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New Strained SOI Fabricated By Laser Annealing Technology

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Introduction

Strained SOI MOSFETs are attractive devices for small sized devices and low power CMOS because of the high electron and hole mobilities, the low parasitic capacitance and the steep swing. SIMOX technology[1)], Ge condensation technology[2)] and a wafer bonding and etch back method[3, 4)] have all been proposed as strained SOI fabrication technologies. However, these technologies need high temperature annealing and more complex processes. Therefore, we wanted a more conventional strained-Si SOI structure process.

In this paper, we propose a new strained SOI fabrication process using a laser annealing technology. We confirmed that laser annealing can relax the strain of the SiGe on SOI. The strained Si on SiGe/SOI (SGSOI) can enhance the electron mobility of NMOSFETs at about 180% compared with unstrained Si on SiGe/SOI.

Experiment

Figure 1 shows the fabrication process for the strained SOI structure. We used conventional SOI wafers with a 400 nm of buried oxide. The SOI layer was thinned by thermal oxidation and wet etching down to ~10 nm (I). First, the strained $Si_{1-X}Ge_X$ (X = 0.2 - 0.25) layer with 40-50 nm thickness was grown on SOI substrate (GSOI) using UHV-CVD (II). Next, a XeCl excimer laser beam with λ=308 nm was irradiated on the SiGe surface at room temperature (III). The temperature of the SiGe/Si layers on insulator rose to over 1000 °C for several 10 ns because of the pulse-duration of about 40 ns[5)]. The pulse heating process using a ultra-violet beam is effective for raising the temperature of thin films on insulator. After that, a 20 nm thick strained Si layer was re-grown on the SiGe layer (SGSOI) using UHV-CVD (IV). Raman spectra, SIMS profiles and TEM photographs were investigated to confirm the strained-Si/relaxed SiGe/Si on insulator (SGSOI) structures. The field effect mobilities for NMOSFETs were also studied to confirm the effect of strained-Si by comparing with and without laser irradiation. The gate oxide of SiO_2 (50 nm) was used.

Results and discussions

1. Strained-Si /SiGe/Si on insulator structure

Figure 2 shows a comparison between Si-Si Raman spectra from 490 to 540 cm^{-1} for GSOI ($Si_{1-X}Ge_X$:x = 0.2) with and without laser annealing at 280mJ/cm^2. The Si-Si Raman peak of GSOI at 515 cm^{-1} moves to 510 cm^{-1} by laser annealing at 280mJ/cm^2. In fig. 3, we show the Si-Si Raman peaks of $Si_{1-X}Ge_X$(x = 0.2, 0.25)/ Si on insulator (GSOI) against laser power density. Laser power densities were changed from 0 to 280mJ/cm^2. Si-Si Raman peaks of GSOI gradually shifted to lower Raman shift side. This result shows that SiGe layer is relaxed by laser annealing. Figure 4 shows the Raman spectrum of SGSOI (x = 0.2) with laser annealing at 280mJ/cm^2. The spectrum is divided into three oscillations for strained Si, relaxed $Si_{0.8}Ge_{0.2}$ and Si substrate. The Si-Si peak position of the strained-Si on $Si_{0.8}Ge_{0.2}$ at 280mJ/cm^2 was 516 cm^{-1}. Figure 5 shows the Si-Si Raman peak of strained-Si of SGSOI against laser power density. Figure 5 is consistent with the result of fig. 3. Figure 6 shows the depth profiles of Ge for the SGSOI structures with and without laser annealing by SIMS. Both of the depth profiles of Ge in the interface between Si and SiGe layers are almost the same profile. Figure 7 shows TEM photographs of a cross sectional view of strained Si (20nm)/$Si_{0.8}Ge_{0.2}$ (40nm)/Si (10nm) on insulator with laser irradiation at 280mJ/cm^2. The Si and SiGe layers are fabricated uniformly. The insert shows TEM lattice images of the interface between the strained-Si and $Si_{0.8}Ge_{0.2}$ layers. The strained-Si layer has a high crystalline quality.

