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1984

Invention of the non-latch-up IGBT (Toshiba)

~ Discrete Semiconductor/Others ~

Akio Nakagawa of Toshiba invented and released a non-latch-up type IGBT in 1984. In 1986, Toshiba commercialized this device as a practical, non-latch-up type IGBT.

For the purpose of reducing the ON-resistance value of the high voltage power MOSFET, H.W. Backe and C.F. Wheatly of RCA showed the basic IGBT structure in 1980, then Baliga of GE fabricated the first prototype and announced the result in 1982. Since the gate drive of MOSFET is easy, not easily damaged, and the switching frequency can be set high, downsizing of system can be easily accomplished. However, since the MOSFET is a unipolar type device, it has a disadvantage that the ON-resistance value rapidly increases with the increase in breakdown voltage, and it also has a restriction in realizing a high power device. IGBT improved these drawbacks.

Fig.1 is a cross-sectional view of a power MOSFET, and Fig.2 shows that of an IGBT. While a normal MOSFET has an n+ layer drain on the back side of the chip, the IGBT has a p+ layer. While the N-channel MOSFET utilizes only electrons as carriers, the IGBT utilizes the conductivity modulation effect using both carriers of electrons and holes by injecting holes from the p+ layer to the n- layer, and it is possible to lower the resistance value of the n- layer. In this way, it became possible to reduce the ON-resistance value of the high voltage MOSFET.
However, as shown in Fig.2, this device has a four-layer structure of p-n-p-n like a thyristor. For this reason, latch-up phenomenon easily occurs, destroying the device, and practical application was difficult. Nakagawa's non-latch up IGBT solved this problem and surprisingly expanded the application range. As shown in Fig. 3, by setting the emitter of the IGBT in a stripe structure, periodically deleting a part of the n+ region of the emitter and optimizing the channel length, it became possible to suppress excessive saturation current, and together with the expansion of the outflow path of holes, the latch-up tolerance and high current capacity were greatly improved.
After that, the IGBT was continuously improved in the trade off relation of ON-resistance reduction and switching speed, by the adoption of trench gate structure, thin wafer PT (Punch-Through), FS (Field Stop) structure, and so on. It became possible to make the system quieter and more compact by increasing the switching frequency. Furthermore, since parallel operation is easy, further improvement of high-power capability was achieved by using modular structure: PM (power module). In 1989, Mitsubishi developed IGBT-IPM (Intelligent Power Module) with an IC chip mounted in the module with control and protection function, and it was further developed into a device that was hard to break and easy to use.
At present, IGBT is widely used as a most suitable device for inverter application, for white goods such

as air conditioners, washing machines, refrigerators, IH cookers, for industrial use such as elevators, robots, machine tools, and for electric vehicles.

