In-situ etching of semiconductor with CBr_4 in MOCVD reactor

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In-situ etching of III-V semiconductor in a MOCVD reactor is an important technology for reducing impurity accumulation at regrowth interface, especially regrowth on Al-containing materials. Chlorine containing materials, such as hydrogen chloride (HCl) and carbon chloride ($C_xH_yCl_z$), were used as etching gases for the fabrication of mesa shape in AlGaAs/GaAs [1,2] and GaInAsP/InP [3] structure. These materials also improve the selectivity of growth of aluminum containing compound on the masked substrate. Bromide is similar to chloride concerning the etching effect, and has advantage of lower damage on apparatus. We studied the selective growth of AlGaInAs with carbon tetrabromide (CBr_4) to reduce polycrystals on dielectric masks [4]. In this report, in-situ etching of InP, GaInAsP and AlGaInAs DH structure with CBr_4 in MOCVD reactor was studied for the first time.

All of the experiments were carried out in the vertical quartz MOCVD reactor. The pressure of reactor was 101hPa. The substrate temperature was varied from 540 to 660℃. The CBr_4 are solid state under room temperature and carried into reactor by hydrogen carrier gas. The maximum flow rate of CBr_4 was 6.4μmol/min. The samples used in this study were InP wafer, GaInAsP and AlGaInAs epitaxial wafers, as shown in fig.1. SiN stripe masks were patterned on those wafers. The in-situ etching with CBr_4 was carried out under PH_3 pressure.

First, etching of InP was executed. Figure 2 shows the dependence of etching rate of InP on CBr_4 flow rate. The etching rate was proportional to the flow rate. The temperature of substrate did not affect etching rate of InP. These results indicated that the etching process of InP was limited by the amount of CBr_4.

Next, GaInAsP and AlGaInAs epitaxial wafers were etched by CBr_4. The substrate temperature and CBr_4 flow rate were 600℃ and 3.2μmol/min, respectively. The etching time was 30minuets, which was enough time for etching of InP upper cladding layer and so SCH layer was etched about for 8 minuets. Figure 3 shows the scanning electron microscopy (SEM) pictures of the samples after etching. For GaInAsP sample(a), many residues remained on the surface. On the contrary, mirror-like surface was obtained for AlGaInAs sample(b), and undercut etching of InP cladding layer was observed. CBr_4 could easily react on InP, however, it could not etch AlGaInAs layer at all. It was assumed that Al-Br compound did not desorbed from the surface, so that Al containing layer acted as an etching-stop layer for CBr_4 and remained Br atoms were used for undercut etching of InP layer. It was concluded that the etching effect of Br on group III atom was In>>Ga>Al in our condition.

In order to investigate the quality of the regrowth interface, AlInAs layer was successively grown on AlGaInAs layer. CBr_4 was introduced into reactor during growth to enhance the selectivity [4]. Mirror-like surface without any defect was obtained for the sample prepared by in-situ etching. However, when AlGaInAs layer was exposed to the air after InP etching, rough surface was obtained after regrowth. Impurities at the regrowth interface were measured by secondary ion mass spectroscopy (SIMS). The oxygen concentration was reduced for the sample with in-situ etching, though carbon, which was included in CBr_4, was the same level between the sample with and without etching These results showed that in-situ etching using CBr_4 was very effective to obtain high-quality regrowth interface.

In summary, in-situ etching in MOCVD reactor was carried out with CBr_4, and it was found that InP layer was easily etched and AlGaInAs layer could be used for etching-stop layer. When epitaxial layer was successively grown after in-situ etching, high-quality regrowth interface, such as reduced defects and oxygen concentration, was obtained.

Reference
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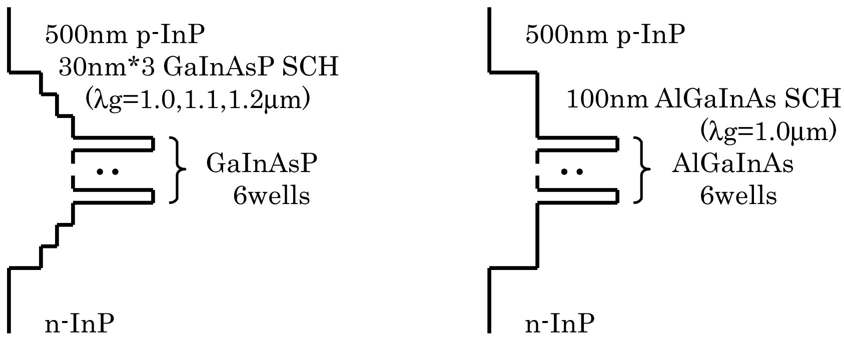


(a) GaInAsP wafer (b) AlGaInAs wafer

Fig.1 Layer structures of samples.

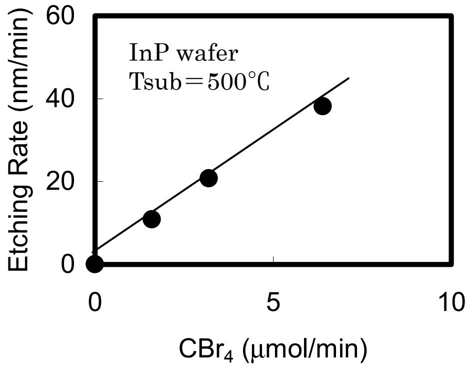
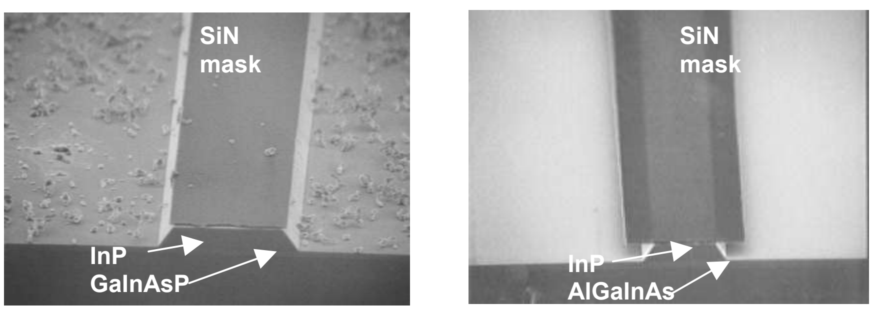


Fig.2 The dependence of etching rate of InP on CBr_4 flow rate.



(a) (b)

Fig.3 SEM pictures of GaInAsP (a) and AlGaInAs (b) wafer after etching with CBr4.