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1997

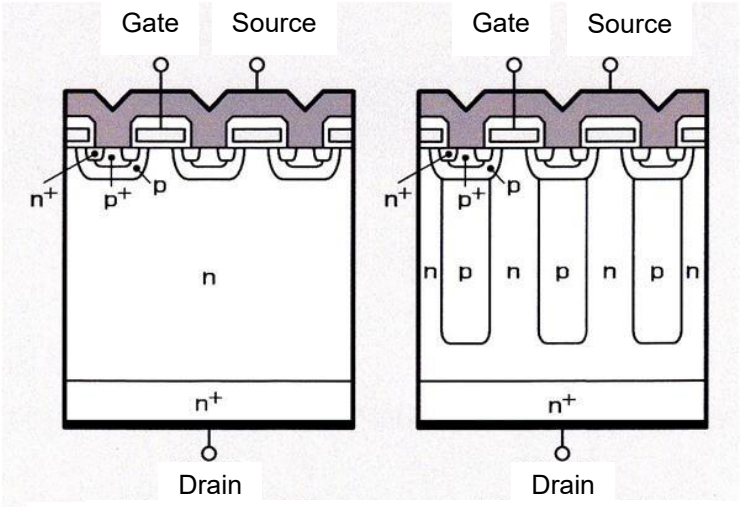
Invention of the super-junction MOSFET (Fuji Electric Co., Ltd.)

~ Discrete Semiconductor/Others ~

In the conventional high-voltage power MOSFET, the drift layer was formed with a lightly doped n-layer to extend the depletion layer to maintain the withstand voltage. Therefore, the drift layer became thicker for the device with higher withstand voltage, and ON-resistance increased with the lower impurity concentration and higher resistance of the drift layer. This is called the trade-off relation between ON-resistance and withstand voltage. In the conventional structure, there is a relation of Ron $\propto$ Vb^3 (cube of Vb), where Ron is ON-resistance and Vb is withstand voltage.

Fujihira et al. of Fuji Electric devised a MOSFET in which a periodic p-n column structure in the drift layer was formed, and they named it a super junction (SJ) structure. In the conventional device, the depletion layer extends in the longitudinal direction from the bottom of the p-layer to low concentration n-layer in OFF-state, whereas in the SJ structure the depletion layer extends in the lateral direction from the vertically extended p-n junctions. Since depletion tends to occur even when the impurity concentration of the n-layer is high, the ON-resistance can be reduced to 1/100 or less as compared with the conventional type while ensuring a high withstand voltage in the OFF-state.

Since the announcement in 1997, the SJ-MOSFET has been actively developed by each company. By increasing the aspect ratio with the lateral miniaturization of the SJ structure under the progress of crystal growth and processing technology, reduction of the ON-resistance per unit area has been proceeding.



(a) Conventional MOSFET (b) SJ-MOSFET

Cross-sectional structure diagram of conventional structure (DMOSFET) and super junction (SJ) MOSFET

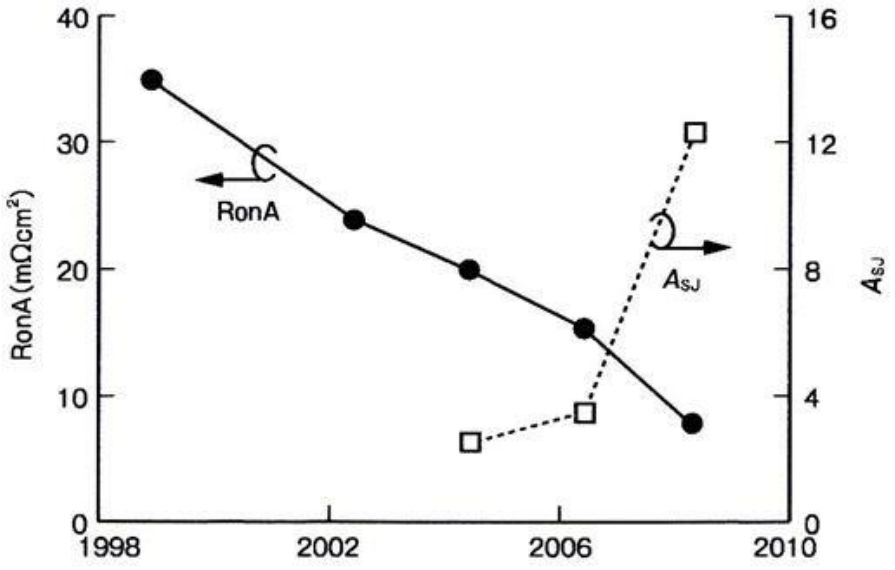


図3. 学会発表における600 V系SJ-MOSFETのRonA推移 — SJ構造の横方向の微細化でA_{SJ}を大きくし，RonAの低減を進めてきた。

Reductions in on-resistance(RonA) of 600 V-class SJ-MOSFETs reported at technical meetings

Reduction of ON-resistance per unit area of SJ-MOSFET
(ASJ: Aspect ratio of p-n column)

References:

(1) T. Fujihira, “Theory of semiconductor superjunction devices” Japanese J. Appl. Phys. Vol. 36, pp. 6254-6262, (1997)

(2) T. Fujihira, & Y. Miyasaka、"Simulated superior performances of semiconductor superjunction devices” Proc. Intl. Symposium on Power Semiconductor Devices and ICs, pp. 423-426, (Jun 1998)

Version 2019/2/20