Interface Structures and Electrical Properties of Epitaxial Ca-Digermanide/n-Ge (111) Contacts

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Introduction

Germanium (Ge), which is a group-IV semiconductor, is a promising channel material for high performance advanced CMOS because of their higher electron and hole mobilities. However, reducing the contact resistance of metal/*n*-Ge interface is still a foremost issue owing to the strong Fermi level pinning phenomenon at the valence band maximum edge of Ge [1], which causes a quite large Schottky barrier height (SBH) at the metal/*n*-Ge interface.

To reduce SBH, some approaches have been proposed e.g., interlayer insertion [1], epitaxial interface [2], and Van-der-Wals interface [3]. Among them, we have addressed epitaxial metal-germanide/*n*-Ge contact with using a lower work function metal. Previously, we demonstrated a significant SBH reduction in epitaxial-$HfGe_2$/*n*-Ge(001) contact, and suppressing strain relaxation may be effective for the further SBH reduction until to 0.31 eV [4].

Toward the further SBH reduction, in this study, we focused on $CaGe_2$ because $CaGe_2$ shows a lower work function, and the smaller lattice mismatch to Ge (~1.4 %) than $HfGe_2$. The epitaxial growth of $CaGe_2$ on Ge(111) has been already developed in other studies [5]. However, the device fabrication using $CaGe_2$ is beset due to its structural instability to atmosphere exposure and water immersion. In this study, we proposed the fabrication method of Schottky barrier diodes (SBDs) of $CaGe_2$/*n*-Ge(111) contact and discussed their electrical properties featuring the impact of the interface quality.

$CaGe_2$ growth and SBDs fabrication

First, *n*-Ge(111) wafer (resistivity of 7.9 Ω·cm, impurity concentration of ~10^{15} cm^{-3}) was prepared as a substrate. After chemical cleaning of a diluted HF (~1%) solution and deionized water, a 20-nm-thick $CaGe_2$ layer were epitaxially grown by solid source molecular beam epitaxy method at various growth temperatures, T_g of 520–620 °C. As a reference, an amorphous $CaGe_2$ layer was also prepared at T_g of room temperature (RT). The sample was taken out and immediately introduced into Al evaporation chamber. Then, blanket Al layer was deposited by vacuum evaporation method as a cap layer. Subsequently, circle shaped patterns were formed by photolithography and chemical etching of Al and $CaGe_2$ layers by diluted HF (~1%) and H_2O_2, respectively. Finally, Al backside electrode was also formed by vacuum evaporation method.

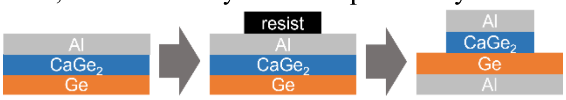

Figure 1: Schematics of SBD fabrication process.

Results and discussions

Figure 2 shows the current density-voltage (*J*–*V*) characteristic of the fabricated SBDs measured at RT. Note the result of the sample without $CaGe_2$ layer was also shown as a reference. Al/*n*-Ge(111) and Al/amorphous-$CaGe_2$/*n*-Ge(111) SBDs showed clear Schottky properties with a reverse current density of 10^{-2} A/cm^2 at voltage of −1 V. On the contrary, we can observe a clear increase in a reverse current density by introducing epitaxial $CaGe_2$ layer, inferring the SBH decrease.

Furthermore, we found that T_g increase results in much increase in a reverse current density and Ohmic characteristics were obtained in T_g of 580 and 620 °C. For the sample with T_g of 560 °C, SBH value was estimated to 0.17 eV via the temperature dependence of *J*–*V* characteristics. This is much lower than our previous study of $HfGe_2$/*n*-Ge(001) contact; 0.31 eV. Although the fabricated SBDs still include leakage currents, the obtained results would support the concept for the SBH reduction to use the epitaxial contact using a low work function metal. In the presentation we will also discuss linkage between SBH reduction and interface quality of $CaGe_2$/*n*-Ge contact.

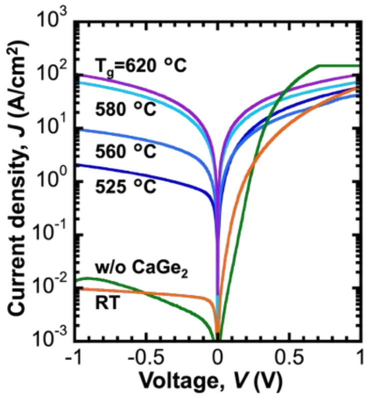

Figure 2: *J*–*V* characteristics measured at RT for the Al/$CaGe_2$/Ge/Al SBDs.

Conclusion

This study explored the electrical characteristics of $CaGe_2$/*n*-Ge(111) contact. We obtained Ohmic characteristics for the sample grown at higher T_g. The results obtained in this study would support the concept for the SBH reduction to use the epitaxial contact using a low work function metal.

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References

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