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LC-3

Pronounced Enhancement of the Growth Rate in Lateral Solid Phase Epitaxy of Amorphous $Si_{1-x}Ge_x$ ($x \approx 0.05$) Films

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$Si_{1-x}Ge_x$ alloy is important for fabrication of future high speed devices such as heterojunction bipolar transistors and modulation-doped FETs with high hole mobility. Since an SOI (silicon-on-insulator) structure formed by lateral solid phase epitaxy (LSPE) of an amorphous Si (a-Si) film is suitable for fabrication of p-channel FETs in stacked CMOS devices[1], it is interesting to incorporate Ge atoms in the a-Si film for improving the performance of the FETs. Thus, in this paper, we investigate LSPE characteristics of amorphous $Si_{1-x}Ge_x$ films deposited on SiO_2/Si (100) structures with seed openings. So far, a few interesting results have been reported on vertical SPE of $Si_{1-x}Ge_x$ films on Si substrates[2,3]. However, to our best knowledge, no experimental results have been reported on LSPE of $Si_{1-x}Ge_x$ films.

$Si_{1-x}Ge_x$ films were formed by implantation of Ge ions into polycrystalline Si films about 220nm thick, which were deposited at 600°C on SiO_2/Si (100) structures with seed openings. The direction of seed stripes was [010] and their width was about 10μm. First, Si films were amorphized by 2-step implantation of 200keV and 300keV Si^+ ions to a dose of $2\times10^{15}cm^{-2}$. Then, in order to enhance the LSPE growth rate and the growth length, P ions were implanted to such doses that the maximum concentration in the films was about $3\times10^{20}cm^{-3}$[1]. These samples were used as the reference of x=0. Next, Ge ions were implanted with energies of 200keV and 300keV to form the $Si_{1-x}Ge_x$ films. The implantation doses of Ge ions were so adjusted that the x-value in the $Si_{1-x}Ge_x$ films were 0.05 and 0.1, except for the surface region. A typical profile of Ge atoms is shown in Fig.1. The samples were finally furnace-annealed in dry N_2 ambient for inducing LSPE. The annealing temperatures were 560°C and 580°C. The growth characteristics were observed with Nomarski optical microscopy.

Figure 2 shows typical optical micrographs of $Si_{1-x}Ge_x$ samples with x=0.05 and 0.1, which were annealed at 580°C for 40 minutes. The white area around the seed stripe corresponds to the LSPE region, while the black area remains as amorphous phase. We can see from these photographs that the average LSPE lengths under these conditions are about 10μm and 2μm for x=0.05 and x=0.1, respectively. We can also see from comparison with the reference sample of x=0 that the growth rate is much enhanced only in the sample of $Si_{0.95}Ge_{0.05}$. It is also interesting to note that the facet formation at the seed corner is much pronounced in the sample with x=0.05.

The LSPE growth characteristics of the $Si_{1-x}Ge_x$ films are summarized in Fig.3 and Fig. 4 for two annealing temperatures of 560°C and 580°C, respectively, where the horizontal axis shows the annealing time, and the vertical axis shows the growth length. The open diamond, closed squares, and closed circles in the figures correspond to the samples with x=0, 0.05, and 0.1, respectively. We can confirrm from these figures that the growth rate of the $Si_{0.95}Ge_{0.05}$ film is fastest and the growth length is longest. The maximum SPE length of the $Si_{0.95}Ge_{0.05}$ film is about 21μm at present and its growth rate is about 6 times faster than that of amourphous Si film at 580°C. We can also see that the growth in $Si_{0.9}Ge_{0.1}$ films stops for a few hours at a length about 2μm from the seed edge and it proceeds again for the longer annealing. The stopping period is longer at the lower temperature. Similar tendency can be observed even in the $Si_{0.95}Ge_{0.05}$ sample at 560°C. This phenomenon has never observed in LSPE of amorphous Si films. Thus, it may be explained either by accumulation of strain in the mixed crystal films or by pile-up of Ge atoms (snow plow effect). The maximum SPE growth length may be farther prolonged by optimizing the Ge composition, the annealing temperature, and so on.

In summary, LSPE characteristics of amorphous $Si_{1-x}Ge_{1-x}$ films are investigated. It has been found that the growth rate is much enhanced around the Ge composition of 0.05 and that the growth stops in midway when the Ge composition is too high. These phenomena may be explained either by a strain effect or by an impurity effect of Ge atoms.

