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Electrical Characteristics of Polysilicon CMOS Analog and Driver Circuits for Intelligent IGBTs

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1. Introduction

Polysilicon device technology is attracting considerable interest, since polysilicon devices can be fabricated directly on insulator layers such as glass or thick field oxide film on silicon devices. Since polysilicon is usually utilized as gate material for MOS-gate control in discrete devices such as IGBTs etc., polysilicon circuits can readily be utilized as control and protection circuits for vertical power devices. Polysilicon CMOS circuitry, formed on power devices, will realize three dimensional system power ICs in a reasonable cost[1][2]. So far, polysilicon circuits were only applied to power MOSFET protection.

In this paper, we investigate the analog circuit performance of 0.8 μm gate length polysilicon CMOS fabricated on a thermal oxide film. We show, for the first time, that the improved polysilicon analog circuits works sufficiently rapidly to protect IGBTs. Adopting the circuits, various intelligent and protection functions can be realized on the same chip. It was experimentally verified that 20 A/600 V high power IGBT can be driven and safely protected from over current load or load short-circuit failure by the polysilicon circuits.

2. Device fabrication and characteristics

The schematic cross section of polysilicon NMOSFET is shown in Fig. 1. Amorphous silicon of 500 nm in thickness was deposited on thermally oxidized silicon wafers by LPCVD. The wafers were then annealed at 600 ℃ for 8 h to form polysilicon layers. The gate oxide film was thermally grown with a thickness of 40 nm. The gate electrode was a phosphorus-doped polysilicon film with a width of 10 μm. The gate length was 0.8 μm.

Figure 2(a) and 2(b) show the drain voltage current (Vd-Id) characteristics of NMOSFET and PMOSFET devices with 10 μm channel width and 0.8 μm channel length. In the NMOSFET device, when the gate voltage was 10 V, the drain current was 600 μA at a drain voltage of 6 V, and Ron·Area product was 104 $m\Omega \cdot mm^2$. Ron·Area product of PMOSFET was 96 $m\Omega \cdot mm^2$. The NMOSFET and PMOSFET breakdown voltages were more than ±15 V, respectively.

3. Analog and driver circuits

We have evaluated the performance of the polysilicon analog and driver circuit. Figure 3 shows the driver circuits and the input and output waveforms. The driver circuit had an ability to drive a 1000 pF capacitor in 100kHz frequency at Vcc of 10V. The gate delay time was evaluated by a ring oscillator, consisting of 31 CMOS inverter stages in Fig. 4. The short gate delay time of 400 ps was achieved.

Figure 5 shows the polysilicon comparator circuit including the cascaded triodes. The wide proper operation range from 2 V to 7 V was obtained for the fabricated polysilicon comparator for Vcc of 10V. An over current protection circuit was tested using the comparator circuit. It was experimentally verified that the gate voltage of power device was safely shut down within 600 nsec when an over current condition was detected by a sense circuit, as seen in Fig. 6. The comparator circuit can be utilized for over current and over temperature protection.

Figure 7 shows a load short-circuit protection circuits for IGBTs rated 20A/600V. The protection blocks consist of a voltage detector, detecting forward voltage of an IGBT, and a shunt polysilicon power MOSFET. When the forward voltage of the IGBT is excessively large, the protection circuit considers the condition as load short-circuit and immediately decreases the gate voltage to a predetermined value to reduce the conduction current.

Figure 8 shows the measured static current voltage characteristics with the load short-circuit protection. IGBTs cannot conduct current under a large forward voltage.

Figure 9 shows the transient behavior of the load short-circuit protection. It is seen that the protection works within 250nsec to reduce IGBT current. If an IGBT is unintentionally turned-on under a load short-circuit condition, 300V DC voltage is directly applied to the IGBT and an excessively large current tries to flow in the IGBT. The protection circuit detect the abnormal condition by voltage sensing signal (Vsense) and reduce the gate voltage (Vg) within 250nsec from 12V to 6V, which is slightly above the threshould voltage. An excessively large current is prevented to flow in the IGBT and the device can be protected.

