Extended Abstracts of the 2003 International Conference on Solid State Devices and Materials, Tokyo, 2003, pp. 158-159

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A New Protection Circuit of IGBT (Insulated Gate Bipolar Transistor) for Short-Circuit Withstanding Capability

Byung-Chul Jeon, In-Hwan Ji, Min-Koo Han and Yearn-Ik Choi*

#50, 301-1115, School of Electrical Eng., Seoul Nat'l Univ., Shinlim-dong, Kwanak-ku, Seoul 151-742, Korea
Phone: +82-2-880-7254, Fax: +82-2-875-7254, e-mail: mkh@snu.ac.kr
*School of Electronics Engineering, Ajou University, Paldal-Gu, Wonchun-Dong, Suwon, Korea

1. Introduction

It is well known that IGBTs (Insulated Gate Bipolar Transistor) exhibit the trade-off relationship between forward voltage drop and short-circuit withstanding capability because shorter channel length and smaller threshold voltage can results in large saturation current of IGBTs [1].

In order to improve the trade-off relationship, various protection schemes such as current sensing scheme [1] and V_{CE} sensing scheme [2] have been reported. However, it is known that the limited availability and the consistency of the sense ratio from device to device may have to be evaluated in case of current sensing scheme [3]. Also, the circuit employing V_{CE} sensing scheme should provide blanking time to allow for the turn-on switching process [3].

The purpose of our work is to propose a new protection circuit of IGBT for short-circuit withstanding capability without sacrificing forward voltage drop and disadvantages of current sensing and V_{CE} sensing scheme. We report simulation and experimental results of the proposed protection circuit.

2. Operation Principle of protection circuit

The proposed protection circuit of IGBT for short-circuit withstanding capability is shown in Fig. 1. The protection circuit consists of main IGBT, which is protected from over current and short-circuit condition, pass FET and pull down MOSFET M1 and diode D1. It should be noted that the proposed protection circuit differs from the current sensing scheme where the pass FET may not sense over-current but transfer anode voltage to the gate of M1 (at the point of B). It is inferred that disadvantages of the current sensing scheme such as detection accuracy and limited availability and the consistency of the sense ratio could be avoided because the proposed protection circuit does not employ any current sensing.

When the gate voltage V_G is high enough to "turn-on" the main IGBT, the pass FET can transfer anode voltage to the gate of the M1 up to V_G-V_T. When the potential at the point of B is above the threshold voltage of M1, the potential at the point of A is decreased and set by the ratio between R_G and R_D and on-resistance of M1. The diode D1 can lower the gate voltage of the M1 to near 0V when the gate voltage V_G is 0V. It should be noted that the anode voltage could be lower than the threshold voltage of M1 during normal operation and that the protection circuit could be monolithically integrated with the main IGBT.

3. Simulation and Experimental Results

In order to verify the proposed protection scheme, mixed-mode device simulations employing ISE [4] are performed and test circuits employing GP7NB60HD of STMicronics, which is a 600V IGBT, are prepared and measured using 371A high power curve tracer.

Fig.2 shows simulation results of the I-V characteristics of the conventional IGBT and the IGBT with the proposed protection circuit. Threshold voltage of M1 is set to 4.5 V. It is shown that when the anode voltage is increased above 4.5 V, the potential at point A begins to decrease and set to about 9.2V It should be noted that saturation current density and the anode voltage where the protection circuit begins to operate, can be easily controlled by the resistance ratio between R_G and R_D and on-resistance of M1.and by the threshold voltage of M1.

The measured I-V characteristics of GP7NB60HD are shown in Fig. 3 (a) with the gate voltage of 0V, 10V and 15V. It is noted that the saturation current is as high as 80A at V_G=15V, while the operating current level is 7A and that the negative resistance I-V characteristics at V_G=15V in the saturation region can be due to the self-heating effects.

Fig. 3 (b) compares the I-V characteristics of the conventional GP7NB60HD to that of the GP7NB60HD with the proposed protection circuit. The values of R_G and R_D are 10kohm and 1Kohm respectively. It should be noted that the forward voltage drops of the conventional GP7NB60HD and of the GP7NB60HD with the protection circuit are identical and that the maximum current of the GP7NB60HD with the protection circuit is below 25V.

In order to control the saturation current level, the value of R_D are varied from 1kohm to 10kohm with the value of R_G fixed at 10kohm. Fig. 4 shows the I-V characteristics of the GP7NB60HD with the protection circuit at V_G=15V. It is clearly shown that the saturation current level can be controlled by adjusting the value of R_D and that the points where the anode current starts to be decreased are almost the same irrespective of R_D.

3. Conclusion

A new protection circuit of IGBT for short-circuit withstanding capability is proposed without sacrificing forward voltage drop and disadvantages of current sensing and V_{CE} sensing scheme. Simulation and experimental results show that the proposed protection circuit can decrease the saturation current level of IGBT to the needed level by adjusting the resistance ratio between R_G and R_D and on-resistance of M1. It should be noted that the new protection circuit could be monolithically implemented by adding a p-well step to the conventional IGBT process [2].

