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LASER INDUCED REDISTRIBUTION OF ION IMPLANTED AND SURFACE DEPOSITED B IN SILICON: A SIMS STUDY*

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1. Introduction

Recently, it has been shown that high powered pulses of laser radiation can be used to anneal ion implanted silicon [1]. Changes in the implant dopant profile as a result of laser annealing provides fundamental insight into the laser annealing mechanism. Consequently, we have used secondary ion mass spectrometry (SIMS) to investigate the effect of laser annealing on the distribution of ion implanted and surface deposited boron in single crystal silicon.

2. Experimental

To facilitate SIMS depth profiling, the samples were cut into chips approximately 2 mm on a side. The individual specimens were ultrasonically solvent cleaned, affixed to a flat conducting sample mount and overcoated with 20-30 nm of spectrographic grade carbon. The primary beam used was O_2^+ at 16.0 keV impact energy, 15×10^{-9} A beam current and a 5 μm beam diameter. The beam was raster scanned and $^{11}B^+$ sputtered ions were detected from the central 10-15% of the rastered area using an electronic aperturing technique. Depth and concentration scales were established by profiling ion implantation standards prepared at 35 keV energy at doses of 10^{14}, 10^{15} and 10^{16} ^{11}B atoms cm^{-2}. Laser annealing was carried out in air using the output of a Q-switched ruby laser (λ = 0.694 μm, 60 ns pulse duration).

3. Results and Discussion

The result of laser annealing (1.6 J cm^{-2}, 60 ns) silicon implanted to different boron dose levels in the range 10^{14} to 10^{16} cm^{-2} is shown in Fig. 1. The as-implanted profiles are shown to establish the depth and concentration scales. The extent of boron migration and the shape of the final profile is almost the same for crystals implanted to 10^{15} and 10^{16} cm^{-2}, but is somewhat less at a dose of 10^{14} cm^{-2}. The increased redistribution at doses of 10^{15} cm^{-2} and greater is believed related to more efficient absorption of laser light due to increased damage and/or dopant concentration in these crystals. The absorption coefficient at the ruby wavelength is a strong function of the damage in silicon crystals, being about an order of magnitude higher in amor-

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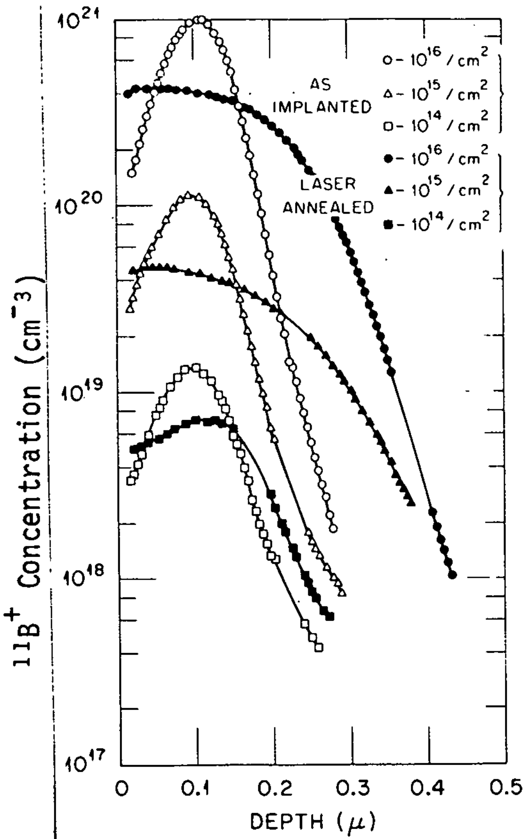

FIG 1. BORON PROFILES IN SILICON IMPLANTED TO DIFFERENT DOSES.

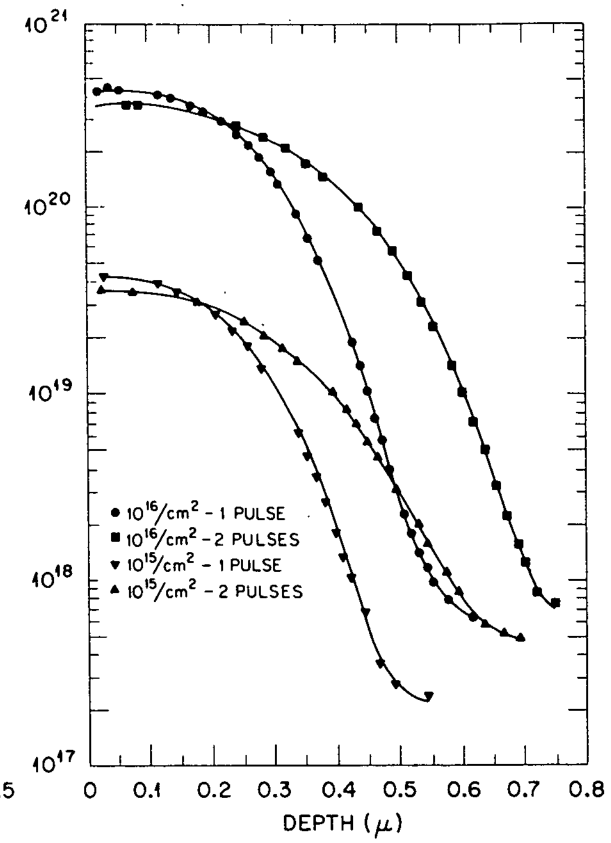

FIG 2. BORON PROFILES IN SILICON AFTER ANNEALING WITH SUCCESSIVE LASER PULSES.

phous silicon as compared to single crystal silicon. In addition, the dopant concentration should increase the absorption coefficient due to free carrier absorption [2]. Integration of the profile peak areas for the as-implanted samples and the corresponding laser annealed samples indicates that no appreciable boron is lost from the silicon during the laser annealing process.