Polysilicon circuits have sufficient ability to protect power devices from failure cases.

4. Conclusion

The present paper has analyzed the basic electrical characteristics of polysilicon analog and driver circuits for power IC application. Ron·Area product of 0.8 μm gate length polysilicon NMOSFET was 104 $m\Omega \cdot mm^2$. It was found that developed MOS gate driver and protection circuits for 20A/600V IGBTs exhibited sufficiently good performance for control and protection circuits to be fabricated on power devices.

Acknowledgment

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References

[1] G.M.Dolny, A.C.Ipri, G.E.Nostrand, C.F.Wheatley and J.Wodarczyk: IEEE Electron Device Lett. Vol.13 (1992) 516

[2] W.Wondrak, R.Constapel, R.Traute, Ch.Bokeloh and R.Herzer: ISPSD (1998) 371

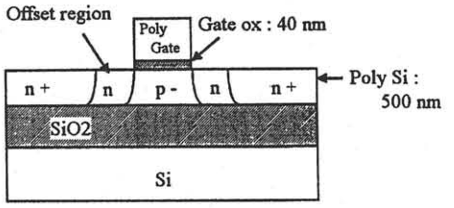

Fig. 1 Cross-sectional view of fabricated polysilicon NMOSFET

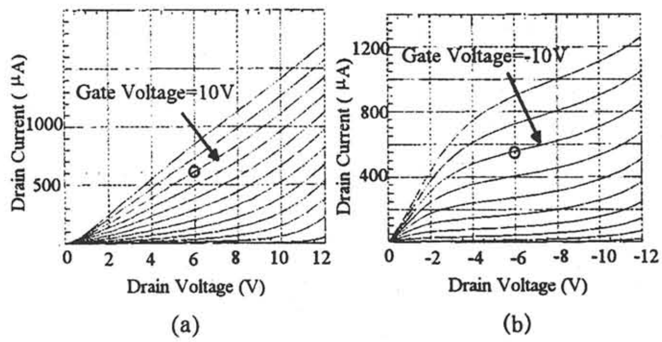

Fig. 2 Vd-Id characteristics of (a) NMOSFET and (b) PMOSFET on 500 nm thick polysilicon. (W/L:10 μm/0.8 μm)

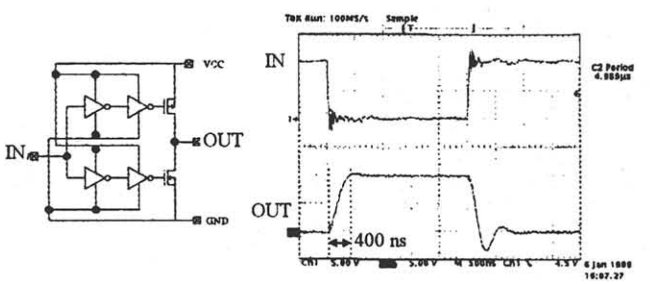

Fig. 3 Driver circuit, and input and output waveforms for 20 A/600 V IGBT

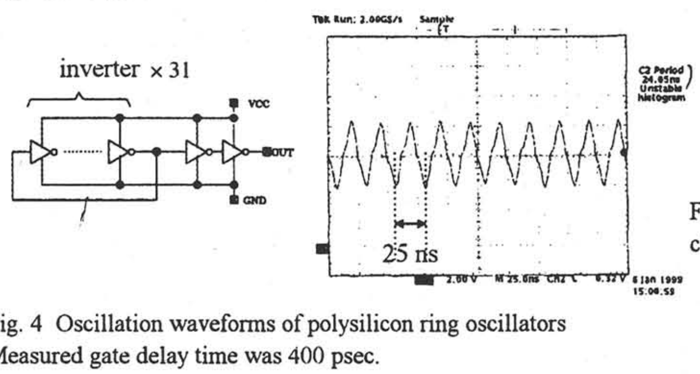

Fig. 4 Oscillation waveforms of polysilicon ring oscillators Measured gate delay time was 400 psec.

