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Computer Controlled Phase-Locked Epitaxy(PLE) of $(GaAs)_m(AlAs)_n$ *using RHEED Oscillation*

T.Sakamoto, H.Funabashi[†], K.Ohta,
T.Nakagawa, N.J.Kawai, and T.Kojima

Electrotechnical Laboratory

1-1-4, Umezono, Sakura, Niihari, Ibaraki 305, JAPAN

† *Japan Aviation Electronics Industry Co. Ltd.*
1-21-6, Dogenzaka, Shibuya, Tokyo 150, JAPAN

Strong intensity oscillations in the reflection high energy electron diffraction (*RHEED*) from *GaAs* and $Al_xGa_{1-x}As$ during molecular beam epitaxy (*MBE*) were reported[1-5]. It was suggested that one period of the *RHEED* oscillations would correspond to one mono-layer growth on (*001*) oriented substrates. It was also reported that the amplitute of oscillations damped rapidly, and decayed after a few tens of periods. The observed azimuth was limited only in [110] in these papers. In this azimuth, the observed intensity at the specular beam position should be the superposition of the intrinsic specular beam spot and the well developed integral order streak. Therefore, observed intensity oscillations of the specular beam at [110] azimuth may be damped rapidly due to the interference between the two beams with different phases.

We present here the observation of oscillations over more than 400 periods in the [100] azimuth. Here, the *RHEED* intensity oscillation is not interrupted by the developed streak after the growth is started. Using these oscillations, the impinging rates of *Ga* and *Al* and even the *Al* mole fraction x of $Al_xGa_{1-x}As$ can be determined accurately.

The phase of the *RHEED* oscillations was analyzed by a computer and the molecular beam shutters were operated at a paticular phase to realize superlattice structures with integral number of mono-layers. Schematic diagram of a computer controlled (PLE) system using RHEED oscillation is shown in Fig. 1. The intensity of a paticlular RHEED spot was measured via an optical fiber by a photo-multiplier. The output of the photo-multiplier was monitored by a computer, and used to controll the molecular beam cell shutters.

Figure 2 shows a typical *RHEED* oscillations during $(GaAs)_3(AlAs)_3$ tri-layer superlattice growth by the computer controlled *PLE*. First, *Al* shutter was opened and three *AlAs* mono-layers were grown. Then, the *Al* shutter was closed, and after a short surface recovery time, *Ga* shutter was opened and three *GaAs* mono-layers were grown. After this *GaAs* layer growth, again a short surface recovery time was put before the *AlAs* layer growth, and so on. This computer controlled *PLE* was applied to the growth of $(GaAs)_2(AlAs)_2$ bi-layer superlattices. Raman scattering spectra of the bi-layer superlattices show splitted lines which are characteristic in the superlattice structures.

Using this *PLE*, the fluctuations of the molecular beams, for example, just after opening the cell shutters, do not affect the multi-layer structures as the number of mono-layers are controlled just by the number of oscillations. This is the advantage of *PLE* over the conventional time measurement method in growing superlattice structures. With this *PLE* method, we can synthesize structures with well defined thickness to the mono-layers. This will be very useful in making multi-quantum well lasers and HEMTs, as well as superlattice devices including CHIRP devices[6])

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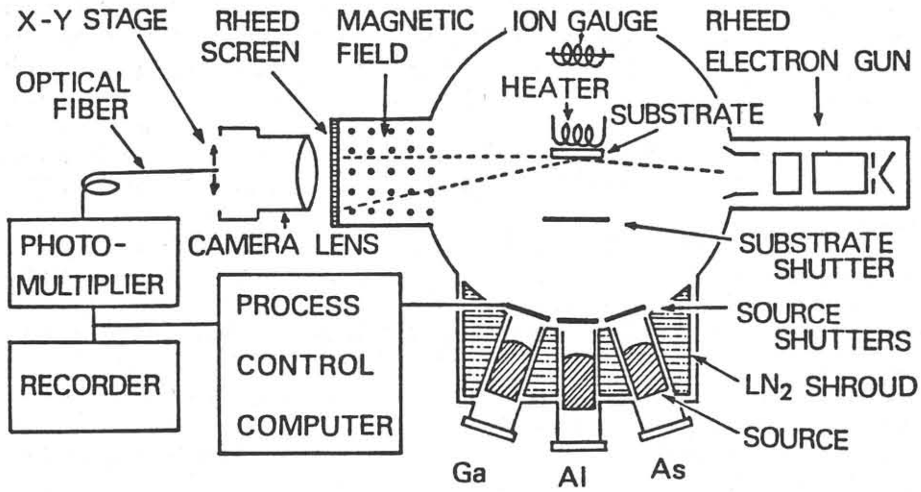

Fig. 1. Schematic diagram of a computer controlled *phase-locked epitaxy* (*PLE*)system using RHEED oscillation.

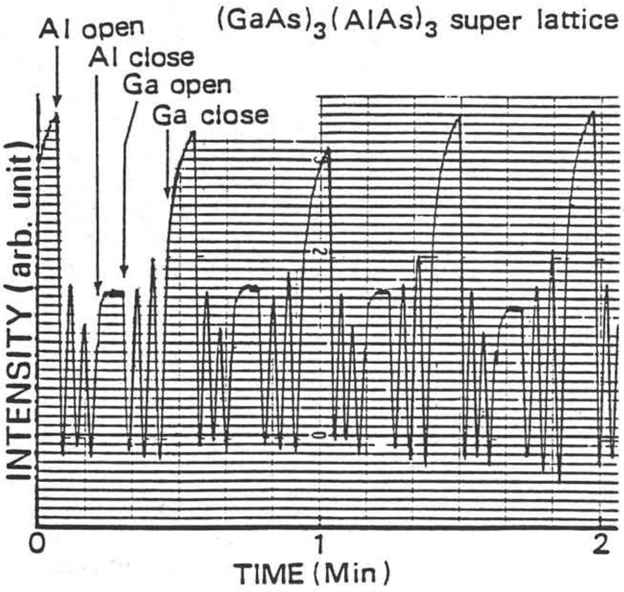

Fig. 2. The RHEED intensity oscillations during the computer controlled growth of $(GaAs)_3(AlAs)_3$ tri-layer superlattice.

References

1) J.J.Harris and B.A.Joyce: Surf.Sci.Lett., *103*, (1981) L90
2) C.E.C.Wood: Surf.Sci.Lett., *108*, (1981) L441
3) J.J.Harris, B.A.Joyce, and P.J.Dobson: Surf.Sci.Lett., *108*, (1981) L444
4) J.H.Neave, B.A.Joyce, P.J.Dobson, and N.Norton: Appl.Phys.,*A-31*, (1983) 1
5) J.M.Van Hove, C.S.Lent, P.R.Pukite, and P.I.Cohen: J.Vac.Sci.Technol., *B-1*,(1983) 741
6) T.Nakagawa, N.J.Kawai, K.Ohta, and M.Kawashima, Electronics Lett., *19*,(1983) 822