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Ultra-wide bandgap junction field effect transistor based on Ga_2O_3-SiC p-n heterojunctions

Junction field effect transistors (JFETs) have advantages in the power device area over metal-oxide-semiconductor field effect transistors (MOSFETs) that are widely utilized in the semiconductor industry. The voltage drop across the dielectric layer can cause the gate voltage needed to deplete the channel to become quite high in MOSFETs. In addition, the dielectric layer in such MOSFETs typically causes a slow response of the drain current to changes of the gate voltage due to charging processes similar to a capacitor, which can be a problem for high-frequency applications.[1] The quality of the oxide dielectric layer has severely limited the performance and stability of the MOSFETs and the complexity of the process increases the cost of the process. These disadvantages can be avoided when p-n junction structures are utilized and therefore many studies have been conducted on high power electronics with JFETs based on wide band gap materials such as SiC, GaN.[2]

Gallium oxide (β-Ga_2O_3), which has a wide bandgap of ~ 4.9 eV with thermal and chemical stability, is one of the promising wide bandgap semiconductor materials for future power electronics. Owing to ultra-high theoretical critical field strength ~ 8 MV/cm of β-Ga_2O_3, β-Ga_2O_3 can have a higher power switching capability with high efficiency. 4-inch-diameter single crystal β-Ga_2O_3 wafer can be produced using melt-growth techniques such as edge-defined film-fed growth, which is a noticeable advantage in terms of economical mass production of power electronics.[3] In the case of β-Ga_2O_3, successful p-type doping and effective hole conduction in β-Ga_2O_3 have not been reported to date. The difficulty in p-type doping is a crucial issue which limits applications of β-Ga_2O_3 in practical devices such as JFETs.

The monoclinic structure of bulk β-Ga_2O_3 crystals allows being exfoliated into ultra-thin flakes in the (100) direction even though β-Ga_2O_3 is not a van der Waals force 2D materials.[4] The exfoliated β-Ga_2O_3 flakes can be easily integrated with various substrate and materials to demonstrate novel (opto) electronic applications. We made a β-Ga_2O_3 -SiC heterojunction p-n diode and JFETs by integrating mechanically exfoliated n-type β-Ga_2O_3 flakes and p-type SiC substrates. The fabricated Ga_2O_3 - SiC heterojunction p-n diode shows good static rectification characteristics. The p-type SiC was utilized as a gate in the β-Ga_2O_3 n-channel JFET, while the n-type β-Ga_2O_3 was utilized as a gate in the SiC p-channel JFET. Both of β-Ga_2O_3 n-channel JFET and SiC p-channel JFET showed electrical characteristics with good air stability. This heterojunction based wide-band-gap nanodevice shows new opportunities for novel high-power nanoelectronic devices. More details of our work will be discussed in the presentation.

References

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Figures

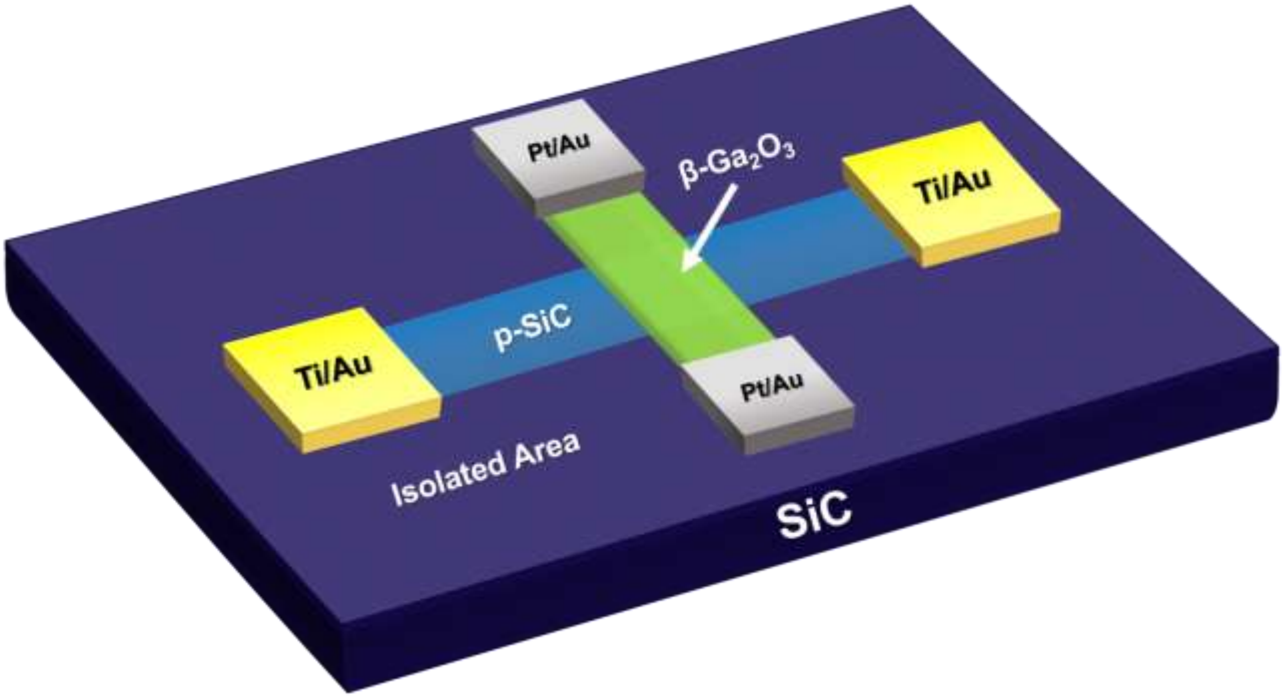

Figure 1: Schematic of junction field effect transistor based on Ga_2O_3-SiC p-n heterojunction