, 1975, with Vertical Overflow Drain (VOD) function, Electric Shutter function and Global Shutter function with MOS-Capacitor Buffer Memory that created our new digital imaging and TV era.

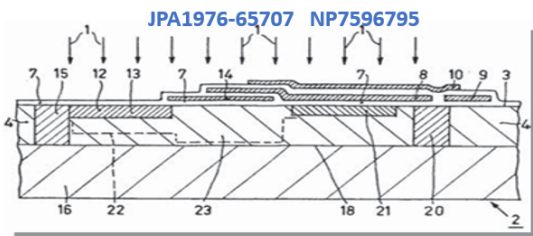


Figure 6. The double junction type buried photodiode image sensor reproduced from Netherland Patent Application NPA [6]

[6] Japanese Patent Application JPA1976-65707 (Patent No. 7596795, filed on June 9, 1975, Netherland)

[7] Y. Hagiwara, Japanese Patent Application JPA 1975-127646 on N+NP+NP-P+ Triple Junction Type Pinned Photodiode with Back Light Illumination with the CCD type MOS capacitor Buffer Memory for Global Shutter Function.

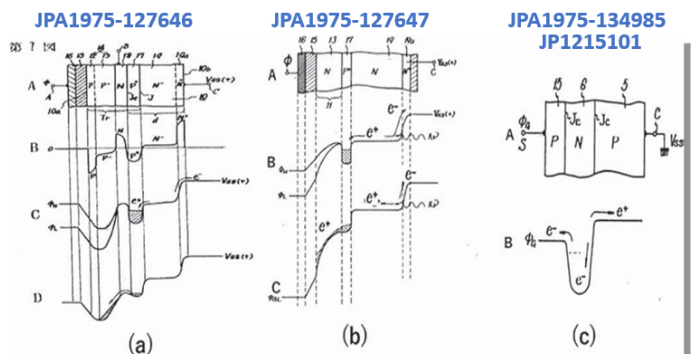


Figure 2. Reproductions from the Japanese Patent Applications of (a) the N+NP+NP-P triple junction PPD, (b) the N+NP+N double junction PPD, and (c) the PNP double junction PPD

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<https://www.elsepub.com/pdf/doi/10.55092/20250003>

Please support me to make the PP-NP-P+ Double Junction Type Solar Cell
Japanese Patent Application JPA2020-131313