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Short Communication

Zn doping into InP induced by Nd: YAG continuous wave laser

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Abstract

Nd:YAG continuous wave (CW) laser ($\lambda = 1.06$ μm) was used to irradiate Zn film deposited by evaporation deposition on the n-type InP substrates. The PN junction was obtained. The depth of the junctions and the doping distribution dependence upon the irradiation time and the irradiation power density were investigated. The relation between the depths of the junctions and the thickness of Zn deposition is linear. The hole concentration of uniform distribution, shallow junction, and heavy doping concentration are attained (10^{19}–10^{20} cm^{-3}). The primary mechanism of Zn doping is considered that alloy junctions form after irradiated.

Keywords: InP; Laser inducing; Zn doping

1. Introduction

The interaction of laser and semiconductor materials has been attracting considerable interest due to the advantage of the unique temporal and spatial control exercised over the laser energy flow, simple laboratory apparatus, no demand of vacuum surroundings [1–3]. The solid source doping induced by laser on Si substrate has been investigating since 1990 in Japan [4]. There is also report about diffusion of Zn into GaAs induced by CW CO_2 laser using a solid state diffusion source [5].

Recently, P-InP/i-InGaAs/n-InP double heterojunction structure is widely used to fabricate long wavelength detectors in optic fiber communication system. Generally, the method of sealed tube Zn diffusion is taken to fabricate P-InP/$In_{0.53}Ga_{0.47}As$/InP PINs. ZnP_2 is used as diffusion source to form PI junction in the active region. The process must be performed in sealed quartz tubes, which will result in high product cost and long producing period. Another way is open tube diffusion, but the high diffusion quality is not easily reachable. In order to overcome above disadvantageous factors, we put forward a new method.

In this paper, we will report the doping of Zn into n-InP substrate induced by Nd:YAG continuous wave laser.

2. Experimental

Our experiments were performed on a series of n-type InP substrates (the background doping concentration $n_0 \sim 10^{19}$ cm^{-3}). Zn films were deposited on n-InP substrate by evaporating deposition in a vacuum chamber, 10^{-5} mm Hg, with different thickness. The interface of Zn/InP and the surface of Zn film were analyzed by scanning electron microscope (SEM). For this intention,

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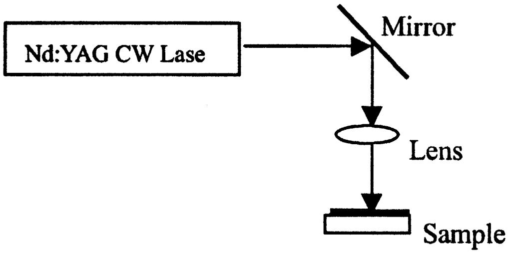

Fig. 1. The schematic drawing of the experimental apparatus for doping induced by laser.

Hitachi S-520 SEM was applied to investigate the surface quality of the Zn film and the interface of Zn/InP.

Fig. 1 shows a schematic drawing of the experimental apparatus for doping induced by laser. The laser beam ($\lambda = 1.06$ μm) from Nd:YAG continuous wave laser was reflected by the mirror and focalized by the lens, then irradiated on the sample. The temperature of the region irradiated was controlled by laser beam power density and irradiation time.

In order to clear the remained Zn on the sample surface, all the irradiated samples were cleaned with dilute hydrochloric acid solution and deionized water, orderly. The profile hole concentration of Zn doping into n-InP substrate region and doping depth was measured by the Bio-Rad PN4300PC electrochemical *C–V* profiler (ECV).

3. Results and discussion

From Fig. 2, we can observe that Zn film clings to InP substrate closely, and the surface of Zn film is uniform and compact. Zn film was used to be dopant resource and cap layer on InP as well.

Nd:YAG continuous wave laser ($\lambda = 1.06$ μm) irradiated Zn film surface. The energy of photons is absorbed by a great deal of free electrons in zinc, and the free electrons react with crystal lattices. It results in rapid increase of zinc temperature. Heat energy is transferred to InP substrate instantaneously. Zn dopes into n-type InP as effective acceptor. The p-type InP is obtained.

We irradiated several samples with the same Zn film thickness by different the irradiation power densities and irradiation times, firstly. The hole concentrations versus profile depth with Zn film thickness of 1.2 μm were measured by ECV as shown in Fig. 3.

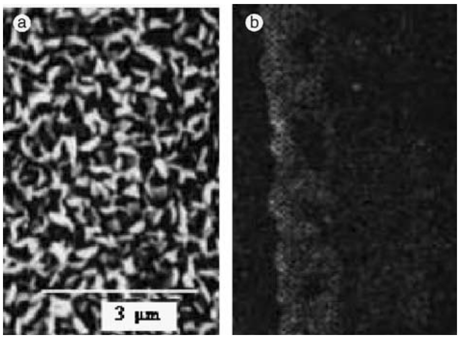

Fig. 2. (a) The surface quality of Zn film and (b) cross section SEM micrographs of Zn/InP.

