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LATTICE LOCATION AND ELECTRICAL BEHAVIOUR OF GROUP III AND V ELEMENTS IMPLANTED INTO SILICON

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ABSTRACT

Lattice location experiments were made during isochronal anneals on As, Sb and Ga implanted silicon with Rutherford backscattering and channeling techniques. A reverse annealing effect was found for As between 700 and 800°C. The high substitutional component of Sb found at 700°C decreases with increasing anneal temperature. In diffused tails practically all Sb atoms occupied substitutional lattice sites. For Ga implants no attenuation was found up to 800°C.

АННОТАЦИЯ

Были исследованы положения внедренных атомов As, Sb и Ga в кристаллических решетках кремния в зависимости от температуры отжига. Измерения проводились с помощью обратного рассеяния ионов и использовался метод основывающийся на эффекте каналирования. Для атомов As, при температуре отжига 700-800 °С наблюдалось явление "отрицательного отжига". В случае атомов Sb,при температуре отжига 700°С показывается большое значение замещающего компонента, которое уменьшается с ростом температуры отжига. Часть атомов сурьм, диффундирующих внутри кремния занимает практическо вся замещающее положение в кристаллической решетке. Для атомов Ga до температуры отжига 800°С ни замещающие ни междоузельные компоненты примесей не наблюдались.

KIVONAT

Si-ba implantált As, Sb és Ga atomok rácshelyekre történő elhelyezkedését vizsgáltuk Rutherford visszaszórásos analizis és csatornahatáson alapuló technika segitségével. A minták hőkezelése izokron módon történt. As esetén 700-800°C között "reverse annealing" jelenséget észleltünk. Sb esetén 700°C-nál a szubsztituciós komponens értéke nagy. A hőkezelési hőmérséklet növelésével ez az érték egyre csökken. A diffundált Sb atomok gyakorlatilag teljes mértékben szubsztituciós rácshelyeket foglalnak el. A Ga atomok 800°C-ig sem szubsztituciós, sem szabályos intersticiális helyeket nem foglalnak el.

In early works on lattice location of group III and V elements implanted into silicon [1,2,3] some basic phenomena were described. It was concluded that group V elements are closer to the expected behaviour, while group III elements show more pecularities /e.g. replacement mechanism during annealing/.

Lattice location experiments during an isochronal annealing were made on As, Sb or Ga implanted silicon for different fluxes during implantation. Fluxes of 0.1 and 1.0 or 4.5 $\mu A/cm^2$ were applied. The substrates were held at room temperature during implantation. Annealing was carried out in dry argon atmosphere using 30 min anneals at each temperature.

Backscattering experiments were made on a 5 MeV Van de Graaff accelerator with 1.5 MeV He^+ ions. Ortec surface barrier detector and standard Ortec electronics were used with a goniometer and an on-line multichannel analyser. Spectra were taken in random and aligned crystals in <111> and <110> directions. Investigating the lattice location of the species, the corrected attenuation /A/ in the impurity spectrum is given by

$$A = 100 \frac{A_r - A_a}{A_r / 1 - \chi_{min} /} \quad \text{per cent,}$$

where A_a is the channeled yield in the impurity peak, A_r is the random yield in the impurity peak and χ_{min} is the smallest ratio of aligned to random yields. The attenuation A is the percentage of impurity atoms lying along the atomic rows aligned with the analysing beam [3].

If values of A are close to unity and are at the same time equal in <111> and <110> directions, A gives the percentage of substitutional atoms [1]. If the attenuation is higher along the <111> than the <110> directions, this indicates that some of the implanted atoms are on tetrahedral interstitial sites.

In Figs. 1-6 the annealing of the disorder and corrected attenuations are displayed as a function of isochronal annealing for different fluxes during implantation and for different implantation energies. The total number of substrate atoms removed from lattice sites during implantation, computed by using the data of Ziegler et al. [4], is also given in the figures.