2. Electric properties

Figures 8 (a) and (b) show the comparison between I_D-V_D characteristics for unstrained and strained SOI MOSFETs. (a) is for $Si_{0.75}Ge_{0.25}$ and (b) is for $Si_{0.8}Ge_{0.2}$. The I_D in strained-Si NMOSFET has been enhanced compared to that in unstrained-Si NMOSFET. The magnitude of difference depends on the Ge contents and laser power densities. Figure 9 shows the laser power dependence of field effect mobilities. The mobility was deduced from g_{max} (transconductance). The mobility in strained-Si/ $Si_{0.75}Ge_{0.25}$/ SOI is approximately 180% larger than that of unstrained-Si/ $Si_{0.75}Ge_{0.25}$/ SOI. Figure 10 shows the relation of field effect mobilities and Si-Si Raman shift for strained-Si. This shows clearly that electron mobilities are enhanced by the strain in Si by laser annealing technology.

Conclusion

We have proposed a new fabrication technology for a strained SOI structure by laser annealing. We can control the relaxation of strained-$Si_{1-X}Ge_X$ /SOI by changing the laser power density. Strained SOI using this technology improved electron mobilities in NMOSFETs to 180% compared with unstrained-Si SOI. This technology is a low thermal budget and simpler process.

References

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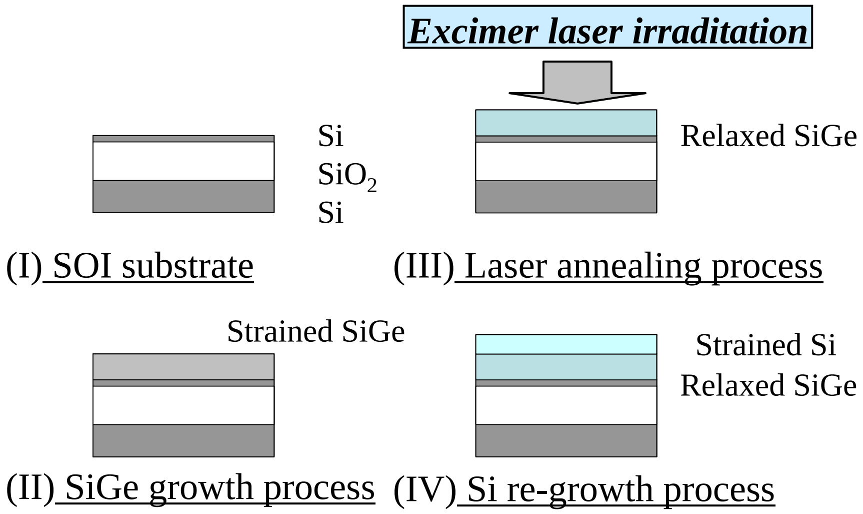

Fig.1: Process flow of strained Si/SiGe/SOI(SGSOI) structure.

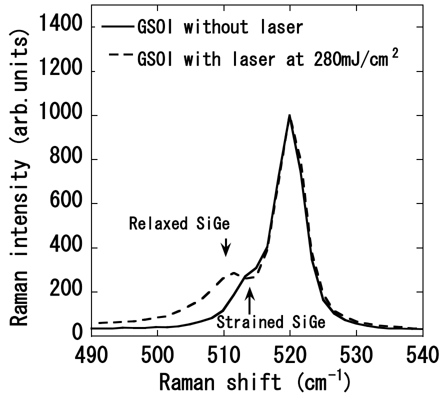

Fig. 2: Si-Si Raman spectra from 490 to 540 cm^{-1} for $Si_{1-X}Ge_X$/SOI (x=0.2)with and without laser irradiation.

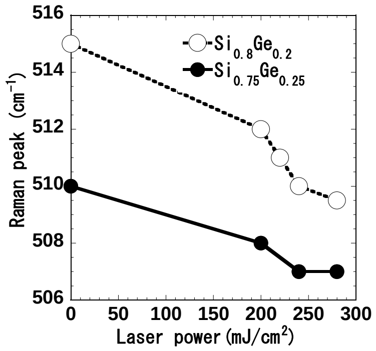

Fig. 3: Laser power dependence of Si-Si Raman peak for relaxed SiGe.

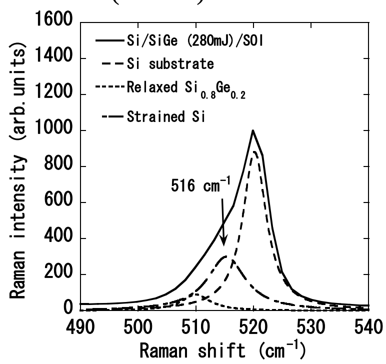

Fig. 4 Si-Si Raman spectrum for SGSOI with laser irradiation.

