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The Growth of Single Domain GaAs on Ge (100) Substrate by MOCVD

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GaAs layer deposited on Ge(100) substrate was found to construct a single domain structure by introducing intermediate layers between GaAs and Ge. The intermediate layers were constructed of thin GaAs and GaAlAs. The single domain GaAs on Ge(100) had a smooth surface and showed a mobility as high as that of GaAs on GaAs substrate. Optimum growth conditions and procedure to obtain a single domain GaAs layer on Ge(100) substrate by MO-CVD are discussed and electrical properties of the layers are demonstrated.

(1) Introduction

Ge has a close lattice constant and a thermal expansion coefficient to GaAs. So, heteroepitaxial properties between these materials have been studied by some workers using CVD[1)] and MBE[2)-5)] method. It was reported that Ge on GaAs substrate exhibited an atomically smooth growth, whereas, GaAs layers on Ge(100) and (110) substrates, especially on (100) substrates, showed rough surfaces because of antiphase domain structures.[1),2)] When GaAs was deposited on Ge(100) surface, rough surface which was attributed to the formation of antiphase domains was observed by RHEED after only 1 - 2 monolayers were grown.[2)] In (110) epilayers, it was reported that antiphase domain structures were less observed than in (100) layers grown by CVD.[1)] By MBE method, it was reported that large area of single domain GaAs could be obtained due to the surface reconstruction of Ge by suitable surface treatments in MBE system.[6)]

In this paper, it is reported that the intermediate GaAs/GaAlAs layers introduced between Ge substrates and GaAs epilayers are effective to eliminate the antiphase domain structures of GaAs on Ge(100) substrates.

(2) Experimental

A low pressure MO-CVD system with a vertical reactor shown in Fig.1 was used in the experiments. Source gases used were TMG:$Ga(CH_3)_3$, TMA:$Al(CH_3)_3$ and AsH_3. Carrier gas was H_2 and the total flow rate was 1.5 SLM at low pressure of 100 Torr. The flow rate of H_2 bubbling TMG was 1 SCCM, and the growth rate was 500 Å per minute for GaAs. TMA was introduced further into the reactor by H_2 bubbling to obtain a GaAlAs layer. The flow rate of AsH_3 was 60 SCCM which was unchanged through the experiments. (100) oriented Ge wafers were used as substrates. Each mechanically polished wafer was degreased, cleaned and etched by 1 HF : 4 HNO_3 prior to incorporation into the reactor. The morphology of growth layers were observed with microscope, and some wafers were etched by molten KOH to observe the etch pit patterns. The electrical properties were measured by conventional Van der Pauw method, and the values were compared with those of the layers on semi-insulating GaAs substrates which were set into the reactor with Ge substrates.

(3) Results

The GaAs epilayers grown directly on Ge(100) substrates showed whity rough surfaces as reported in other papers. Fig.2 shows the such surface and Fig.3 shows the typical etch pit pattern of the layer. The surface was constructed of many small antiphase domains which had two different directions, and etch pits linked to the shape of grooves at the domain boundaries. When the intermediate layers which were alternately grown thin GaAs and GaAlAs layers were introduced between Ge substrate and GaAs epilayer, the top GaAs layer became a single domain structure and had a smooth surface. Fig.4 shows the such surface, and Fig.5 shows the etch pit pattern of the layer. The sample had 5 GaAs and 5 GaAlAs layers in the intermediate layers. The thickness of the first GaAs layer was about 300 Å and those of the other layers were about 500 Å. The top GaAs had a thickness of 3 μm. The top layer can be seen to be a single domain structure in which all etch pits have a same direction and no domain boundary can be seen.

By varying the constructions and the growth conditions of the intermediate layers, some informations were obtained, which are as follows.

(a) The intermediate layers of GaAs/AlAs structures were not effective. Only GaAs/GaAlAs structures were effective to obtain single domain layers. The introducing ratio of TMA for GaAlAs layers did not so affect the domain properties in the range of $0.15 \leq (TMA)/((TMG)+(TMG)) \leq 0.5$, in which our experiments were performed.

(b) A thin GaAs layer of 100 - 300 Å should be deposited on Ge at first. When GaAlAs layer was deposited at first, or the first GaAs layer was as thick as several thousands angstroms, a single domain GaAs could not be obtained. The thickness of GaAlAs layers did not so affect the domain properties.

(c) Relatively high growth temperature (the temperature of the thermo-couple in the graphite pedestal) of about 700°C was suitable. At as high as 750°C, pits were increased on the surface, whereas, at low temperature of about 600°C, the antiphase domain structures could not be disappeared.

(d) Only one GaAs and one GaAlAs layer were sufficient for the intermediate layers to obtain a single domain crystal when the other growth conditions were optimized. Multilayer structures were, however, seen to improve the surface morphology.

The carrier densities of the single domain GaAs epilayers grown on Ge(100) substrates at 630°C are shown in Fig.6 as well as those of the layers on GaAs. The values were about $10^{16}cm^{-3}$ of n-type, except the very large value of the layer without the intermediate layers. When GaAs was grown on GaAs substrate, the high purity layer (electron density of 10^{14}-$10^{15}cm^{-3}$) could be obtained under the used growth conditions. So, relatively high carrier densities would be due to the autodoping from Ge substrates which were not backsealed.