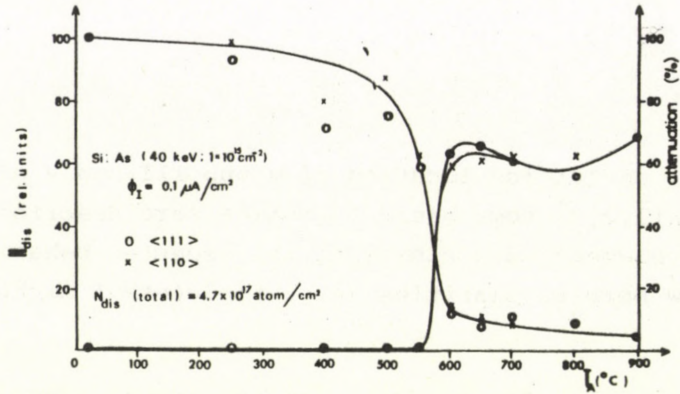

Fig. 1.

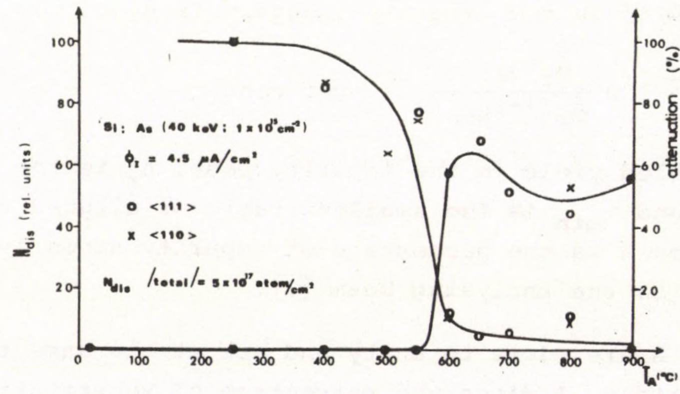

Fig. 2.

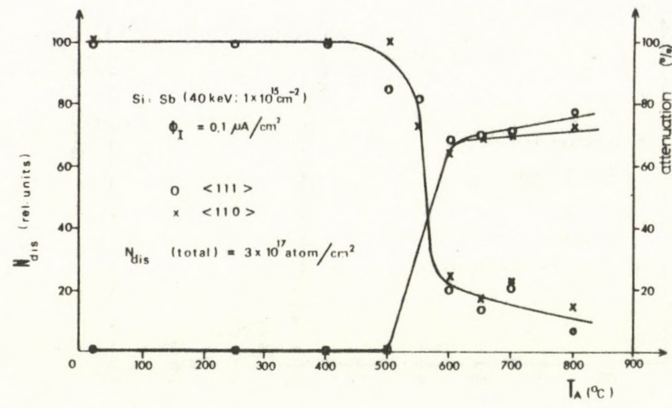

Fig. 3.

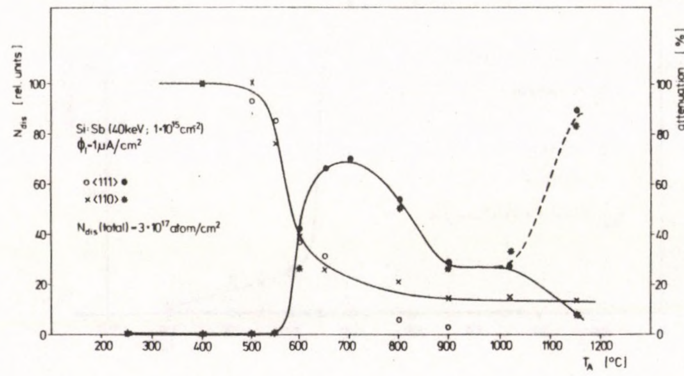

Fig. 4.

