Medium-voltage MOSFETs for PDP-use

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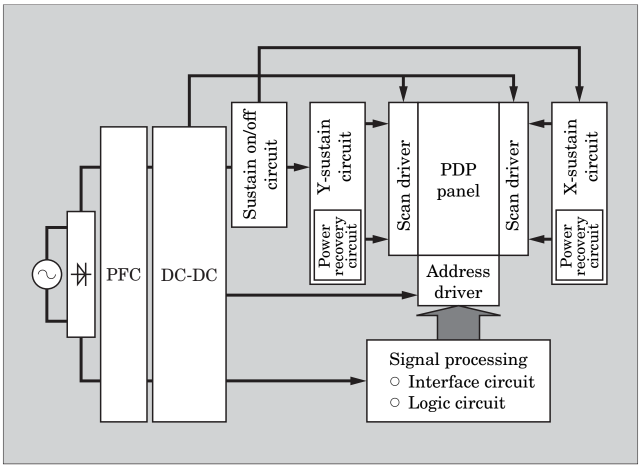
1. Introduction

Flat-screen televisions are a digital consumer appliance of modern convenience, and plasma display panel (PDP) flat-screen televisions are capable of displaying high definition images on a large screen. With the evolution in PDP technology towards higher quality images, larger screen size and lower cost, and with the partial start-up of digital terrestrial television broadcasting in Japan, the popularity of PDPs is increasing at a rapid rate.

PDP technology is trending toward lower power consumption, higher brightness, quieter (fan-less) operation, and thinner panel sizes. Similarly, the attributes of higher efficiency and smaller and thinner size are required of the sustain circuit that controls the plasma light emission. Figure 1 shows the basic circuit configuration of a PDP. The sustain circuit consists of an on/off circuit, a main circuit (X/Y sustain circuits) and a power recovery circuit, and also utilizes several dozens of power MOSFETs (metal oxide semiconductor field effect transistors). Because a large current flow occurs instantaneously, it is important for this sustain circuit to have low on-resistance. In addition, the attributes of small size (reduced number of parallel elements) and thinner profile (surface mounting) are also required.

Fig.1 PDP circuit configuration



In response to these requirements concerning PDP sustain circuits, Fuji Electric has used its existing high-voltage SuperFAP-G series technology to develop a new SuperFAP-G series, ranging from 150 to 300 V, for use in PDP sustain circuits. Additionally, in response to requests for even smaller size and higher efficiency, Fuji Electric is developing trench MOSFETs capable of realizing even lower resistance. It is anticipated that the application of these products will enable small mounting area and more efficient mounting due to the reduced number of MOSFET elements in the sustain circuit and also small cooling elements (heat sinks) and higher operating efficiency due to the lower loss.

The product line and characteristics of the Super FAP-G series and the trench MOSFETs are described below.

2. Characteristics of PDP Power MOSFETs

It is important that the power MOSFETs used in PDP sustain circuits have low on-resistance. Characteristics of the SuperFAP-G series and the trench MOSFETs are described below.

2.1 Characteristics of the SuperFAP-G series

Compared to the conventional MOSFET, the SuperFAP-G series features an improved gate-drain charge (Q_{gd}) tradeoff relation, the charging time constant determined by the on-resistance (R_{on}) and turn-off loss, also a dramatic improvement in the $R_{on} \cdot Q_{gd}$ MOSFET figure-of-merit. The following technology was adopted to realize these characteristics.

(1) QPJ technology

Resistivity of the epitaxial layer is the predominant component of on-resistance in a MOSFET and simply lowering this resistivity causes the drain-source breakdown voltage to decrease. A conventional MOS FET has a 3-dimensional cellular structure, and high electric fields exist locally in portions of the structure. As an improvement to the conventional structure, the quasi-plane junction (QPJ) shown in Fig. 2 was developed. The QPJ features a bonded planar cellular structure realized by fabricating a dense arrangement of low concentration shallow p^- wells instead of the deep p^+ wells used conventionally. Accordingly, the electrical fields in the cellular structure are reduced, enabling the use of an epitaxial resistive layer having lower resistivity than that of the epitaxial resistive layer in a conventional MOSFET.

By employing the QPJ structure, the width of the n^- silicon region (current path) becomes narrower and shorter, and Q_{gd} can be decreased. On the other hand, the narrowing of the n^- silicon region is correlated to an increase in on-resistance, and a tradeoff relation exists between the width of this region and Q_{gd}. The increase in on-resistance is caused by narrowing of the current path in the n^- silicon region due to an expanding depletion layer. In order to limit this expansion of the depletion layer, the concentration of impurities in the n^- silicon region was optimized and the tradeoff relation improved. By applying these enhancements, $R_{on} \cdot Q_{gd}$ was decreased by approximately 60 % compared to Fuji Electric's conventional MOSFET. Table 1 lists characteristics of a SuperFAP-G and a conventional product.

