Fabrication of Metal-Nitride/Si Contacts with Low Electron Barrier Height

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Fabrication of metal/semiconductor contact with low electron barrier height and low parasitic resistance is important for high-performance CMOS devices. Recently, we succeeded in the formation of a TiN/Ge contact with extremely low electron barrier height (Φ_{BN}) less than 0.1 eV, which was fabricated by direct sputter deposition from a TiN target and low temperature anneal at 350°C [1,2]. In this study, we apply this technique to Si to form low Φ_{BN} contact.

The substrates were p- and n-type (100) Si with a resistivity of 10 Ω·cm. A 50 nm-TiN film and 50 nm-Al film were deposited on the Si substrate by rf magnetron sputtering using a TiN target and thermal evaporation, respectively. The Al/TiN film was patterned using a lift-off technique. Finally, postmetallization annealing (PMA) was carried out at 400°C in N_2 for 10 min, which was the optimal PMA condition.

Figures 1(a) and 1(b) show the J-V characteristics for the TiN/p-Si and TiN/n-Si contacts, respectively. The TiN/p-Si contact showed rectifying behavior and TiN/n-Si contact showed Ohmic-like behavior. These J-V results suggest that the TiN/Si contact has high hole barrier height (Φ_{BP}) and low Φ_{BN}. Actually, the Φ_{BP} obtained from the forward J-V characteristic of TiN/p-Si was 0.85 eV. Note that the Φ_{BP} found in this study is one of the highest barrier heights among metal/p-Si contacts, which is comparable to that of an ErSi/Si contact [3]. The Φ_{BN} is obtained as 0.27 eV from the relation of $\Phi_{BN} + \Phi_{BP} = E_g$, where E_g is the energy bandgap of Si (1.12 eV).

For comparison, we also fabricated Ti/Si contacts using the same fabrication method. The J-V characteristics are also shown in Figs. 1(a) and 1(b). The Φ_{BP} and Φ_{BN} were obtained as 0.61 eV and 0.55 eV, respectively. These are in good agreement with the reported values of Ti/Si contact [4]. It is very interesting that the electrical characteristics drastically changed by the addition of N_2 gas during Ti sputter deposition, which is also represented in Figs. 1(a) and 1(b); with increasing an N_2 flow rate, J at reverse bias decreased on p-Si and increased on n-Si, moving towards the J-V characteristics of TiN/Si contacts. We will present the results for other binary metal nitrides.

We fabricated inversion-mode back-gate MOSFET with TiN metal S/D on p-type SIMOX-SOI substrate. The device structure is shown in the inset of Fig. 2. Figure 2 shows I_D-V_G characteristic for the back-gate MOSFET, indicating that channel conductions are well controlled by the V_G. Thus, the back-gate MOSFET exhibits well-behaved n-type inversion-mode operation. The peak field effect mobility (μ_{FE}) estimated from the I_D-V_G characteristic was 650 cm^2/Vs. The D_{it} of the SOI/BOX interface estimated from the subthreshold slope of 203 mV/dec was 1.1×10^{11} $cm^{-2}eV^{-1}$. These values are comparable with universal electron mobility and D_{it} value of SiO_2/Si [5]. Thus, the test device structure with TiN S/D, which could be easily prepared without high temperature process, is useful for the electrical characterization of SOI substrate.

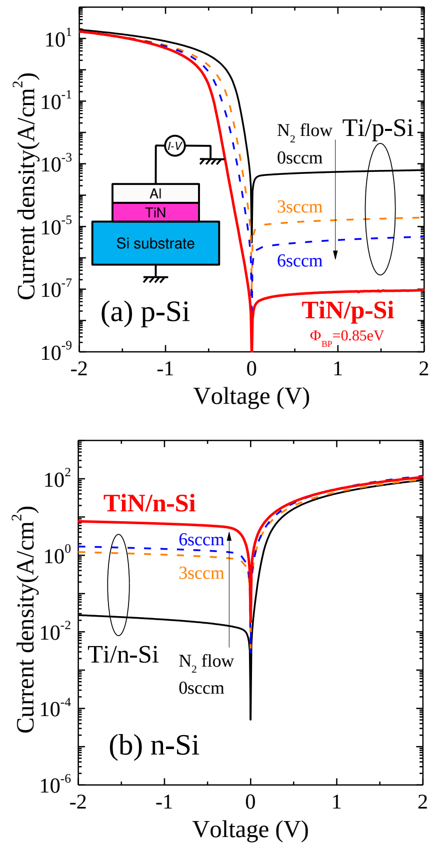

Fig. 1 J-V characteristics of (a) TiN and Ti contacts on n-Si and (b) TiN and Ti contacts on p-Si. Measurement temperature for all samples is RT.

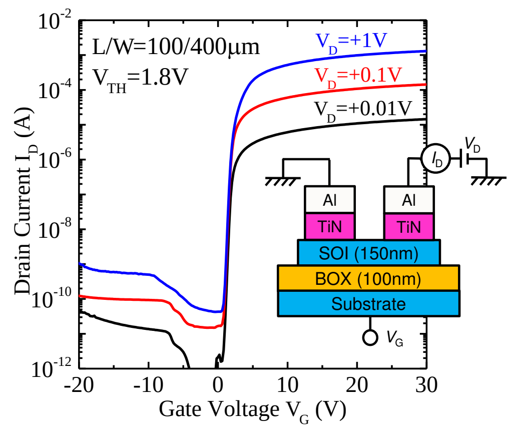

Fig. 2 I_D-V_G characteristic for the fabricated inversion-mode back-gate MOSFET. The cross-sectional schematic image of the MOSFET is also shown as an inset.

References

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