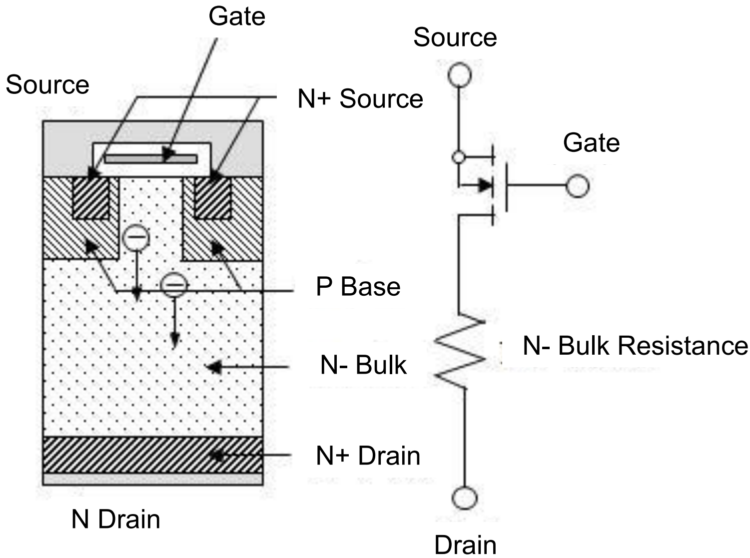

Fig.1 Equivalent Circuit and Structure of MOSFET

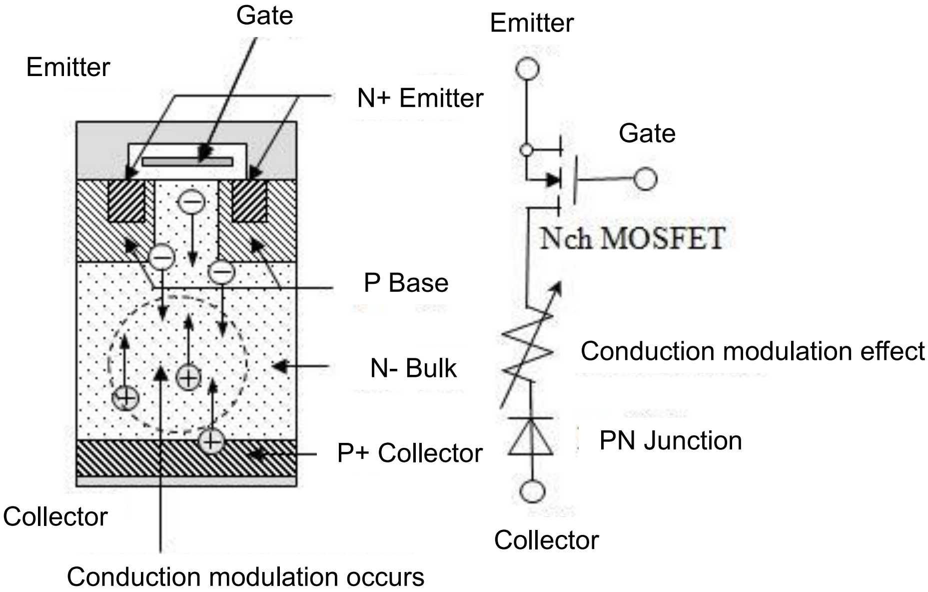

Fig.2 Equivalent circuit and structure of IGBT

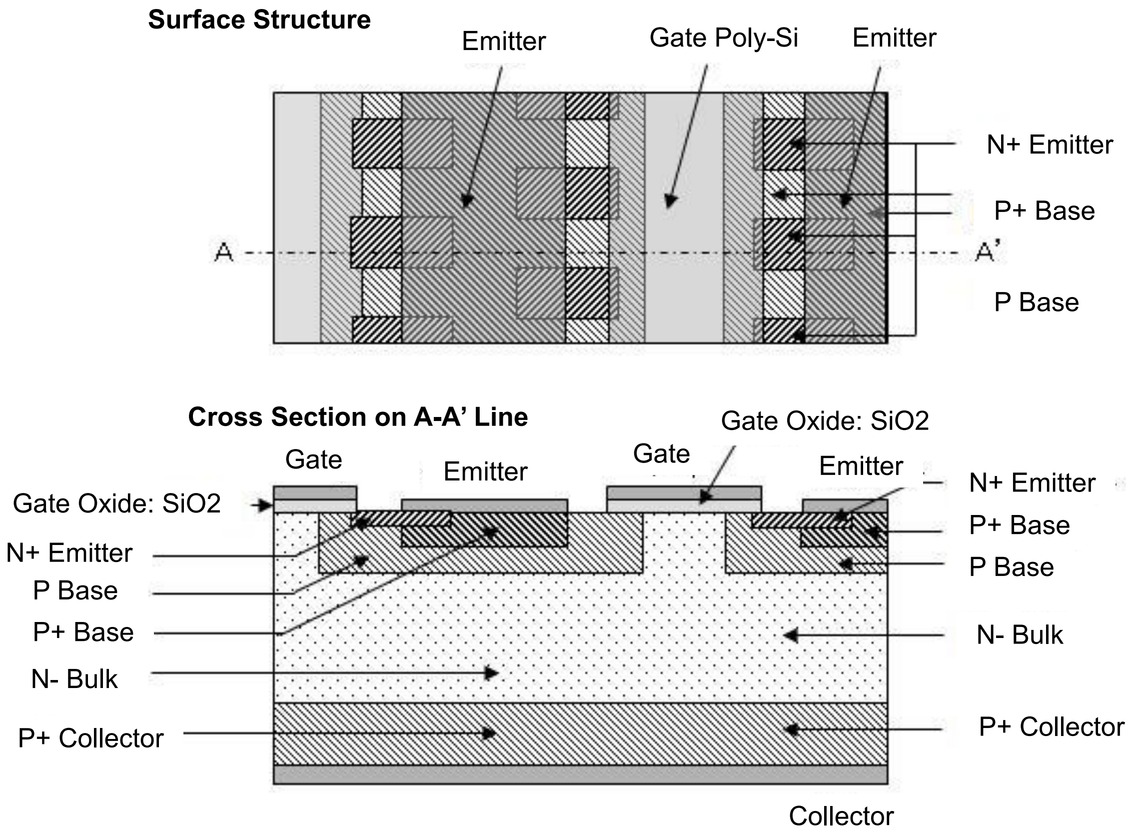

Fig.3: Structure of non-latch-up IGBT

Photo 1: Non-latch up type IGBT first released by Toshiba
(By courtesy of Toshiba)

References:

[1] A. Nakagawa et al., "Non-Latch-Up 1200V, 75A Bipolar-Mode MOSFET with Large SOA", IEEE IEDM Digest of Technical Papers, pp. 860-861 (1984)

[3] B.J. Bariga et al. "The Insulated Gate Rectifier: A New Power Switching Device," IEEE IEDM Digest of Technical Papers, pp.264-267 (1982)

[4] G. Majumdol, et al. "A New Series of Smart Controllers", IEEE-IAS, pp. 1356-1362 (1989)

[5] B. Jayant Baliga, Fundamentals of Power Semiconductor Devices, Springer, (2008)

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