References

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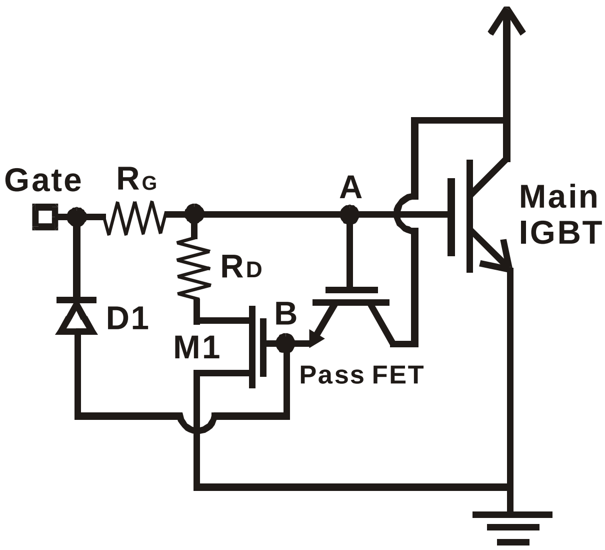


Fig. 1: The cross-sectional view of poly-Si TFT used in ESD test

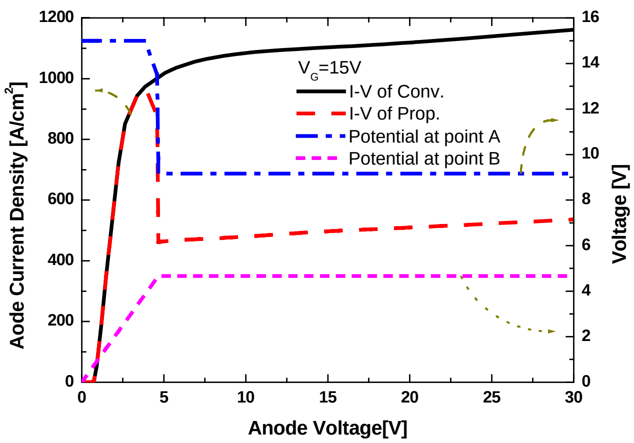
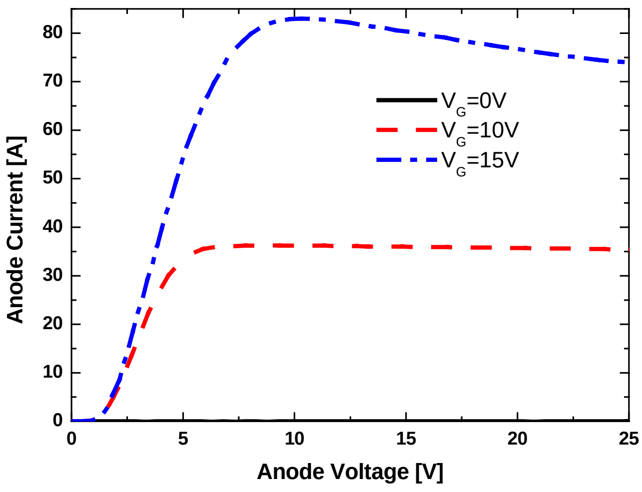
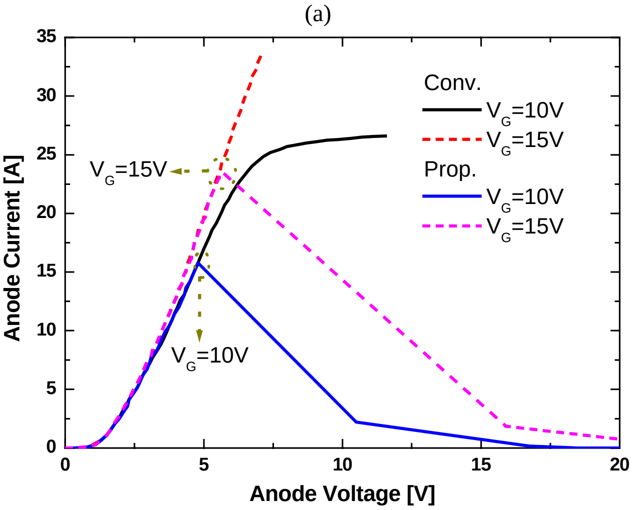


Fig. 2: The simulated I-V characteristics of the conventional IGBT and the IGBT with the protection circuit.



(a)



(b)

Fig. 3: The measured I-V characteristics of (a) the conventional GP7NB60HD and (b) of the GP7NB60HD with the protection circuit.

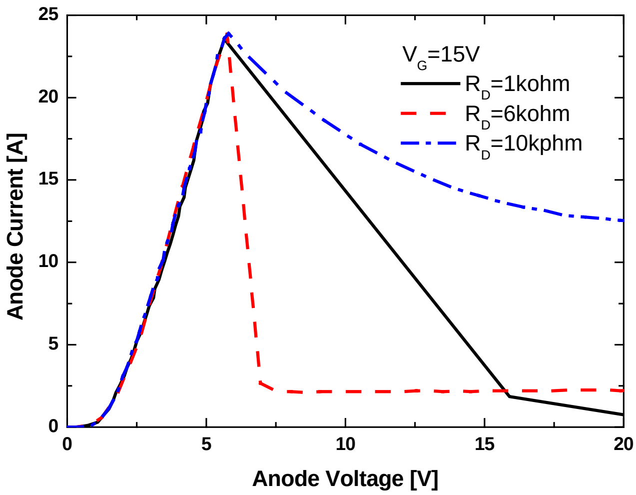


Fig. 4: The measured I-V characteristics of the GP7NB60HD with the protection circuit at V_G=5V varying the value of R_D.