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Gas Source Si-MBE Using SiH_4

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In Si device technology, it becomes important to fabricate thickness- and doping level-controlled thin epitaxial layer at low temperature. Si-MBE technology has been expected to satisfy these requirements. However, the conventional E-gun evaporator type Si-MBE has several disadvantages such as low thruput, spitting defects and the impossibility of the selective growth on SiO_2 patterned wafers. To get rid of these obstruction and to make Si-MBE technology more practical, gas source Si-MBE was newly developed. In this study, the apparatus and the performance of gas source Si-MBE, especially initial surface cleaning, film thickness uniformity, spitting defect-free growth and selective growth are reported for the first time.

The gas source Si-MBE apparatus was schematically shown in Fig. 1. SiH_4 was used as a source gas and introduced into the growth chamber from the gas source cell having a sub-chamber, which was designed for the precise gas flow control. A 4 inch Si(100) wafer was used as a substrate. At first, the thin protective oxide layer on the wafer was thermally evaporated in the ultra high vacuum growth chamber. In this initial cleaning stage, SiH_4 exposure was found to be effective in saving the cleaning time. At the substrate temperature of 840°C, 10 min. cleaning time without SiH_4 was shortened to 2min. with 1 sccm SiH_4 exposure.

After the initial cleaning, Si films were grown at 880°C. 1 sccm SiH_4 was introduced into the growth chamber. The pressure during the growth was 1x10-4 Torr. The growth rate was 0.15 µm/hr. The grown film had a mirror surface and showed a sharp 2x1 superstructured RHEED pattern. These were the evidence for the high quality epitaxial film. The uniformity of the film thickness was ±4%. On the film grown by gas source Si-MBE, there was no spitting defect which was always observed on the film grown with E-gun evaporator type Si-MBE. The optical microscopic photographs of both results were shown in Fig. 2.

Si layers were also grown on the Si(100) 4 inch wafer on which 1µm thick SiO_2 pattern was constructed. In this case, no Si deposition was observed on the SiO_2 film. The Si layer grew only on the bare Si substrate epitaxially. The cross sectional SEM photograph was shown in Fig. 3. The grown film was also studied with TEM. It was shown in Fig. 4. The poly-Si growth, which appeared in E-gun evaporator type Si-MBE, was not observed on the SiO_2 film. The selectivity in gas source Si-MBE was perfect. No defects were observed in the bare Si window area except for the region near the edge.

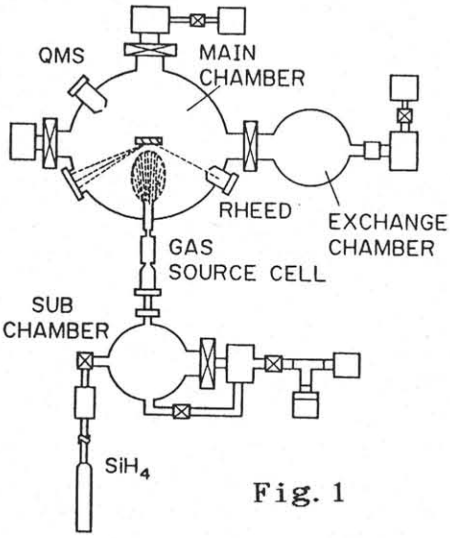


Fig. 1

Gas Source Si-MBE Apparatus

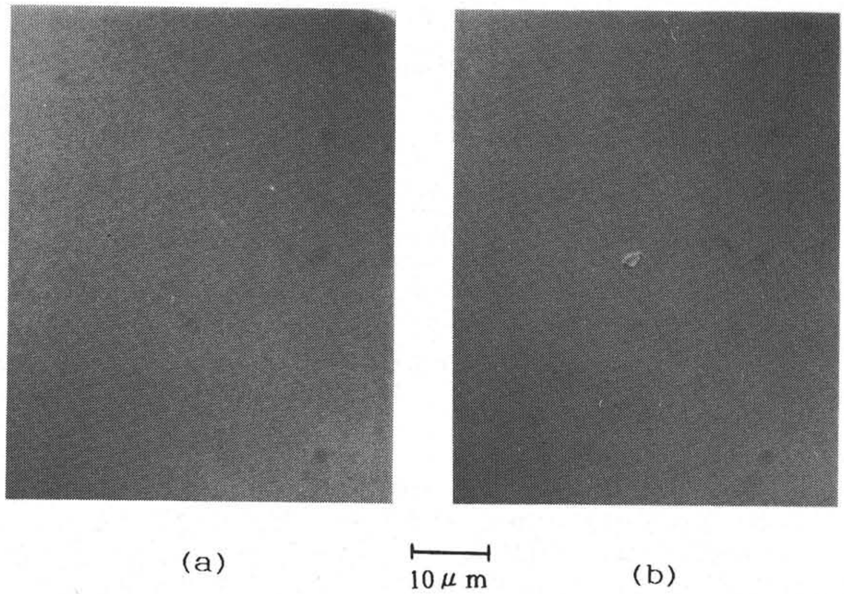
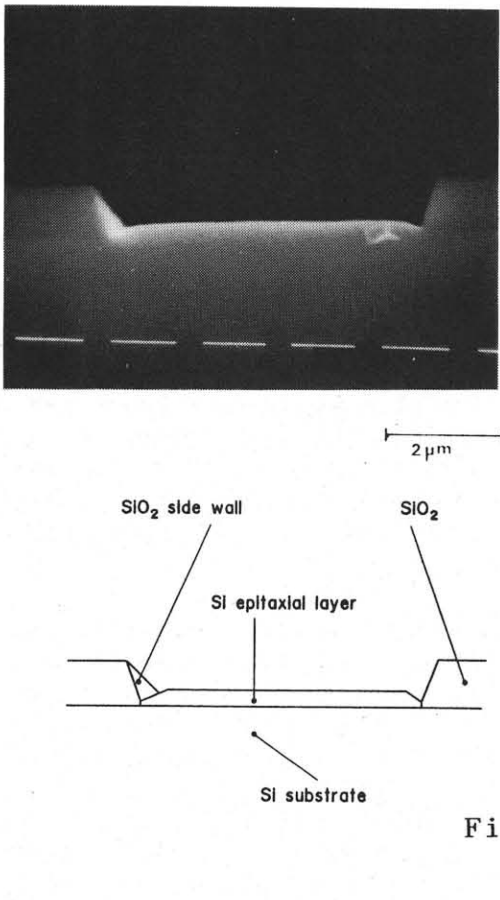


Fig. 2 Film surfaces grown by gas source Si-MBE (a), and E-gun evaporator type Si-MBE (b)



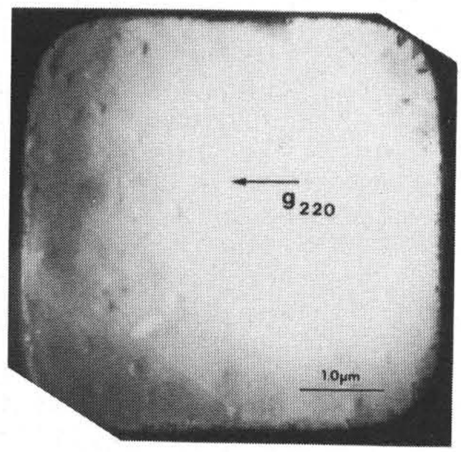


Fig. 4

TEM image of the selective growth layer by gas source Si-MBE

Fig. 3 Cross sectional SEM image of the selectively grown structure by gas source Si-MBE