

## 1975-85

### **Improvement of photodiode for image sensor** **(Sony, Hitachi, NEC, Toshiba)**

~ Discrete Semiconductor/Others ~

**Semiconductor History Museum of Japan says that Hagiwara invented Pinned Photodiode.**

In 1975, Sony proposed using a PNP transistor as the photodetector [3]. By providing a P<sup>+</sup> layer (emitter) for the light incident section, the sensor electrode that covers the entire light receiving surface of the photodiode can be eliminated to improve the light sensitivity greatly. It was a basic proposal for a pinned photodiode with a P<sup>+</sup> layer on the surface of the light receiving part.

【3】Y. Hagiwara, Japanese Patent JP1975—134985

Next, proposals were made separately by Hitachi and Sony to use the P<sup>+</sup> layer as the substrate potential. In 1977, Hitachi presented a structure in which the high-concentration surface P<sup>+</sup> layer is connected to a P-type substrate (well) and pinned it to the same potential as the substrate to increase the charge storage capacity and widen the dynamic range of the photodiode [4].

【4】N. Koike, I. Takemoto. Japanese Patent JP1977—837

In 1978, Sony announced an FT (Frame Transfer) -CCD image sensor, using the photodiode with the same structure [5]. Sony succeeded for the first time in the world in prototyping a VTR-integrated color movie camera using a 2 / 3-inch 280,000-pixel FT-CCD image sensor that developed this technology, in 1981 [6].

【5】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): Japanese Journal of Applied Physics, vol. 18, Supplements 18-1, pp. 335-340, (1979)

【6】I. Kajino, M. Shimada, Y. Nakada, Y. Hirata and Y. Hagiwara, "Single Chip Color Camera Using Narrow channel CCD Imager with Over Flow Drain", Technical Report of The Institute of Image Information and Television Engineers, vol. 5, no. 29, pp. 32-3S, (1981)

**NEC in 1982 and Kodak in 1984 developed Pinned Photodiode but they did not invent it.**

In 1980, NEC analyzed in detail the relationship between the electric potential of the N layer of a photodiode in which the P layer was pinned to the substrate potential and the potential of the transfer gate to an external circuit. They then demonstrated a principle of operation that completely transfers the signal charges while keeping the potential of the depleted N layer higher than the channel potential of the transfer gate by a required value or higher, realizing image lag free operation [8][9]. The design methods based on this operation principle of the pinned photodiode focusing on this N-layer potential were widely studied and have been standardized as the Pinned Photodiode for today's CCD and CMOS image sensors.

The Pinned Photodiode is a photodiode in which the entire N layer is covered with a P layer. The part of the P layer on the light incident surface is heavily doped P<sup>+</sup>(Fig.1). Kodak named this structure Pinned Photodiode in 1984 because the P<sup>+</sup> surface of the light incident surface was pinned to the substrate potential. This device has features such as high light sensitivity, wide dynamic range, image lag free, much smaller dark current due to reduced influence of GR center on the light receiving surface, and no white scars.