(2) Guard ring

By employing a design that uses the QPJ structure, the device will achieve a reduced cellular electric field and it will be possible to use a low-resistance epitaxial layer. However, by continuing to use the conventionally designed breakdown structure, a problem occurs in that the electrical field of the breakdown structure becomes greater than that of the cellular structure, and the breakdown voltage cannot be ensured. It is essential for the electric field of the

Fig.2 Comparison of SuperFAP-G chip structure (QPJ structure) and conventional MOSFET

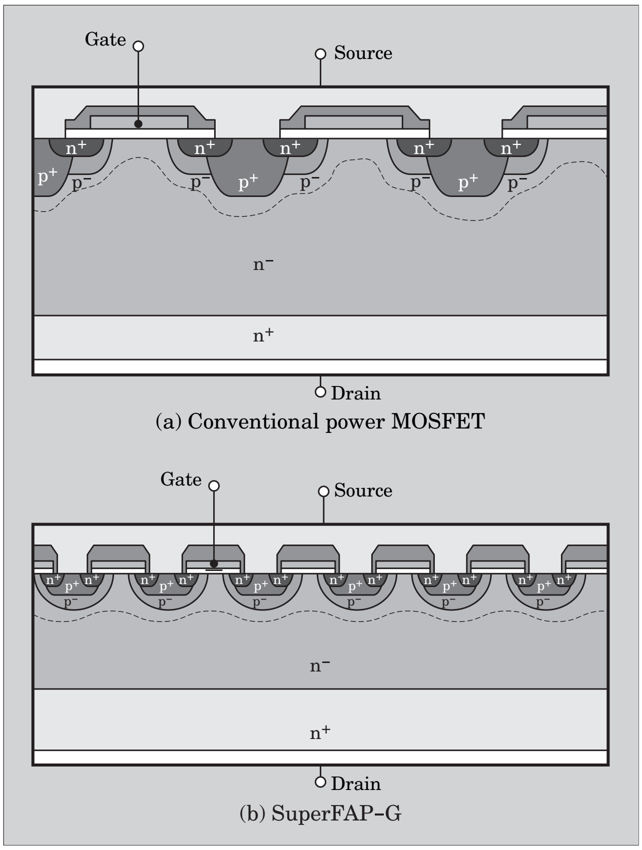
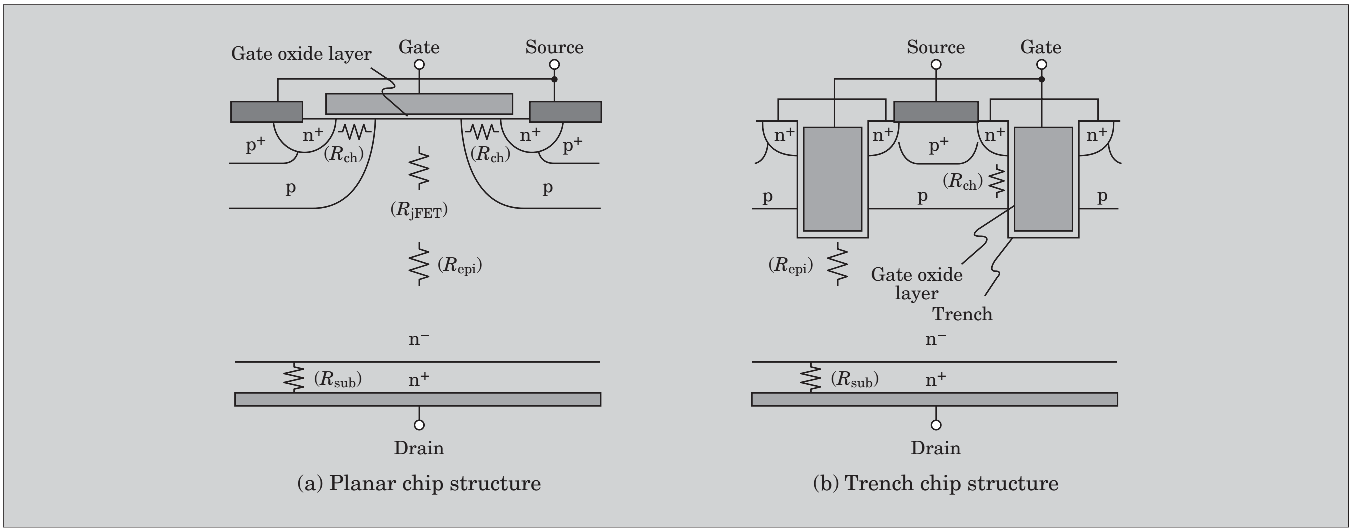