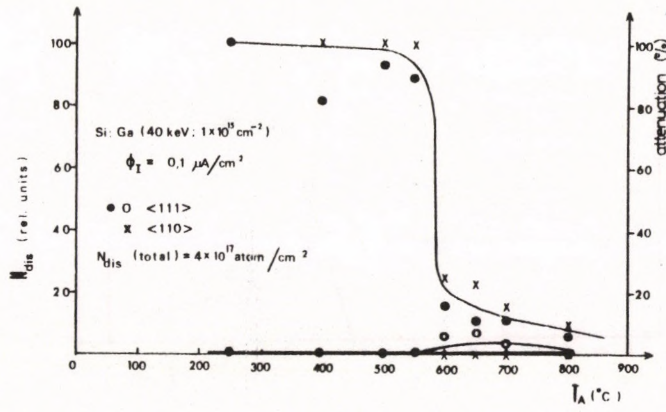

Fig. 5.

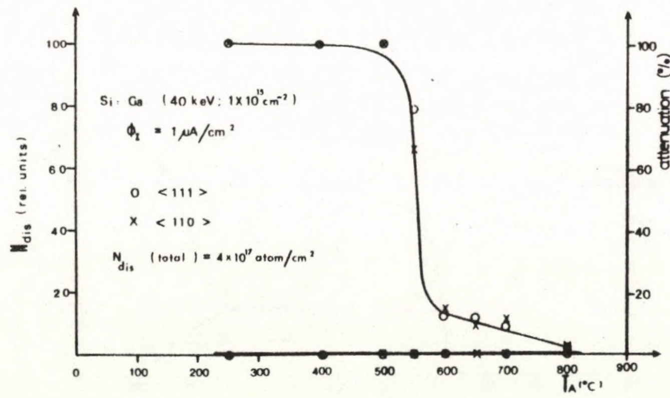

Fig. 6.

Besides lattice location experiments, some samples were investigated by electrical and infrared techniques. The infrared absorption on free carriers was measured as a function of isochronal annealing of 80 keV implanted As into silicon /Fig. 7/.

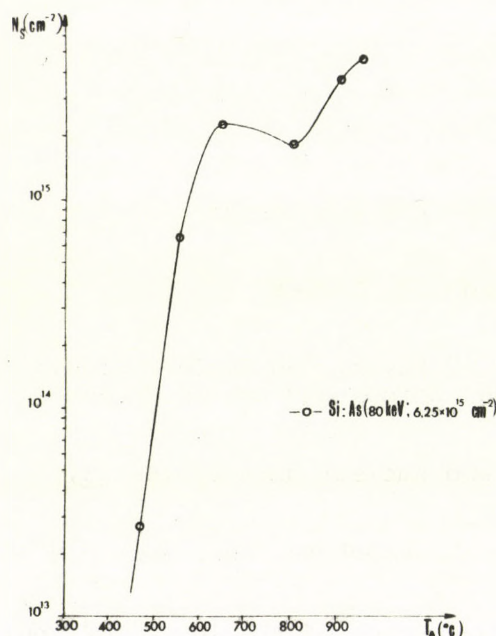

Fig. 7.

Results

The annealing of the disorder does not show any special features as compared to the results of previous investigators [2]. It is also clear that no appreciable flux dependence was observed for even a greater change in flux than one order of magnitude.

In the temperature range 700-800°C, the substitutional component of arsenic decreases indicating the existence of reverse annealing. This might be associated with the replacement mechanism between Si interstitials and arsenic dopants /Figs. 1-2/ [5]. The increase in substitutional level at higher temperatures may perhaps be interpreted as an enhanced recombination of interstitial arsenic with thermally activated vacancies. Reverse annealing was obtained also from infrared measurements at the temperature range of 700-800°C before reaching full electrical activity /Fig. 7/.

The annealing behaviour of Sb implants is shown in Figs. 3-4. In the case of 0.1 μA/cm^2 implant the <111> and <110> orientations have the same attenuation, therefore the antimony does not occupy tetrahedral interstitial lattice sites. Attenuation curve in Fig. 4 shows an appreciable substitutional component of Sb at 700°C anneal as reported earlier [6]. This portion decreases at higher anneal temperatures. At the highest temperatures, however, where diffusion takes place, the diffused part is fully substitutional, while for atoms still in the peak of the implanted distribution the attenuation decreases with increasing temperature.