Hall mobilities of these layers are shown in Fig.7. The values of epilayers on Ge were as large as those of the layers on GaAs, except that of the layer grown directly on Ge. When GaAs was deposited directly on Ge, the layer had antiphase domain structure and, furthermore, mutual diffusion at the interface would occur. So, the observed high carrier density and extremely low mobility would show the properties of high doped interface layer. Hall mobilities were not so affected with the number of GaAs and GaAlAs layers in the intermediate layers. This would be suported by the fact that only one GaAs and one GaAlAs layer could construct the top GaAs of a single domain crystal.

Fig.8 shows the carrier densities of GaAs layers having antiphase domain structures. GaAlAs layer between Ge and GaAs was introduced to obtain GaAs layer of antiphase domain structure and to isolate the layer from Ge/GaAs interface. The values were also about $10^{16}cm^{-3}$ of n-type due to the autodoping. Hall mobilities of these samples are shown in Fig.9. The values were less than the factor of 2/3 compared with the layers on GaAs. This fact shows the antiphase boundaries not only roughen the surface, but also decrease the mobility.

(4) Summary

Single domain GaAs epilayers were obtained on Ge(100) substrate by introducing the intermediate layers which were constructed with alternately grown thin GaAs and GaAlAs layers. The top GaAs epilayers showed good surface morphology and high Hall mobilities which were comparable to those of the layers on GaAs substrates. The optimum growth conditions and procedure of the intermediate layers by MO-CVD method were to grow thin GaAs layer of 100 - 300 Å at first, to construct the layers with GaAs and GaAlAs and to grow at relatively high temperature of about 700°C. The reason why single domain GaAs epilayers were obtained on

Ge(100) substrates by the GaAs/GaAlAs intermediate layers are not clear. It will be attributed to the effects of GaAs/GaAlAs interface.

(5) Acknowledgement

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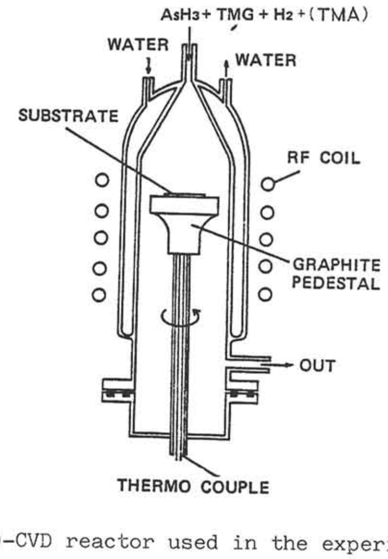

Fig.1 MO-CVD reactor used in the experiments.

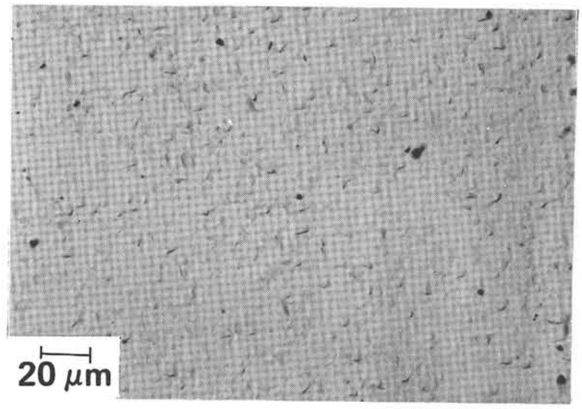

Fig.2 Surface view of GaAs grown directly on Ge(100) substrate.

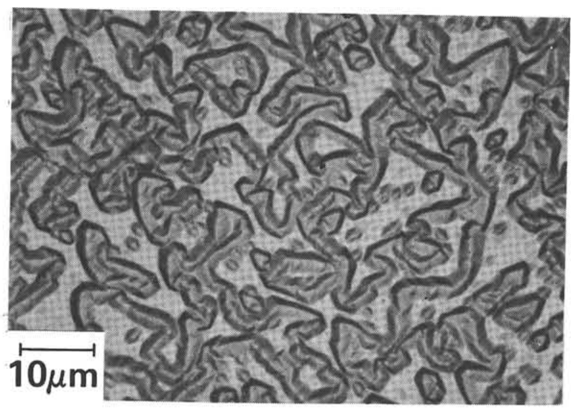

Fig.3 Etch pit pattern of GaAs grown directly on Ge(100) substrate.

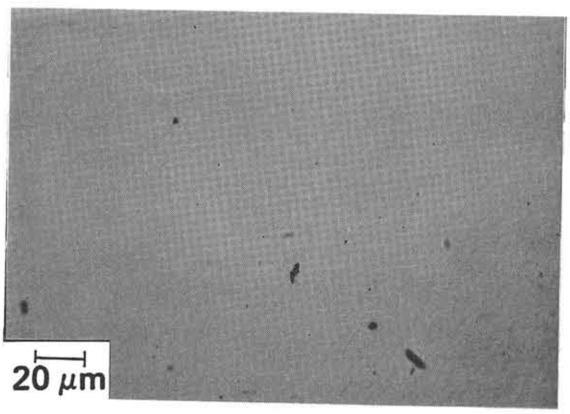

Fig.4 Surface view of single domain GaAs on Ge(100) substrate.