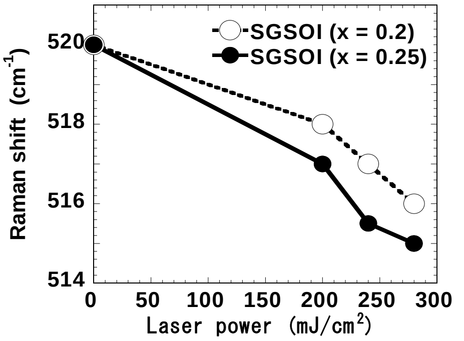

Fig. 5: Laser power dependence of Si-Si Raman peak for strained Si.

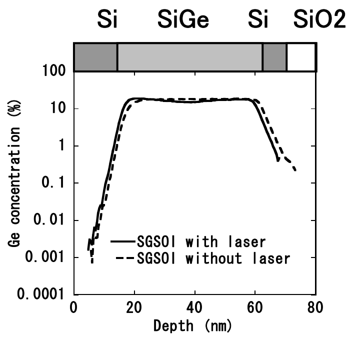

Fig. 6: Depth profiles of Ge for SGSOI.

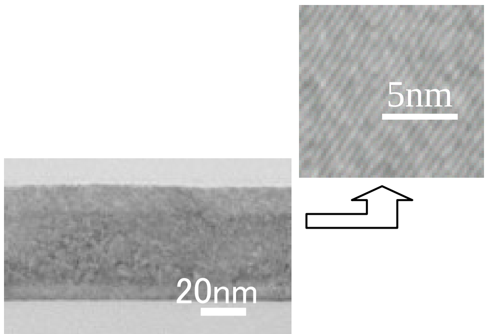

Fig. 7: TEM cross-sectional images and lattic image of strained SGSOI (x = 0.2).

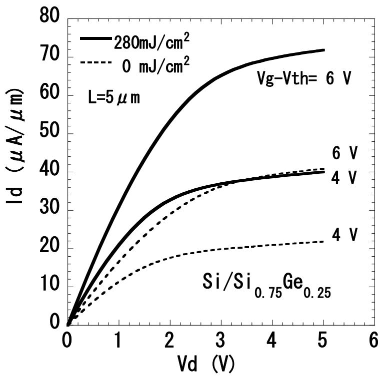

Fig. 8(a): Id vs. Vd characteristics of strained Si and unstrained Si NMOSFETs of SGSOI.(x=0.25).

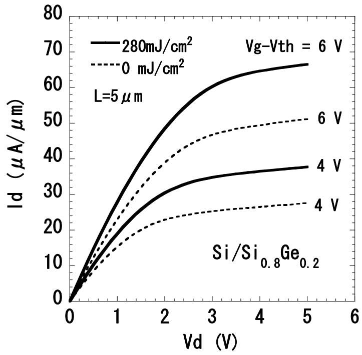

Fig. 8(b): Id vs. Vd characteristics of strained Si and unstrained Si NMOSFETs of SGSOI(x = 0.2).

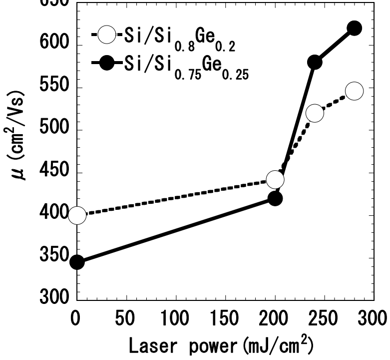

Fig. 9: Laser power dependence of field effect mobilities.

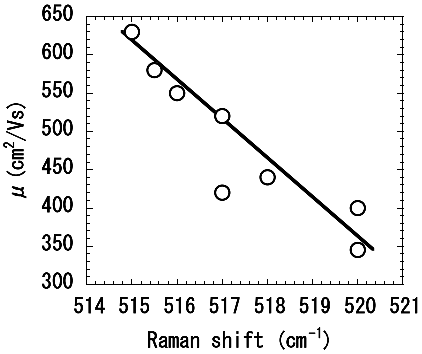

Fig. 10: Si-Si Raman peak for strained Si dependence of field effectmobilities.