	Experiment title: Structure stability of short period GaAs/AlGaAs and AlInAs/InGaAs superlattices	**Experiment number**: HS-3291
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Report:

The aim of the project was to investigate the chemical composition profile of the AlAs/GaAs superlattices to be used as distributed Bragg reflectors for vertical cavity surface emitting lasers (VCSELs), and heterostructures making up quantum cascade lasers (QCLs).

1: Distributed Bragg Reflectors.

High quality Bragg mirrors for VCSEL applications should be characterized by high reflectivity and low series resistance of the stack in order to protect the whole structure from the thermal heating. It was reported [1] that by using graded interfaces the DBR series resistance can be significantly reduced compared to abrupt interfaces. In our project two different techniques were employed to modify interfaces between successive layers of the AlAs/GaAs based Bragg mirror: one consists in growing intermediate layer with varying chemical composition between AlAs and GaAs layers, another one consists in applying high energy ion irradiation and thermal annealing to introduce grading in the interfaces. In order to determine the chemical composition profile for structures with modified interfaces high resolution x-ray diffraction analysis was employed and rocking curve for each sample has been measured. In the case of a rocking curve the low-order satellites close to the Bragg peaks give the overall shape of the composition through the period, whereas the higher-order satellites give information about the finer details, for example the interface shape [2]. Due to this fact the investigation of the chemical composition profile by means of x-ray diffraction calls for collecting data in wide angular range and this makes that we are dealing with very low intensities, in this case the synchrotron radiation proves to be invaluable. In the course of the experiment a series of superlattices with modified interfaces by means of both mentioned above methods have been investigated. In Fig.1 there are experimental and calculated rocking curves presented for superlattice with intermediate

$Al_{0.5}Ga_{0.5}As$ layer, in Fig.2 & 3 rocking curves for superlattices where ion intermixing technique and thermal annealing has been employed to modify interfaces.

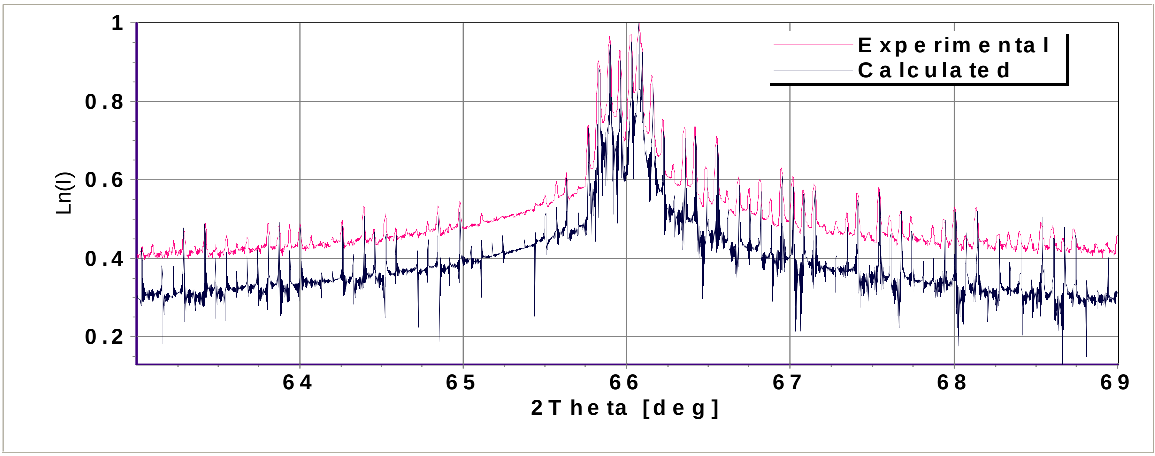


Fig.1 (004) experimental and symulated rocking curves for 23- period (52.9nm GaAs, 20nm $Al_{0.5}Ga_{0.5}As$, 63nm AlAs i 20nm $Al_{0.5}Ga_{0.5}As$) superlattice.

