Student Paper

Hole Mobility Calculations in Strained SiGe PMOSFETs

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SiGe channel under strain for increased mobility has attracted much attention for potential use in next generation CMOS (Complementary Metal Oxide Semiconductor) technology [1]. Due to the enhanced mobility of strain engineering, the Ge content in the channel with strain is a worthy expectable technology. Ultra thin epitaxially-grown SiGe (epi-SiGe) on Si with compressive strain has the advantages of high mobility, low cost, and compatibility with current Si manufacturing processes. Higher Ge concentrations in the SiGe channel have been reported on Si (100), (110), and (111) with 200 %, 200%, and 110 % hole mobility enhancements, respectively [2-4]. However, the substrate orientation and carrier transportation direction should be optimized for mobility enhancement. In this work, we use a 6-band k•p approach to describe the SiGe valence band structure [5] that includes the impact of spin orbit interaction and strain. A full band approach is essential for hole transport in order to properly capture the warped nature of the valence band and the resulting influence on hole mobility. We have calculated the hole mobility for SiGe PMOSFETs by using the Momentum Relaxation Time (MRT) approximation according to the Kubo–Greenwood formulation [5]. The scattering mechanisms included in our calculations are the acoustic and optical phonons, the surface roughness scattering, alloy scattering. Our calculation reproduces experimentally measured low field mobility in bulk Si and Ge PMOSFETS. For the alloy-scattering potential, a wide range of values between 0.2 and 1.0 eV has been reported in the literature. In this paper, U_{alloy} = 0.7 eV is chosen. Figs. 1-6 show hole mobility as a function of Ge mole fraction for different wafer orientations and channel directions. We found that the (110)/[110] configuration for SiGe (110) PMOSFET with Ge content of 100% yields the highest mobility enhancement. In summary, we have used a Kubo–Greenwood mobility formula to study the hole mobility performance in a p-channel SiGe PMOSFET. The models used in the calculations have been validated against experimental data. Calculations have then been used to consider the impact of SiGe materials, alloy scattering and biaxial compressive strain owing to (001), (110), and (111) Si substrate orientation on the hole mobility performance to give an indication of the potential performance of this potential PMOSFET.

References

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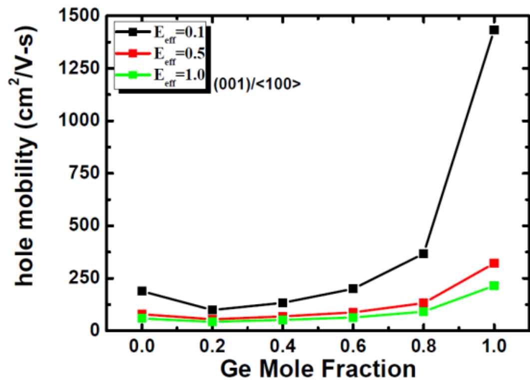

Fig. 1 Hole mobility as a function of Ge mole fraction for SiGe PMOSFET along <100> channel direction and (001) wafer orientation. Note that unit of E_{eff} is MV/cm.

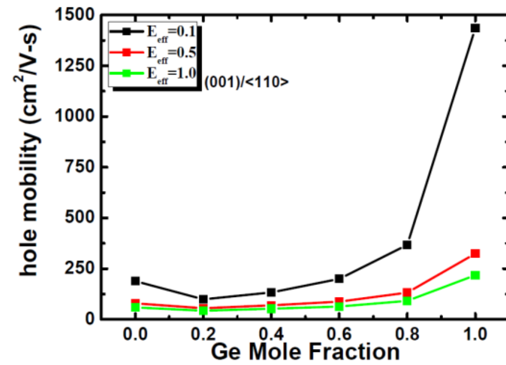

Fig. 2 Hole mobility as a function of Ge mole fraction for SiGe PMOSFET along <110> channel direction and (001) wafer orientation. Note that unit of E_{eff} is MV/cm.

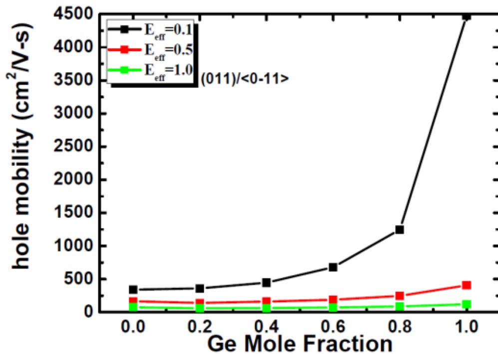

Fig. 3 Hole mobility as a function of Ge mole fraction for SiGe PMOSFET along <0-11> channel direction and (011) wafer orientation. Note that unit of E_{eff} is MV/cm.

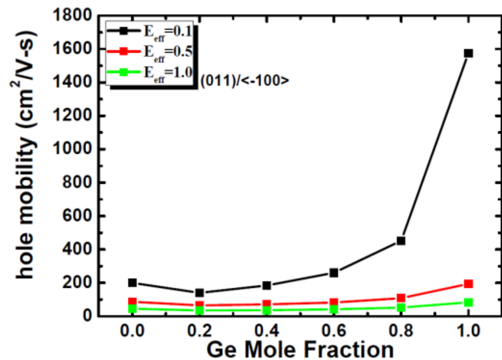

Fig. 4 Hole mobility as a function of Ge mole fraction for SiGe PMOSFET along <-100> channel direction and (011) wafer orientation. Note that unit of E_{eff} is MV/cm.

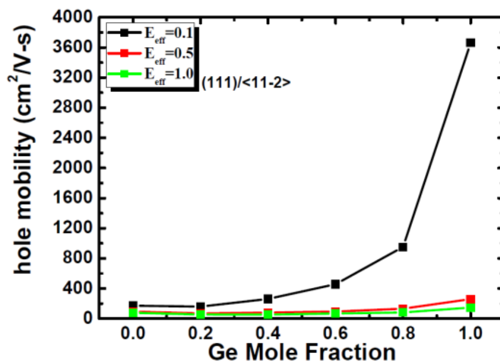

Fig. 5 Hole mobility as a function of Ge mole fraction for SiGe PMOSFET along <11-2> channel direction and (111) wafer orientation. Note that unit of E_{eff} is MV/cm.

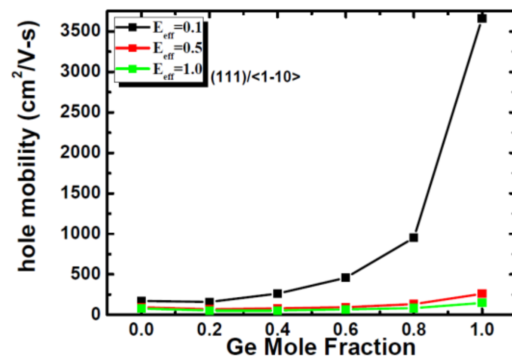

Fig. 6 Hole mobility as a function of Ge mole fraction for SiGe PMOSFET along <1-10> channel direction and (111) wafer orientation. Note that unit of E_{eff} is MV/cm.