Figure 2 shows the relationship of the dopant profile on the number of successive laser pulses. This is illustrated for silicon implanted with boron to doses of 10^{15} and 10^{16} cm^{-2} and annealed with one and two successive laser pulses (1.7 J cm^{-2}, 60 ns). Most of the redistribution takes place during the first pulse, but additional redistribution is observed during the second pulse. A third pulse produced no significant further broadening of the profile. These results show that the crystal can be remelted after the first laser pulse. This may occur due to increased free carrier absorption by the implanted dopant. Calculations [3] show that for pure single crystal silicon the absorption is too low for melting to occur under these conditions.

Another application involves the use of laser irradiation to form large area p-n junctions in silicon by a process of laser induced diffusion [4]. For this application, the dopant is deposited on the surface as a film approximately 100 Å thick by evaporation. The deposited surface is then irradiated with pulsed laser light and during the time the near surface region is melted, the deposited dopant diffuses into the crystal and is made electrically active by being incorporated into substitutional lattice sites. The profile of boron obtained after laser irradiation of boron deposited silicon is given in Fig. 3 and shows the penetration of boron to a depth of several thousand angstroms. This appears to be a very attractive method for fabricating shallow p-n junc-

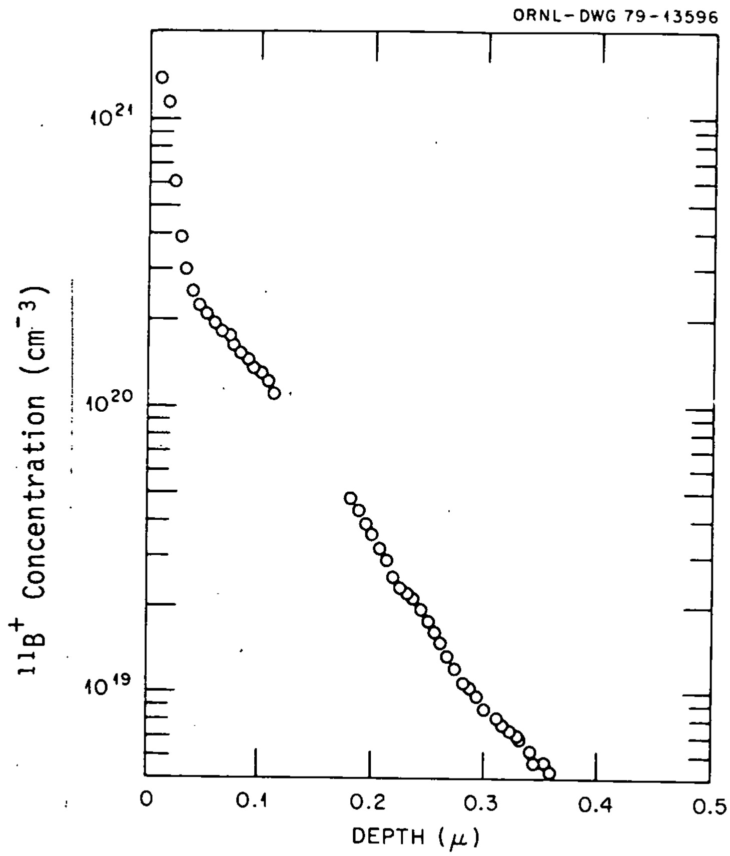

Fig. 3 Profile of boron deposited silicon after laser annealing

tions because the depth of melting and subsequent dopant diffusion can be carefully controlled by the laser energy density.

4. Conclusions

SIMS investigations have shown that pulsed laser annealing of ion implanted and surface deposited silicon leads to significant dopant redistribution. Comparison of calculated profiles to SIMS determined profiles provides strong evidence that the laser annealing mechanism involves melting of the crystal, diffusion of dopants in liquid silicon, followed by epitaxial regrowth [5].

References

1. R. T. Young, C. W. White, G. J. Clark, J. Narayan, W. H. Christie, M. Murakami, P. W. King and S. D. Kramer, Appl. Phys. Lett., 32, 139 (1978).

a. A. A. Grinberg, R. F. Mekhtiev, S. M. Ryvkin, V. M. Salmanov and I. D. Yaroshetskii, Sov. Phys.-Solid State 9, 1085 (1967).

3. R. F. Wood, private communication.

4. J. Narayan, R. T. Young, R. F. Wood and W. H. Christie, Appl. Phys. Lett., 33, 338 (1978).

5. J. C. Wang, R. F. Wood, and P. P. Pronko, Appl. Phys. Lett., 33, 455 (1988).