Extended Abstracts of the 1997 International Conference on Solid State Devices and Materials, Hamamatsu, 1997, pp. 128-129

The Double-Metal Schottky Power Rectifier: An Adjustable Schottky Barrier Height Low-Power-Loss Diode

Shui Jinn Wang and Jiann Tyng Tzeng

Microelectronics Laboratory, Department of Electrical Engineering
National Change Kung University, 1 Ta Hseuh Road, Tainan 70101, Taiwan, R. O. C

1. Introduction

Schottky barrier diode (SBD) is known as a high-speed and low forward voltage drop device.[1,2] The trade-off between the forward voltage drop and the reverse blocking property is inevitably encountered in the design of conventional SBDs'. In addition, the realization of an optimum Schottky barrier height for SBDs' with minimum power loss is very difficult, because the effective Schottky barrier height of SBDs' can not be well controlled.

In this work, a double-metal structure is proposed for solving the above-mentioned trade-off problem. It offers a simple way for the implementation of low-power-loss SBDs'.

2. Device Structure and Operation Theory

Figure 1 schematically illustrates the concept of the double-metal SBD structure. By suitably interdigitating the low- and high-barrier-height metals, the device beneath the low-barrier-height metal can be fully shielded by the depletion region of the high-barrier-height part under reverse bias, as a result, the reverse blocking property will be determined by the high-barrier-height metal and a high breakdown voltage as well as a low leakage current can be expected, while forward conduction will be dominated by the low-barrier-height metal which gives rise to a low forward voltage.

Figure 2 plots the simulation result of a double-metal SBD with a geometry shown in the inset. The low-barrier-height metal (M_o) is surrounded by the high-barrier-height metal (W or WSi_2). It is seen that the device behaves a forward and reverse characteristics exactly as expected.

3. Experimental Results

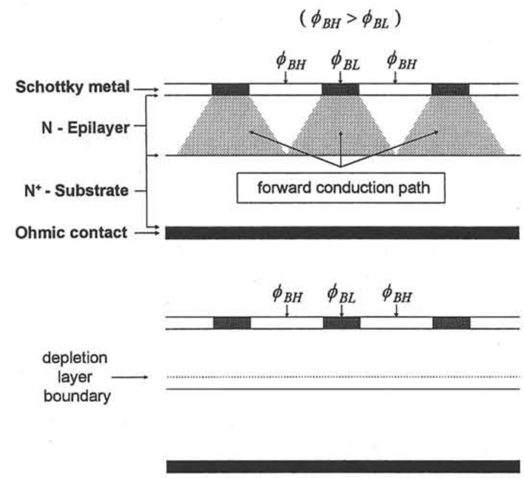

Fig. 1 The schematically diagram of the double-metal Schottky power rectifier. Only portion of the device is shown. The upper diagram shows the case under forward bias, and the lower one is under reverse bias.

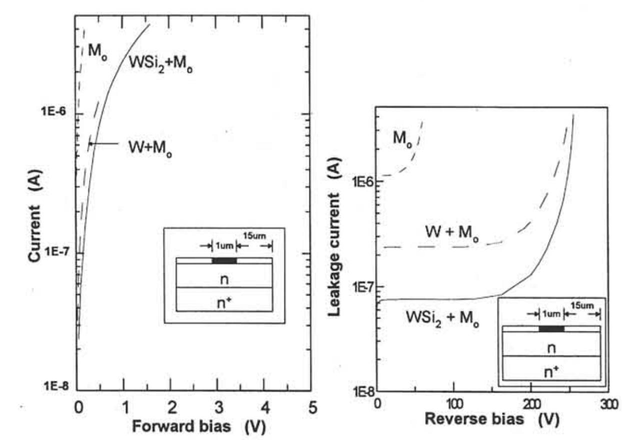

Fig. 2 The simulation results of a double-metal SBD. M_o was employed as the low-barrier-height metal, W and WSi_2 were adopted as the high-barrier-height metal.

Figure 3 shows the experimental I-V characteristics of SBDs fabricated on $n(8.5\mu m, 2\Omega\cdot cm)/n^{+}(0.015\Omega\cdot cm)$ Si epi-wafers. A_g and A_u were served as the low- and high-barrier-height metal, respectively. It clearly shows that both forward conduction current and the reverse leakage current increase with increasing the area ratio which is defined as the ratio of the total low-barrier-height metal area to the total device area.