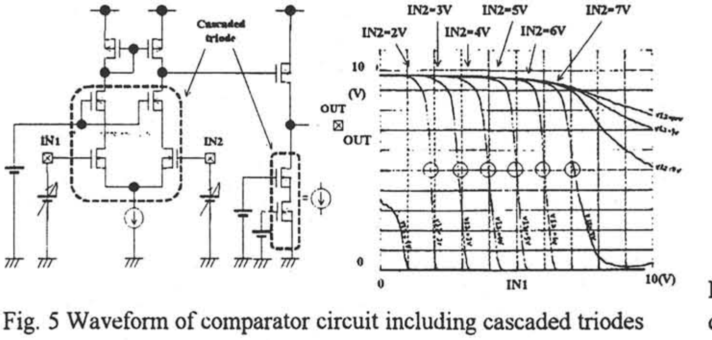

Fig. 5 Waveform of comparator circuit including cascaded triodes

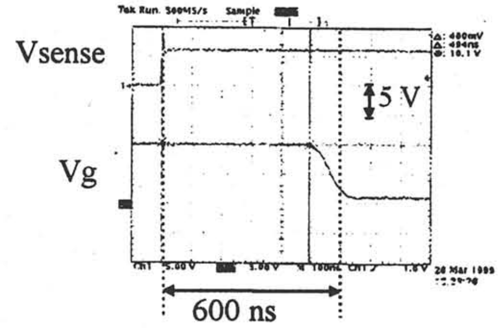

Fig. 6 Transient behavior of over current protection circuit for IGBT. Vsense is the over current sense signal and Vg is the gate voltage.

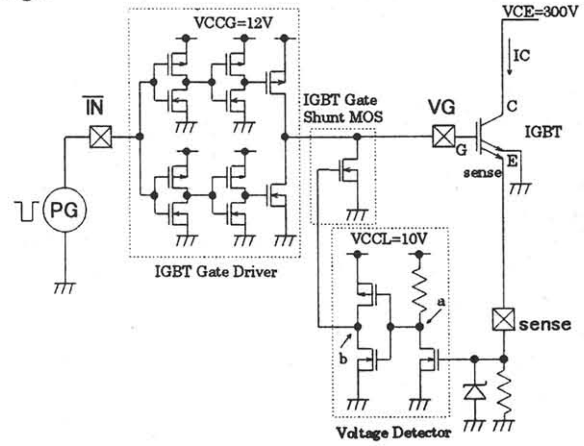

Fig. 7 Load short-circuit protection circuit using polysilicon CMOS

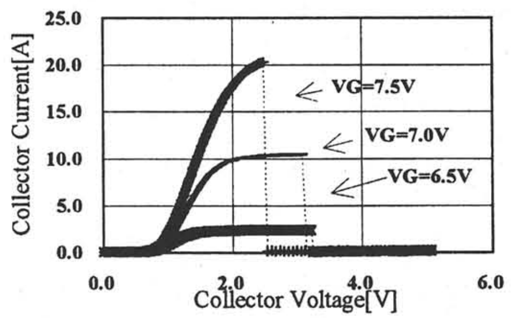

Fig. 8 Static Vd-Id characteristics of 600 V IGBT with short-circuit protection

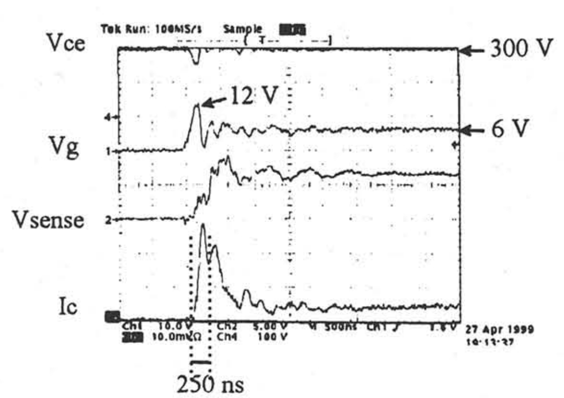

Fig. 9 Transient measurement of output current for 600 V IGBT controlled with load short-circuit protection circuit