Low damage InP sidewall formation by Reactive Ion Etching

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Introduction: Reactive Ion Etching (RIE) using CH_4/H_2 is a useful technique for fabrication of InP based fine structures. However, wet etching process after RIE is normally required to remove dry etching damage.[1,2] In this paper, we report on low damaged InP sidewall formation by ECR (electron cyclotron resonance) RIE and optimized O_2 ECR-plasma treatment without wet etching. Electrical characterization indicates the sidewall is almost the same quality as that formed by wet etching.

Experiment: InP pin junction structure shown in Fig.1 is used for the evaluation of sidewall damage. Circular patterns of SiN are formed and electrodes are made in the center of the SiN patterns. Mesa structure was formed by CH_4/H_2 ECR-RIE and O_2 plasma treatment. While RIE condition is fixed to optimized condition for smooth surface, O_2 plasma condition is varied. In addition to the electrical characterization, SEM and AES measurement are also done.

Result: Fig. 2 shows the mesa diameter dependence of reverse current (bias voltage is −5V). Reverse current is proportional to the mesa diameter indicating surface leakage current is dominant. Fig.3 shows the O_2 plasma treatment time dependence of the reverse current. There is the optimum time to minimize the reverse current. The current is reduced to the same level as that of the mesa structure formed by wet etching. Fig.4 a to c are SEM photographs of the samples with different O_2 treatment time. There is a hydrocarbon layer on the SiN mask before O_2 treatment (Fig.4a). After 6 minutes O_2 treatment, the hydrocarbon deposition on the mask is completely removed (Fig.4b). This correlates with the reduction of reverse current. Although longer treated sample shown in Fig.4c shows no difference in the SEM photograph of Fig.4b, the reverse current of the sample is increased. Therefore we carried out AES on the sidewall of this sample. The result is summarized in table 1. The reduction of P composition and the existence of oxygen on the surface suggest that O_2 plasma induces sidewall damage like P vacancies or oxidized layer. So we think there is two kinds of leak path on the sidewall, one is a hydrocarbon layer or C-contaminated layer, and the other is a damaged layer made by O_2 plasma.

Conclusion: We evaluate the quality of InP sidewall formed by CH_4/H_2 RIE and subsequent O_2 plasma treatment. We found that the hydrocarbon layer and the damaged layer which is oxidized or P depleted is correlated to leak current path. By optimizing O_2 plasma condition, low damaged mesa structure as the same level as the mesa made by wet etching can be realized.

References: 1. J. R. Sendra and J. Anguita Jpn. J. Appl. Phys. 33 (1994) L390-L393
2. N.Yamamoto, K. Kishi, S. Matsumoto, Y. Kadota, R. Iga, H. Okamoto, and H. Mawatari J. Vac. Sci. Technol. B 15 (1994) 103-108

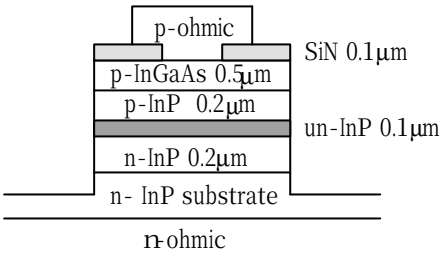


Fig.1 Sample Structure

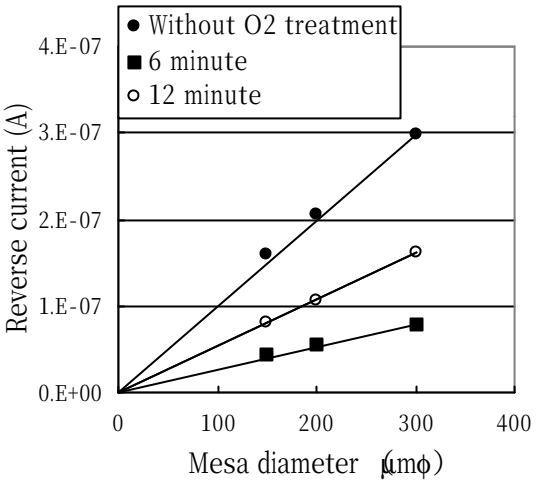


Fig.2 Diameter dependence of reverse current

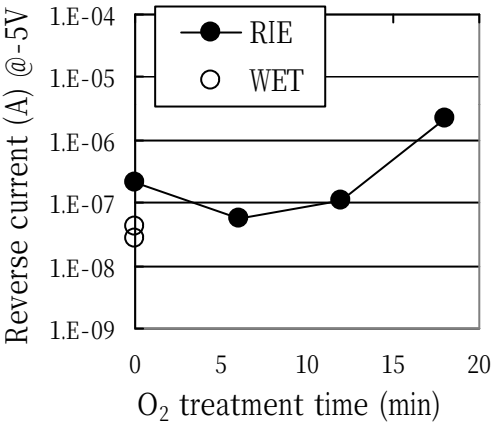
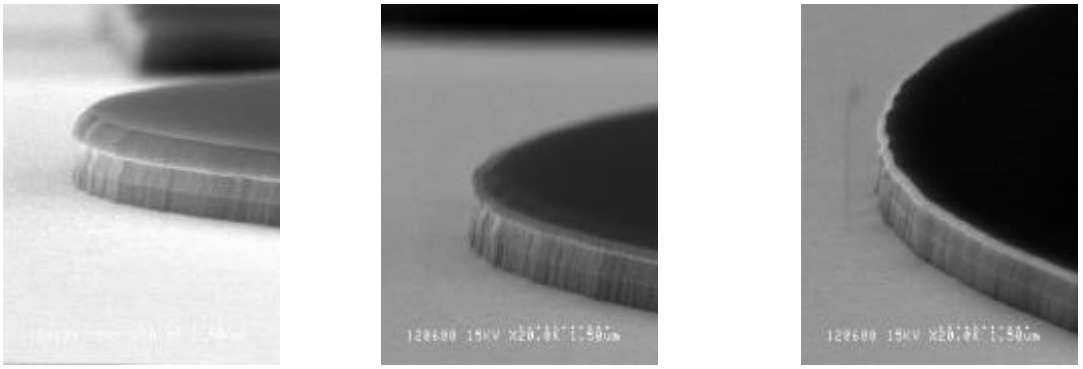


Fig.3 O_2 treatment time dependence of reverse current for the sample of 200μm diameter



a. Without O_2 treatment b. Optimum time (6min) c. Longer Time (18min)

Fig.4 SEM photograph

Table1 μAES analysis on the sidewall after 18 minutes O_2 treatment

	Sputtering Depth	Atomic Percentage			
		C	O	In	P
Longer Time (18min)	0Å	24	38	28	4.5
	50 Å	9.5	22	43	19