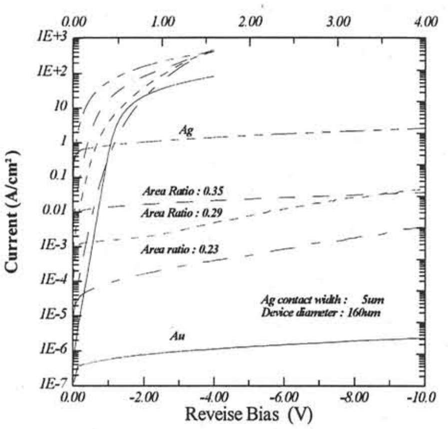

Fig. 3 Experimental *I-V* characteristics of double-metal SBDs'. A_g and A_u were served as the low- and high-barrier-height metal, respectively.

The device was assumed following the widely used thermionic-emission theory of $J = J_s(e^{\beta(V-JR_s)/\eta} - 1)$, where J_s, η, β, and R_s have their usual meanings. Based on parameter extraction, the effective Schottky barrier height of the fabricated diodes as a function of the area ratio is shown in Fig. 4. It is seen that, as x is increased from 0 (the case of $Au-SBD$) to 1 (the case of A_g-SBD), the barrier height decreases from around $0.76\,V$ to about $0.44\,V$. This result indicates that a controllable Schottky barrier height can be realized by suitably designing the area ratio. Accordingly, to realize minimum power-loss power rectifiers, the optimum value of Schottky barrier height (ϕ_B^*) can be arranged in such a way together with a large degree of freedom in choosing Schottky metals.

Figure 5 shows the static power loss of a SiC-SBD (under $J_F = 200\,A/cm^2$ and $V_R = 500\,V$) as a function of the barrier height of the low-barrier-height metal. The high-barrier-height metal was assumed being with $0.5\,V$ larger than that of the low-barrier-height metal. The optimum value of Schottky barrier height for minimum power loss was indicated with ϕ_B^*. It reveals that the proposed structure enables one to realize an optimum effective barrier height for minimum power loss SBDs'.

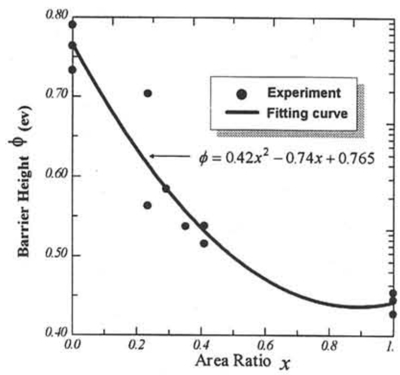

Fig. 4 The effective Schottky barrier height of the fabricated diodes as a function of the area ratio.

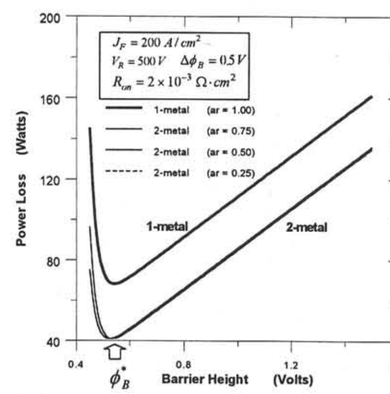

Fig. 5 The calculated results of the static power loss of SBD (50% − *duty cycle*) as a function of the barrier height of the low-barrier-height metal.

4. Conclusions

A novel double-metal structure has been proposed to solve the trade-off problem caused by the Schottky barrier height in the design of low-power-loss Schottky barrier diodes. It is shown that the effective Schottky barrier height of the diode can be controlled by simply adjusting the area ratio of the two metals. Theoretical and experimental results presented in this work reveals the feasibility of the proposed structure.

Acknowledgments

The work was supported by the National Science Council (NSC) of Taiwan, Republic of China, under Contract No. NSC 86-2215-E006-004.

References

1) B. J. Baliga: IEEE Electron Device Lett., 5(1984), No. 6, 194.
2) Y. Yamamoto and H. Miyanaga: IEEE Electron Device Lett., 37 (1990), No. 5, 1364.
3) M. Bhatnagar and B. J. Baliga, IEEE Electron Devices, 40 (1993), 645.