Schottky diode characteristics at metal/surface-damaged Ge

Effect of Ge surface damages on Fermi-level pinning

SBH for n-substrate is generally described by $\Phi_{bn} = S(\Phi_M - \chi) + (1 - S)\Phi_{CNL}$, in which $S$ and $\Phi_{CNL}$ are the pinning parameter and charge-neutrality level (CNL). Ge surface modification should affect both $S$ and $\Phi_{CNL}$. In addition, $\chi$ might also be affected. In the present experiment, Ge surface was modified by Ge ion implantation (acceleration voltage of 100 kV and dose of $1 \times 10^{13}$/cm$^2$), followed by annealing at various temperatures. Fig. 1 shows I-V characteristics of Al/implanted Ge annealed at various temperatures. With an increase of annealing temperature, the reverse leakage current is lowered. This fact means the Schottky diode characteristics are surely affected by the surface quality of Ge.

A couple of points should be noticed. (i) Implanted Ge surface including cases with implanted dopants (P, As, Sb or B) may be different from the initial single crystalline Ge surface even after 625°C anneal. The contact resistance at metal/Ge may not be simply described by the conventional formula [2]. (ii) The remaining defects may change the CNL at the surface. The ohmic characteristic is, however, not observed even in the relatively higher annealing temperature case. It means that the ohmic behavior obtained experimentally [3, 4] is not due to the defect annihilation but due to an intrinsic Fermi-level pinning alleviation. (iii) Advanced methods such as double implantation / laser annealing to enhance the dopant activation should be carefully discussed from the viewpoint of remaining defects and/or imperfect crystallinity. (iv) It should be careful in case of metal deposited by sputtering or ion-beam processes on Ge, because the surface damages on Ge are not easily annihilated.

This view is also supported by the imperfect recovery of the peak FWHM in Raman measurement of Ge-implanted surface (Fig. 2) [5].

Conclusion

Ge-implanted Ge surface shows high reverse leakage current even after thermal annealing. This fact suggests that the FLP on the ion-damaged Ge surface should be carefully considered from extrinsic viewpoints of defect-mediated conduction rather than the change of $S$ or $\Phi_{CNL}$.