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<td>Author(s)</td>
<td>Zhao, YW; Dong, HW; Chen, YH; Zhang, YH; Jiao, JH; Zhao, JQ; Lin, LY; Fung, S</td>
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Creation and suppression of point defects through a kick-out substitution process of Fe in InP


Materials Science Centre, Institute of Semiconductors, Chinese Academy of Sciences, P.O. Box 912, Beijing 100083, People’s Republic of China

S. Fung

Department of Physics, The University of Hong Kong, Hong Kong, People’s Republic of China

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Indium antisite defect InP-related photoluminescence has been observed in Fe-diffused semi-insulating (SI) InP. Compared to annealed undoped or Fe-predoped SI InP, there are fewer defects in SI InP obtained by long-duration, high-temperature Fe diffusion. The suppression of the formation of point defects in Fe-diffused SI InP can be explained in terms of the complete occupation by Fe at indium vacancy. The InP defect is enhanced by the indium interstitial that is caused by the kick out of In and the substitution at the indium site of Fe in the diffusion process. Through these Fe-diffusion results, the nature of the defects in annealed undoped SI InP is better understood. © 2002 American Institute of Physics. [DOI: 10.1063/1.1473695]

Impurity diffusion in semiconductors has been studied extensively in the past. In III–V compounds, the mechanism of atomic diffusion is well understood. Fast impurity diffusers, such as Zn and Fe, usually diffuse via the kick-out substitution mechanism in GaAs and InP. In impurity-diffused InP, defects such as indium precipitate, interstitial-type dislocation loops have been detected. Most of these studies on diffusion involve the comparison of the impurity profile with the fitting to the proposed model in which the influence of vacancy has been considered. However, the influence of impurity diffusion on the formation of point defects in diffused InP has rarely been reported.

In this letter, we present photoluminescence (PL) and photoinduced transient current spectroscopy (PITCS) results of semi-insulating (SI) InP obtained by high-temperature Fe diffusion. By comparing with the results of annealed undoped SI InP, it is found that a number of defects have been suppressed and an indium antisite InP defect is formed in Fe-diffused SI InP.

The samples used in the experiment were prepared by annealing n-type undoped InP wafers grown by the liquid-encapsulated Czochralski (LEC) method. The electron concentration of as-grown LEC undoped InP was (3–6) x 10^15 cm^-3. The annealing was carried out in a sealed quartz tube at 930 °C for 80 h. A quantity of 5N Fe powder and 6N red phosphorus at a mole ratio of 1:2 were charged in the quartz tube before annealing. In this way, FeP2 with moderate vapor pressure can be formed at the annealing temperature and Fe diffusion was thus realized. After annealing, the wafers were cooled at 40 °C/h to room temperature. This process is found to convert the undoped n-type LEC InP to a SI material with resistivity and mobility above 10^7 Ω cm and 3000 cm^2/V s, respectively. The SI InP wafer so formed exhibits a good profile and radial uniformity. This technique has proved to be a promising method for the preparation of high-quality SI substrates. It should be mentioned that undoped LEC InP with a carrier concentration of about 3 x 10^15 cm^-3 can also be annealed into SI material under similar conditions, the only difference being the ambience in the quartz tube is pure phosphorus. For PL and PITCS measurements, 0.6-mm-thick samples polished on one side were used. A layer of more than 60 µm of the SI InP wafer was removed during the lapping and polishing process.

The PITCS system is a homemade setup with a conventional configuration. The PL system is a Bruck commercial ISF120 instrument equipped with an argon-ion laser and a germanium detector and the laser excitation power is 30 mW.

PL spectra of Fe-diffused and undoped SI InP are shown in Fig. 1. A noticeable difference of the spectra is that a broad peak centered at 1.3 eV can be observed in Fe-diffused sample. The spectra of as-grown undoped n-type, Fe-doped and undoped SI InP are basically the same. Since the 1.3 eV peak is only detected in Fe-diffused SI InP, it is reasonable to assume that this PL feature is associated with...
Fe diffusion in the material. During the subsequent high-temperature annealing process, the interstitial indium atom may have a strong tendency to occupy a phosphorus site, hence, forming an antisite defect in the Fe-diffused material. At the same time, as an additional effect, the substitutional occupation of Fe at the indium site means that indium-vacancy-related defects will also be greatly inhibited. A previous study has shown that the formation of these defects in undoped SI InP has a close relationship with the indium vacancy. Indeed, in as-grown InP a hydrogen vacancy complex can be detected. Experimental studies have confirmed that this complex is annihilated in annealed InP and an indium vacancy is produced as a result. Such a process can explain why there are more thermally induced defects in annealed undoped and Fe-doped SI InP than that in Fe-diffused SI InP. Our results also indicate that these defects are not impurity contamination related; otherwise, they cannot be suppressed by Fe diffusion. This interpretation is proving to be very helpful for the understanding of the nature of defects in annealed undoped SI InP.

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**Fig. 2.** Photoinduced transient current spectra of Fe-diffused SI InP (a) and undoped SI InP (b). Curves have been moved for better clarity.