Table 1 Comparison of characteristics of SuperFAP-G and conventional product

Series / Parameter	SuperFAP-G 2SK3535	Conventional product 2SK2254
V_{DS}	250 V	250 V
I_D	±25 A	±18 A
P_D	270 W	80 W
$V_{GS\,(th)}$	3 to 5 V	2.5 to 3.5 V
$R_{DS\,(on)(typ)}$	75 mΩ	130 mΩ
Q_g	50 nC	52 nC
Q_{gd}	16 nC	16 nC
$R_{on} \cdot Q_{gd}$ figure-of-merit	1.20 Ω · nC	2.08 Ω · nC

Fig.3 Planar chip structure and trench chip structure



breakdown structure to be lower than that of the cellular structure, and the development of a breakdown structure capable of reducing the electric field was necessary. While using an epitaxial layer of low resistance, an irregularly-pitched optimized guard ring (OGR) was applied in order to reduce the electric field of the breakdown structure. The electric field was simulated in order to determine the optimal pitch and number of guard rings for a design which realizes a lower electric field in the breakdown structure than in the cellular structure. Moreover, in order to insure reliability, the design was made resistant to any influence from charge accumulation.

2.2 Characteristics of trench MOSFETs

Fuji Electric has previously promoted its Super-FAP-G series that realizes low on-resistance. However, in response to requests from the PDP field for even lower on-resistance, Fuji Electric is concentrating on

Fig.4 Comparison of the ON-resistance components of a 200 V conventional planar chip and a trench chip

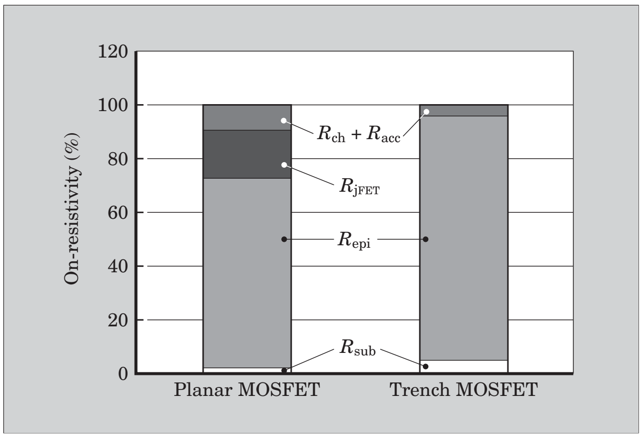


Fig.5 Internal structure of MOSFET (surface mount type)

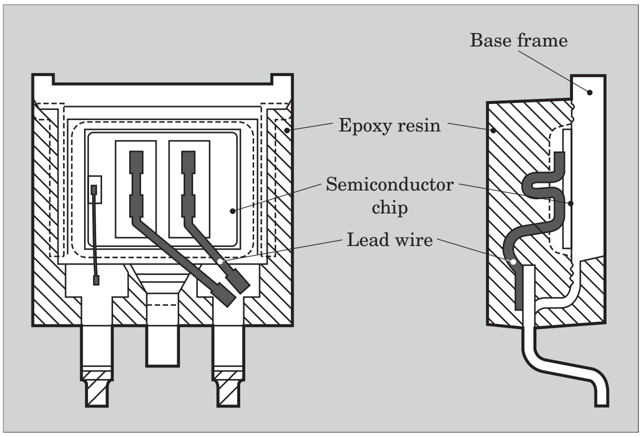


Table 2 Comparison of ON-resistance of conventional MOSFET and trench MOSFET

Drain-source breakdown voltage	On-resistance R_{on} (mΩ)		R_{on} reduction rate
	Conventional MOSFET	Trench MOSFET	
200 V	66	50.6	23.3 %
250 V	100	84	16 %

Table 3 Sheet resistance (calculated value: TO-220 series)

	ϕ = 400 µm×2 wires	ϕ = 400 µm×2 wires Stitch bonding
Sheet resistance calculated value	0.4 mΩ	0.2 mΩ

