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2D inserted Metal / Semicondcutor interface : an attractive candidate for semiconductor MOSFET contact

In the rapid scaling of Si MOSFET, the channel resistance has been decreased continuously. On the other hand, the contact resistance (Rc), one of the main source of the external resistance, has been kept relatively unchanged. As a result, Rc became one of the dominant factors limiting the performance of MOSFET.[1]

One of the main cause of Rc is Schottky barrier between metal and Si in source and drain region. Schottky barrier height (SBH) can be predicted by the Schottky-Mott rule from the difference between the metal work function and the conduction band edge of semiconductor. In principle, Rc can be reduced as lowering SBH with metal with proper work function. However, observed SBH's in Si differ significantly from the predicted values, due to the pinning effect of semionductor.[2]

The current approach to lower Rc is to change the carrier flow mechanism to tunneling emission. To increase the tunneling current, heavily doped Si was used to reduce the tunneling barrier width.[3] However, this method is approaching its limitation because of the dopant solubility in Si, short channel effect, and dopant profile control. As an alternate option, metal-insulator-semiconductor (MIS) structure was presented. The interface insulator is working as a tunnel barrier and de-pinning materials.[4] However, this technique is lack of thermal stability and thickness controllability of insulator layer.

Here, we present a new approach to reduce the SBH and the Rc at the interface between metal and Si with the insertion of 2D, such as, graphene and hexagonal-boron nitride (h-BN). In this approach, 2D materials play two roles: 1. 2D materials effectively changed the metal work-function by dipole formation, 2. 2D materials changed the pinning point of silicon to enable low Schottky barrier formation. We further demonstrate that the 2D inserted metal/Si contact with both low-doped n-Si and high-doped n-Si. Metal/2D/Si device achieved SBH of less than 0.1 eV and Rc of few n$\Omega\cdot$cm^2. We also simulate the SBH of 2D inserted metal/Si interface and the results are in good agreements with experimental results. This proposed 2D inserted technique can be used as sub- n$\Omega\cdot$cm^2 contacts for metal/n-Si and low Rc contact with new semiconductor materials beyond Si CMOS technology.

References

[1] Compbell, J. P.; Cheung, K. P.; Suehle, J. S.; Oates, A., IEEE Electron Device Letters, 32 (2011) 1047
[2] Himpsel, F. J.; Hollinger, G.; Pollak, R. A., Phys. Rev. B, 28 (1983) 7014
[3] Yu, A. Y. C., Solid-State Electronics, 13 (1970) 239
[4] Connelly, D.; Faulkner, C.; Clifton, P. A.; Grupp, D. E., Appl. Phys. Lett., 88 (2006) 012105

Figures

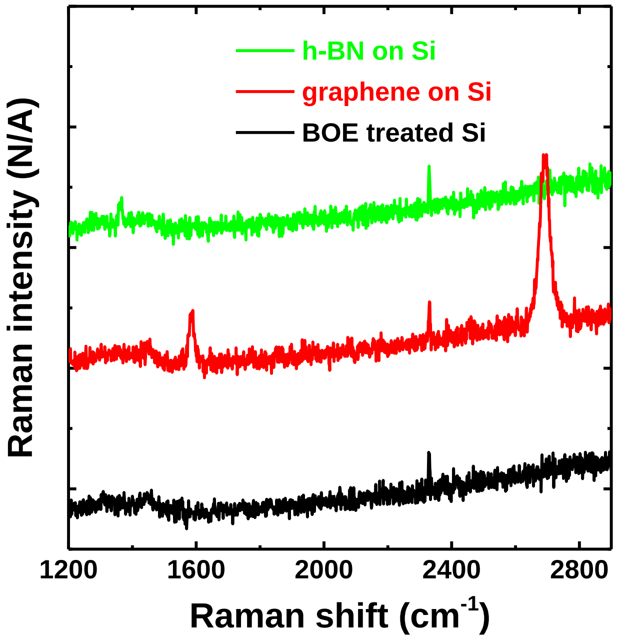

Figure 1: Raman profile for 2D on Si surface and HF treated Si surface. Mono-layer 2D materials were clearly detected in Raman analysis.

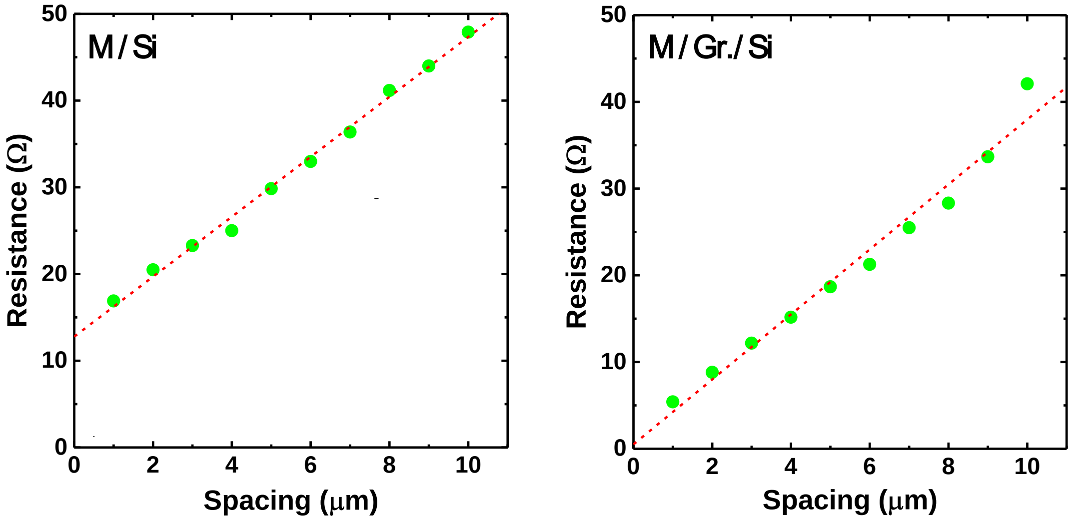

Figure 2: Contact resistance of Metal/Si and Metal/Graphene/Si structure measured by transmission lime method.