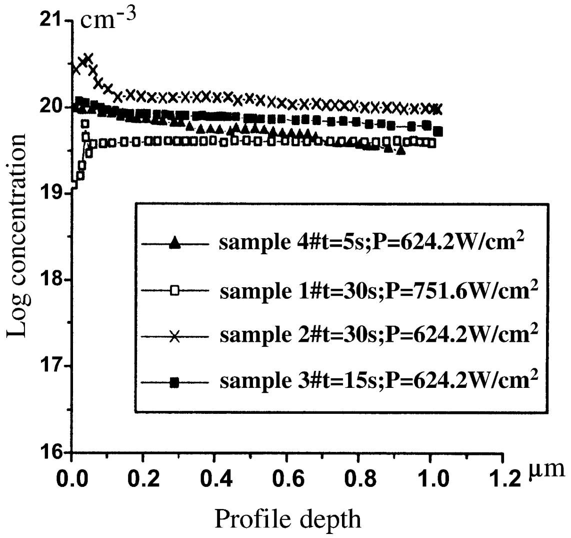

Fig. 3. Hole concentration versus profile depth on the condition of different irradiation power density (P) and irradiation time (t).

Sample #1 and sample #2 were irradiated 30 s with the different irradiation power densities, 751.6 and 624.2 W cm^{-2}, respectively. Sample #2, sample #3 and sample #4 were irradiated with the same irradiation power density 624.2 W cm^{-2} but different times, 5, 15 and 30 s, respectively. The melting point of Zn is 419.6 °C, and InP 1062 °C [6]. Our calculation result shows that the temperature of Zn/InP interface is 433.1 °C with irradiation power density 624.2 W cm^{-2} when treated 5 s, which is above the eutectic temperature of Zn–InP system. In spite of the varying of irradiation power density and irradiation time, hole concentrations do not decrease obviously as the doping depth increases. Besides, when the Zn film is 1.2 μm thick, the depths of p-type region are about the same, 1 μm, regardless of the irradiation power density and irradiation time. It also indicates that the Zn doping depth does not change as the temperature of Zn/InP interface alters. From Fig. 3, we can see the doping distribution is almost uniform. It does not conform to diffusion distribution, Gaussian and error function complement distributions [7]. From these experiments, we can conclude that the mechanism

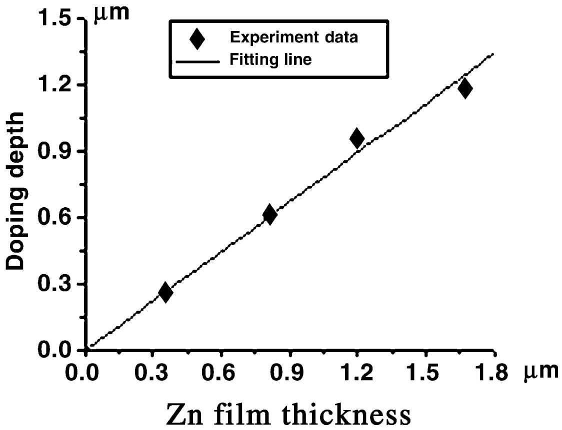

Fig. 4. Doping depth versus Zn film thickness.

of Zn doping into InP induced by CW laser is not diffusion process.

We treated the other group samples with different Zn film thickness on the n-type InP substrates with 624.2 W cm^{-2}, and 15 s. As is shown in Fig. 4, the doping depth increases, proportionally, as the Zn film thickness on the n-type InP substrate increases.

We speculate the mechanism of Zn doping into InP induced by CW laser is alloy process. The Zn–InP system is heated to a temperature higher than the eutectic temperature so that a layer of molten Zn–InP mixture is formed. The temperature is then lowered and the layer begins to solidify. The recrystallized portion forms the heavily doped p-type region on InP substrate. Doping and annealing happened at the same time when the samples were irradiated, which also results in the high hole concentration.

4. Conclusions

The Zn film deposited on n-InP substrate by evaporation deposition was irradiated with Nd:YAG continuous wave laser ($\lambda = 1.06$ μm). We attained P-InP with the character of uniform distribution, high doping concentration and shallow junction. The doping mechanism of Zn/InP induced by continuous wave laser is alloy process. This method has the advantage of convenience, prompt performance and efficiency.

Acknowledgements

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References

[1] Ehrlich DJ, Tao JY. Submicrometer-linewidth doping and relief definition in silicon by laser-controlled diffusion. Appl Phys Lett 1982;41(3):297.

[2] Marinova Ts, Kakanakova-Georgieva A, Kalitzova M, Vitali G, Pizzuto C, Zollo G. XPS depth profiling of laser-annealed Zn^{+}-implanted GaAs. Appl Surf Sci 1997;109/110:80.

[3] Pizzuto C, Zollo G, Vitali G, Karpuzov D, Kalitzova M. Electrical carrier activation induced in Zn-implanted InP by low power pulsed laser annealing. J Appl Phys 1997;82:1.

[4] Sera Fokumura K, Kaneka S. Excimer-laser doping into Si thin films. J Appl Phys 1990;67(5):2359.

[5] Ye YT, Li ZD. China Laser 1997;24(3):237.

[6] Bachmann KJ et al. J Electrochem Soc 1974;121(6):835.

[7] Sze SM. Physics semiconductor devices. 2nd ed. New York: Wiley; p. 66.