The lattice location experiments on Ga doped silicon gave practically no substitutional component up to 800°C anneals /Figs. 5-6/. At higher

temperatures outdiffusion of Ga took place.

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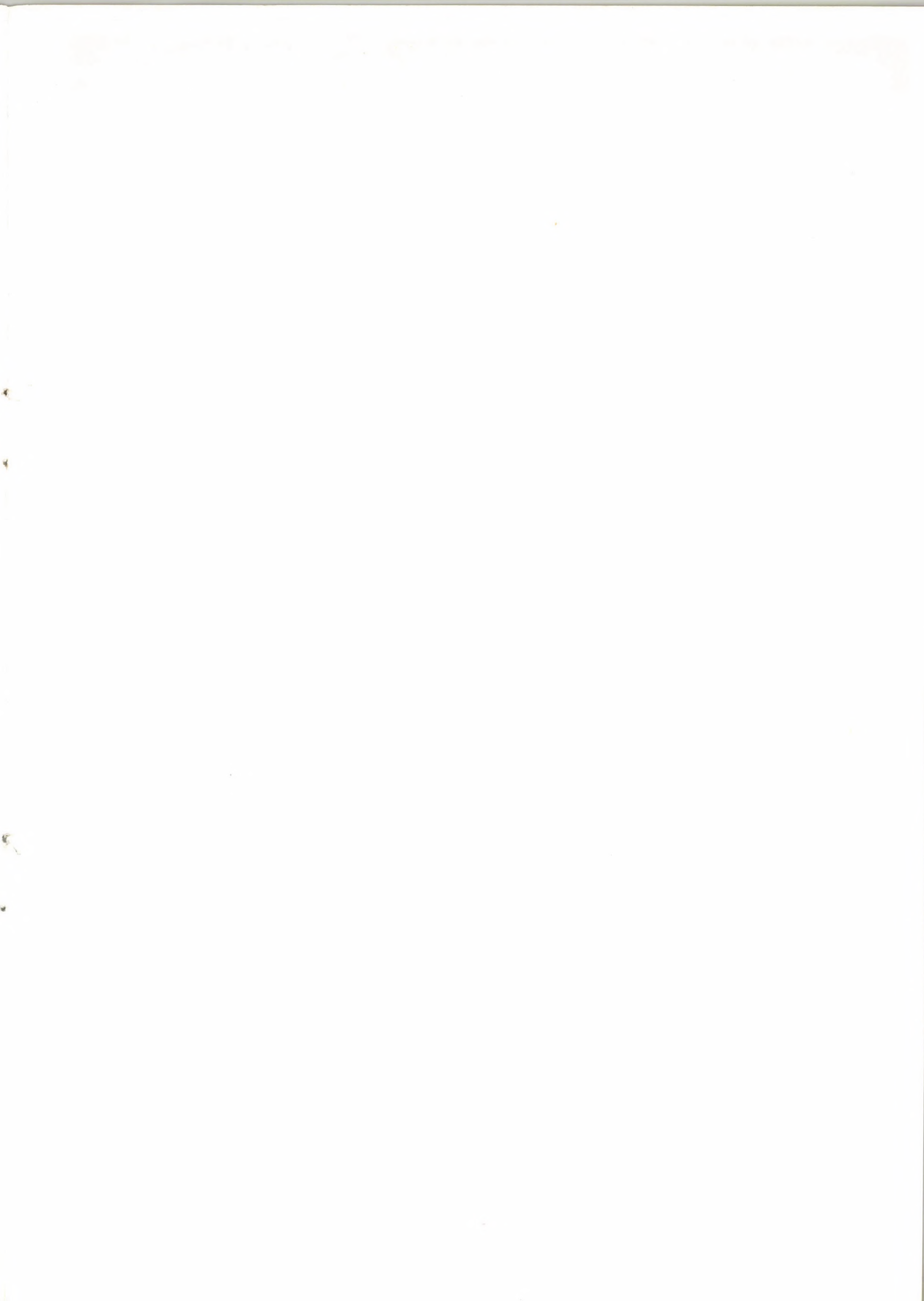

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