< References >

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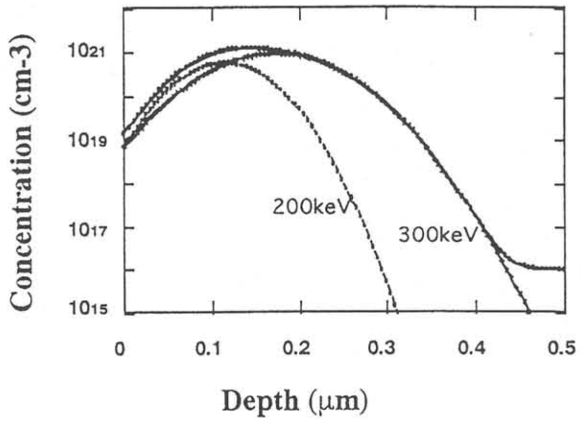
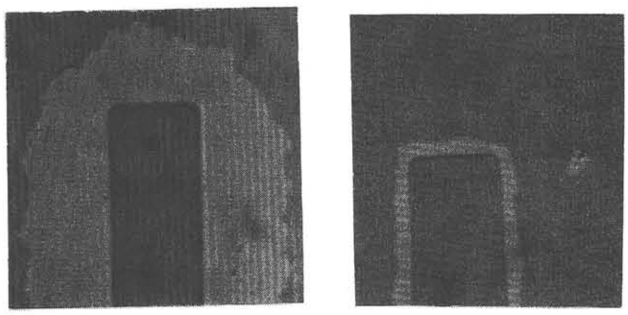


Fig.1 Ge atom profile in a $Si_{0.95}Ge_{0.05}$ sample.



(a) (b)

Fig. 2 Nomarski optical micrographs for the grown regions of the P-doped $Si_{1-x}Ge_x$ samples annealed at 580°C.
(a) x=0.05 (b) x=0.1

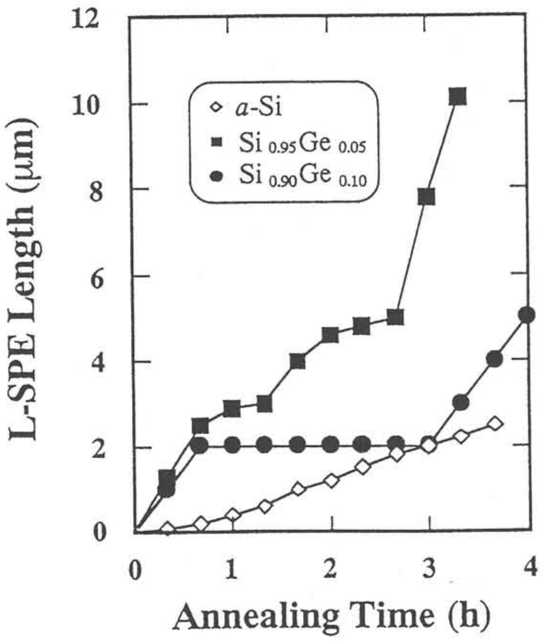


Fig.3 Annealing time dependence of the growth length for P doped $Si_{1-x}Ge_x$ LSPE samples at 560°C.

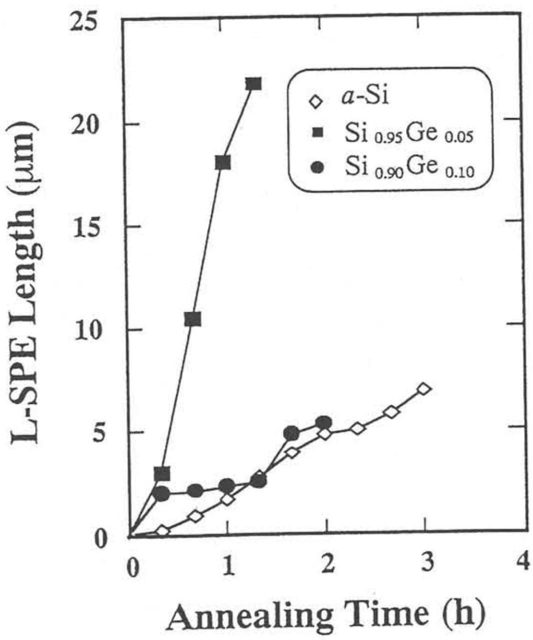


Fig.4 Annealing time dependence of the growth length for P doped $Si_{1-x}Ge_x$ LSPE samples at 580°C.