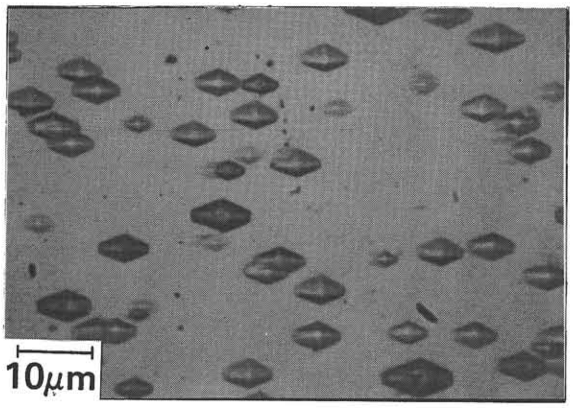

Fig.5 Etch pit pattern of single domain GaAs on Ge(100) substrate.

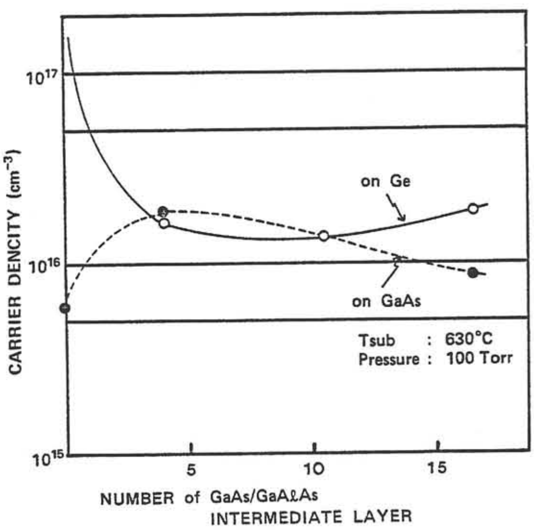

Fig.6 Carrier densities of single domain GaAs on Ge and GaAs on GaAs grown in the same run.

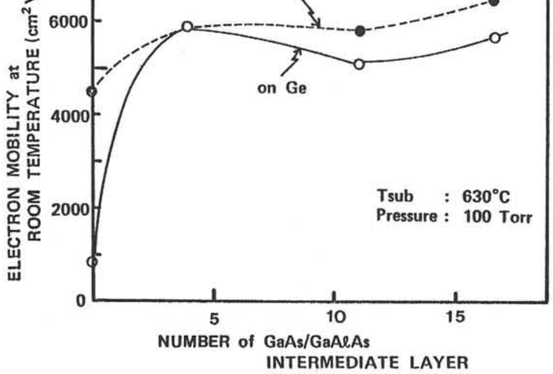

Fig.7 Hall mobilities of the samples shown in Fig.6.

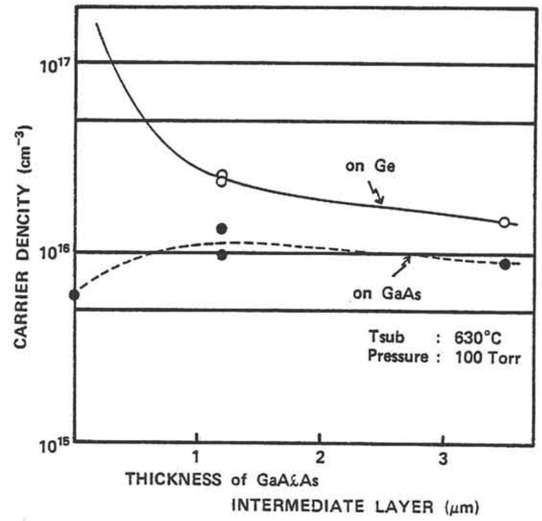

Fig.8 Carrier densities of GaAs having antiphase domain structures and GaAs on GaAs grown in the same run.

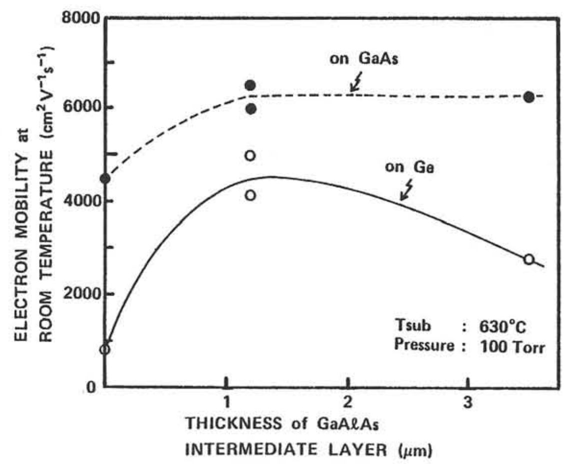

Fig.9 Hall mobilities of the samples shown in Fig.8.