Table 4 Fuji Electric's product line of power MOSFETs for PDP-use

Breakdown BV_{DSS}	Rated current I_D	ON-resistance $R_{DS\,(on)}$	Package					
			TO-220	TO-220F	T-Pack (D2-Pack)	TFP	TO-247	TO-3PF
150 V	57 A	41 mΩ	2SK3590	2SK3591	2SK3592	2SK3593	–	–
	65 A	28.5 mΩ	*FMP65N15T2	*FMA65N15T2	*FMB65N15T2	–	–	–
	92 A	26 mΩ	–	–	–	–	2SK3788	2SK3789
	100 A	16 mΩ	–	–	–	–	2SK3882	–
200V	45 A	66 mΩ	2SK3594	2SK3595	2SK3596	2SK3597	–	–
	49 A	50.6 mΩ	*FMP49N20T2	*FMA49N20T2	*FMB49N20T2	–	–	–
	73 A	36 mΩ	–	–	–	–	2SK3780	2SK3781
	100 A	20 mΩ	–	–	–	–	2SK3883	–
250V	37 A	100 mΩ	2SK3554	2SK3555	2SK3556	2SK3535	–	–
	38 A	84 mΩ	*FMP38N25T2	*FMA38N25T2	*FMB38N25T2	–	–	–
	59 A	53 mΩ	–	–	–	–	2SK3778	2SK3779
	100 A	30 mΩ	–	–	–	–	2SK3884	–
300V	32 A	130 mΩ	2SK3772	2SK3773	2SK3774	2SK3775	–	–
	53 A	72 mΩ	–	–	–	–	2SK3776	2SK3777
	86 A	40 mΩ	–	–	–	–	2SK3885	–

∗ on development

developing next generation products and, based on Fuji's track record of success with the trench gate structure technology (60 V and 75 V devices for automotive use), is optimizing the trench depth and wafer specifications in order to achieve higher performance.

Figure 3 shows a cross-sectional comparison of the planar chip and trench chip structures. In the trench chip structure, a gate is formed on a groove (trench) that passes through the channel, and this enables the cell to be made smaller and the channel resistance (R_{ch}) component and JFET resistance (R_{jFET}) component to be reduced, which had been difficult to implement with the planar chip structure shown in Fig. 4. Table 2 compares the on-resistance of the conventional MOSFET with that of the trench MOS FET. As can be seen, adoption of the trench gate structure achieves a large decrease in on-resistance.

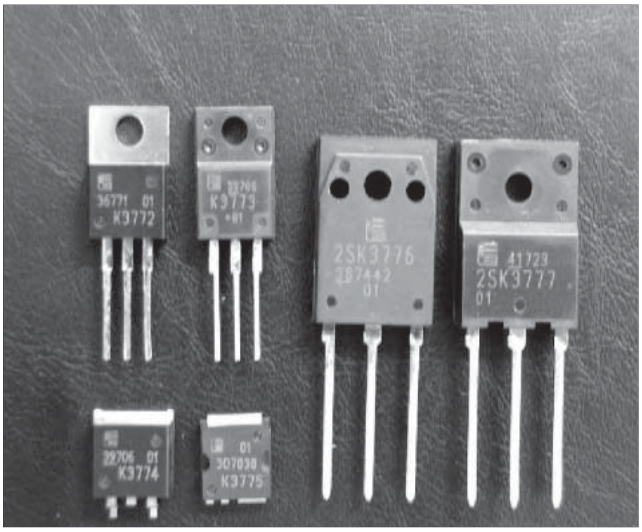
2.3 Reduction of the internal wiring resistance

Because the MOSFETs used in PDPs must have low on-resistance, it is important to reduce the on-resistance of the MOSFET chips and the resistance of wiring inside the package. For low on-resistance chips of the150 V drain-source voltage class, the sheet resistance of the source aluminum electrode on the chip's surface increases as a percentage of the total on-resistance of the product. Figure 5 shows the internal structure of a T-Pack package. A reduction in sheet resistance is achieved by bonding the source aluminum wire to the chip's source electrode in several locations. Table 3 shows the effectiveness of reducing the sheet resistance.

3. Product Line and External Appearance

Table 4 lists a summary of Fuji Electric's power MOSFET series for PDP-use. Figure 6 shows the external appearance of these packages. The product line contains drain-source voltages ranging from 100 to 300 V and a series of TO-220, TO-3PF and TO-247 packages. A series of T-Pack (D2-Pack) and TFP surface-mount products are also available and are anticipated to contribute to the production of thinner sustain circuits.

Fig.6 External view of packages



4. Conclusion

This paper has described features of Fuji Electric's SuperFAP-G series for PDP-use and Fuji's medium-voltage trench MOSFETs, which are still under development. In the future, Fuji Electric intends to continue to develop products optimized for PDPs and to contribute to the development of the PDP industry.

References

(1) Kobayashi, T. et al. High-voltage Power MOSFETs Reached Almost to the Silicon Limit. Proceedings of ISPSD'01. 2001, p.435-483.