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REDUCTION OF ARSENIC DIFFUSION IN SILICON-GERMANIUM BY CO-IMPLANTATION.

Omer Dokumaci, Paul Ronsheim, Anda Mocuta, Dan Mocuta, Paul Kozlowski*, Dureseti Chidambarrao, Philip Saunders*, and Huajie Chen
IBM Semiconductor Research and Development Center (SRDC), Microelectronics Division , Hopewell Junction, NY 12533
* Research Division, T.J. Watson Research Center, Yorktown Heights, NY 10598

Strained silicon is a promising candidate for enhancement of mobility and performance in CMOS devices. One of the most popular ways of obtaining highly strained silicon is to grow silicon on top of relaxed SiGe. Integration of SiGe into CMOS presents profile engineering challenges, especially for heavily doped n^+ regions. For example, arsenic diffuses much faster in SiGe than in Si. This makes shallow junctions very hard to obtain in SiGe. Without shallow junctions, strained silicon devices built on relaxed SiGe can not be scaled down to sub-90 nm nodes. A need exists for a method that significantly reduces the diffusion of arsenic in SiGe.

Arsenic diffusion enhancement in SiGe is believed to be due to higher concentration of vacancies in SiGe than in Si. If an element creates defects which can then trap the vacancies, the co-implantation of that element should reduce arsenic diffusion in SiGe. Silicon implantation is known to create {311} defects below the amorphization threshold and dislocation loops above the amorphization threshold. {311}'s and dislocation loops have the ability to trap vacancies. Argon is known to create bubbles and voids in silicon which can also trap vacancies. Oxygen, on the other hand creates oxygen precipitates in silicon which inject excess interstitials. These excess interstitials can recombine with vacancies and reduce the concentration of vacancies available for arsenic diffusion. Because of these qualities, these three species were selected for co-implantation with arsenic in SiGe.

The starting wafers were 26% SiGe on insulator (SGOI). A thin layer of silicon was grown epitaxially on top of SiGe. After a 35A thick oxide was grown, the wafers were implanted with 3 keV As at a dose of 1.2e15. Then, Ar, Si or O was implanted at doses ranging from 2e14 to 1e16 cm^{-2}. The energies were chosen such that these implants had similar projected ranges and were deeper than the arsenic implant. After a protective oxide layer was deposited, annealing was done in an RTA chamber at 1000°C for 5s.

Fig.1 shows the arsenic profiles with and without silicon co-implants. A low dose silicon implant does not significantly change the arsenic profile although it should create {311} defects and dislocation loops. On the other hand, higher doses of silicon reduce arsenic diffusion significantly, probably because of a much higher density of dislocation loops.

Fig.2 shows the effect of Ar co-implants on As diffusion. All Ar co-implants significantly reduce the diffusivity of arsenic. The lowest dose of 8e14 is most effective in retarding As diffusion. The dependence of diffusivity reduction on dose suggests that even a lower Ar dose may be used to suppress As diffusion. Ar implants are also more effective in reducing As diffusivity than Si implants.

Fig.3 shows the effect of oxygen co-implants on As diffusion. All oxygen co-implants retard As diffusivity, but the higher doses are much more effective than the lowest dose. The behavior of oxygen is similar to silicon in that a very high dose of oxygen is needed to significantly suppress As diffusion. On the other hand, oxygen seems more effective in retarding As diffusion than silicon.

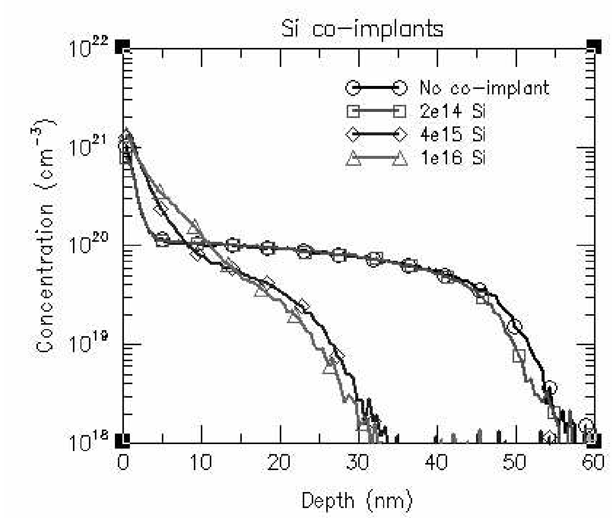

Fig.1: As profiles with and without silicon co-implants.

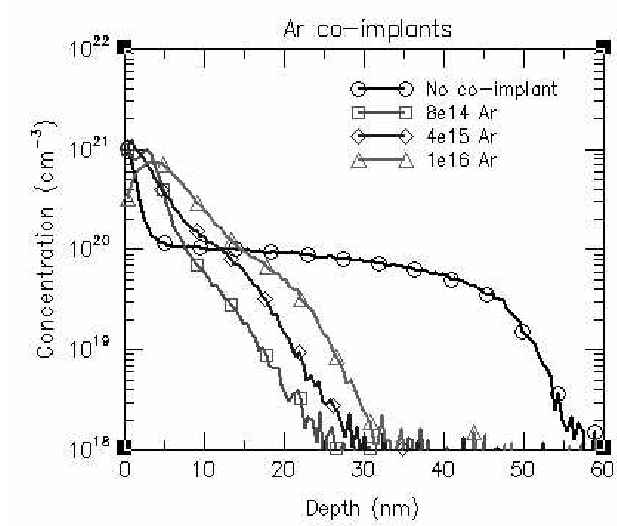

Fig.2 : As profiles with and without argon co-implants.

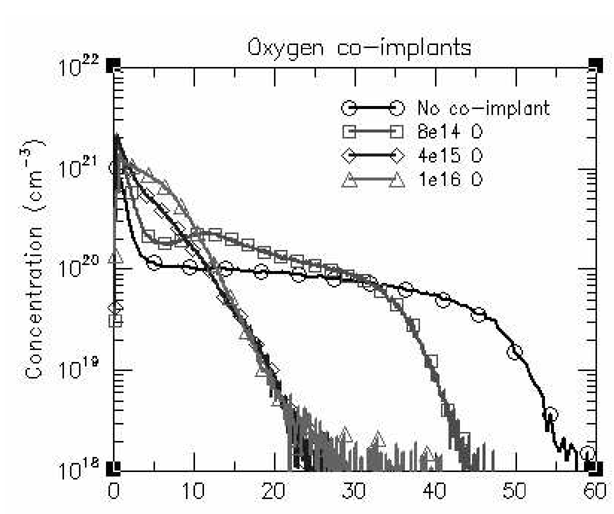

Fig.3 : As profiles with and without oxygen co-implants.