# Letters

Diffusion-induced dislocations in GaP

Dislocations are induced by the stress associated with lattice distortion when impurities with an atomic size different to those of the host atoms, are induced into the semiconductor [1–5]. The induced dislocation density increases with increasing difference of atomic size between the impurities and the host atoms, and the high impurity and vacancy concentrations promote the formation of dislocations [6].

In our work, the effects of phosphorus, added to the diffusion source, and diffusion temperature on diffusion-induced dislocation in GaP were studied. The specimen used was a (1 0 0) crystal grown on a pulled GaP substrate by vapour-phase epitaxy and doped with Te to a free carrier concentration of $1 \times 10^{17} \, \text{cm}^{-3}$. The specimen and the source materials were placed into a quartz ampoule in a vacuum of $2 \times 10^{-6} \, \text{Torr}$ and diffused at 700 to 1100° C. Both zinc and phosphorus source materials were of 99.9999% purity. For the electron microscope examination, the diffused specimens were thinned to about 1500 Å from the back surface of the specimen by an etchant of HCL:HNO_3 in a ratio of 1:2.

Typical electron micrograph of the diffusion-induced dislocations in GaP is shown in Fig. 1, and the measured average dislocation density was $7 \times 10^8 \, \text{cm}^{-2}$ in the case of an elemental zinc source. The induced dislocations tend to lie in the [1 1 0] directions, and a dislocation network was also
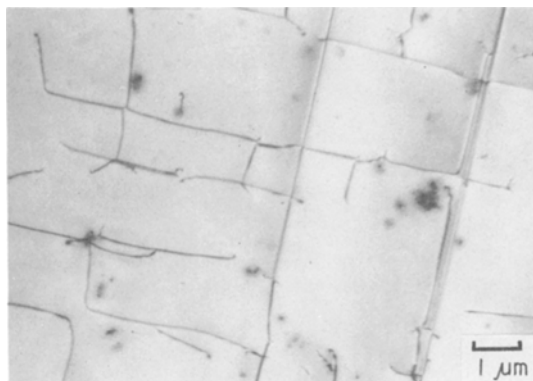
Figure 1 Diffusion-induced dislocations in GaP diffused with Zn at 850° C for 1 h. Zn: 0.2 mg cm⁻³.

Figure 2 Electron micrograph of GaP diffused with Zn and P sources at 850° C for 1 hr. Zn: 0.2 mg cm⁻³; P: 0.05 mg cm⁻³.

formed. The Burgers vectors of the dislocations were $a/2[1 \, 0 \, \bar{1}]$, $a/2[0 \, \bar{1} \, 1]$, and $a/2[\bar{1} \, 1 \, 0]$. An $a/2[1 \, 0 \, \bar{1}] + a/2[0 \, \bar{1} \, 1] + a/2[\bar{1} \, 1 \, 0] = 0$ reaction occurred at the dislocation nodes. In the case of an elemental zinc source, the dislocations were created by diffusion at a higher temperature than 800° C, but the creation of dislocations was repressed by the addition of phosphorus pressure.

Figure 2 shows an electron micrograph of the specimen diffused with 0.2 mg cm⁻³ zinc and 0.05 mg cm⁻³ phosphorus sources at 850° C. The diffusion-induced dislocations no longer observed by the electron microscopy. It is, therefore, estimated that the dislocation density in the specimen is lower than $10^5 \, \text{cm}^{-2}$.

By the addition of phosphorus, the activation energy of the zinc diffusion increased from 2.0 to 2.7 eV as shown in Fig. 3. On diffusing at 850° C, when the activation energy of zinc became larger than 2.5 eV, the diffusion-induced dislocations were no longer observed. The diffusion depth of zinc decreased with increasing additive phosphorus.

The creation of dislocations by zinc diffusion in GaAs was repressed by the arsenic pressure [7, 8]. The repression phenomenon against creation of dislocations in GaP by the phosphorus pressure is considered as follows: (1) the phosphorus pressure suppresses the formation of phosphorus vacancies in the GaP surface, therefore, the dislocations which are formed by the annihilation of the vacancies decrease; (2) the interstitial diffusion
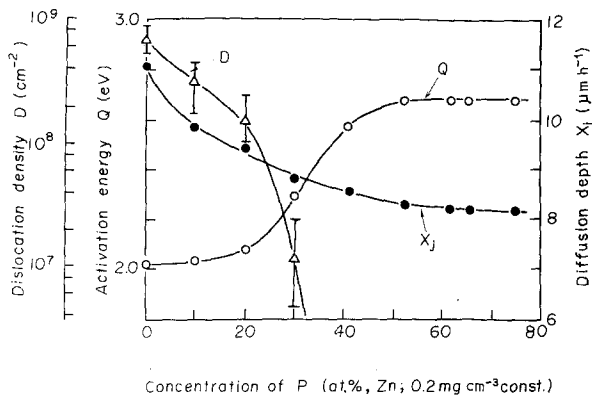
Figure 3 Effects of phosphorus addition on the diffusion-induced dislocation density, the activation energy of zinc diffusion, and the diffusion depth of zinc in GaP diffused at 850° C for 1 h.

of zinc helped by the existence of phosphorus vacancies is suppressed by the increase of phosphorus pressure. Consequently, the lattice distortion in GaP induced by the existence of interstitial zinc decreases.

It is thought that the increase of the activation energy and the decrease of the diffusion depth are due to both the decrease in phosphorus vacancies helping the interstitial diffusion of zinc, and of the short path diffusion of zinc along the dislocations.

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Silicon cerium oxynitride

The existence of a new group of ceramics called the silicon metal oxynitrides was originally suggested by Jack [1]. In these materials the fundamental unit is the $Si(O,N)_4$ group; consequently, they are expected to be isomorphous with similar nitrides, silicates, and phosphates. This group of compounds can be further classified according to size and co-ordination chemistry of the metal ion. For cations similar in size to Si^{4+}, substitution of the Si can occur. Thus, Al [2] and Be [3] can replace the Si in β-Si_3N_4, electrical neutrality being maintained by the appropriate substitution of oxygen for nitrogen atoms. Conversely, if the metal ion is much larger than the Si^{4+} ion, substitution cannot occur and the cation is restricted to a position outside the $Si(O,N)_4$ group. For example, in the silicon lanthanide oxynitrides [4], all of the rare earth oxides examined to date form a compound of general formula $Ln_4Si_2O_7N_2$ (Ln = La, Sm, Y, Dy, Yb, and Er) which is isostructural with the silicates of the cuspidine-wohlerite series (cuspidine: $Ca_4Si_2O_7F_2$). Except for La, the above rare earth oxides also form a silicon oxynitride that is isostructural with the mineral Akermanite ($Ca_2MgSi_2O_7$). An exception to this general behaviour which has been observed for silicon cerium oxynitride is reported in this communication.

CeO_2 * was dry mixed with Si_3N_4† in compositions ranging from 5 to 95 mol % CeO_2. Disc specimens (~ 5 g) prepared by cold compaction of the mixed powders were fired in a N_2 atmosphere

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