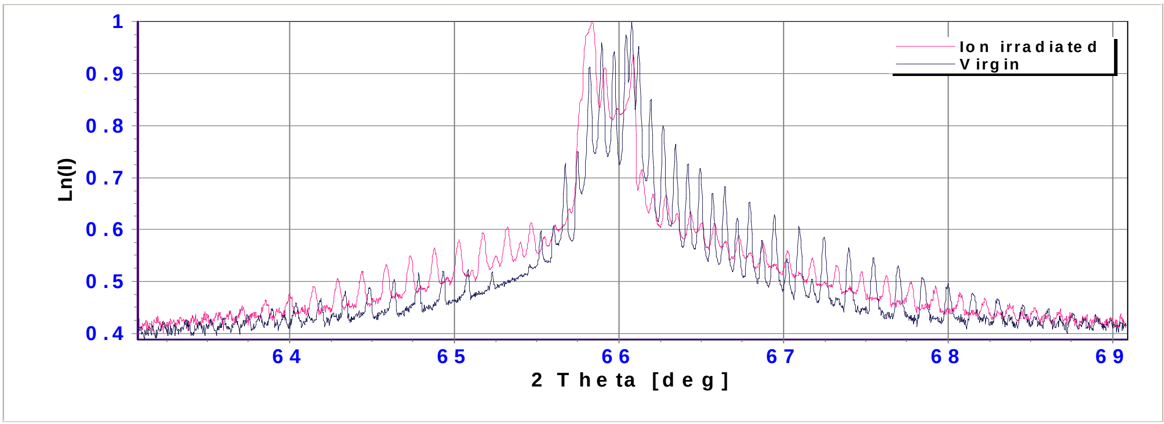


Fig.2 (004) experimental rocking curves for virgin and ion irradiated DBRs.

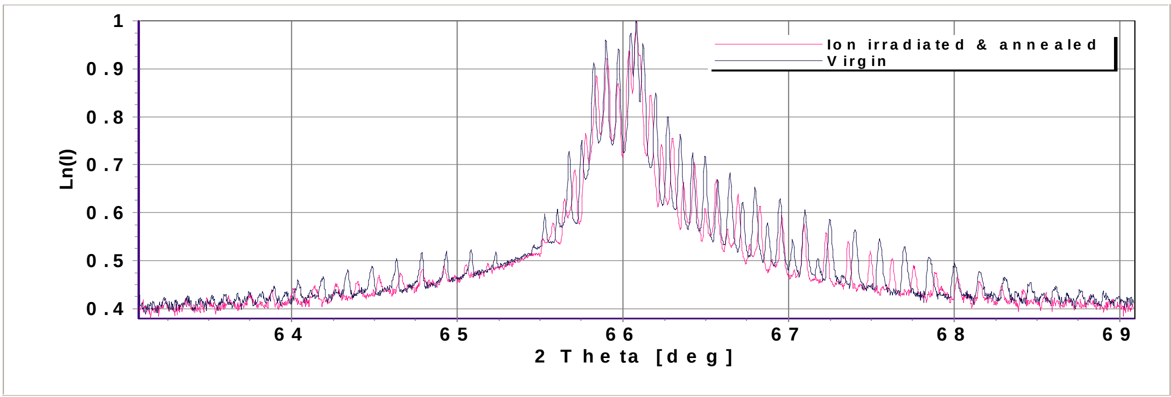
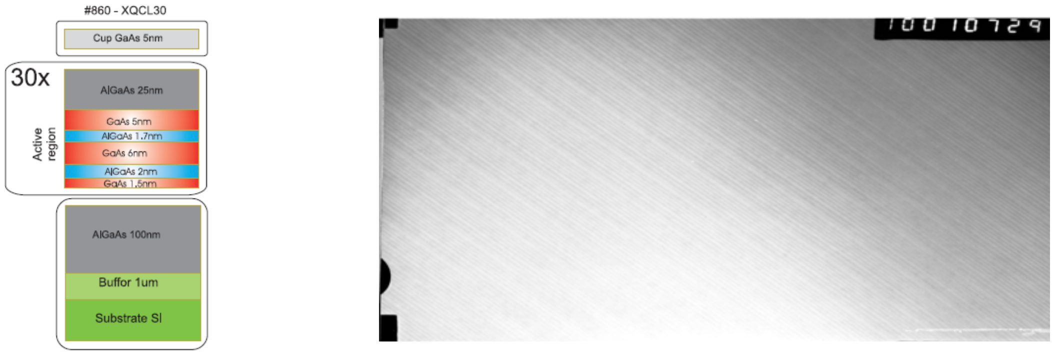


Fig.3 (004) experimental rocking curves for virgin and ion irradiated & annealed DBRs.

2. Quantum cascade lasers.

Another type of heterostructures which have been investigated in the course of the project were the ones designed for application as a quantum cascade laser. The full structure of such a laser consists of a few hundred ultra thin layers with varied chemical composition making up a superlattice where each period is a superlattice in itself. To find out the chemical composition profile for such a structure it is necessary to perform rocking curve measurement in even wider angular range than that used for DBR investigation. We could also expect very weak intensities of higher order satellite reflections. Synchrotron radiation is sufficiently strong to allow registration of these remote satellite reflections. In the course of the experiment we have investigated samples containing: active region, injector, active region + injector, 30x(active region + injector) and the full structure of quantum cascade laser. As an example, in fig.4,5 there are presented QCL structure and its TEM image, experimental and simulated rocking curves for full QCL structure.



a) b)

Fig. 4 a) Structure of quantum cascade laser b) TEM image for heterostructure presented in a)

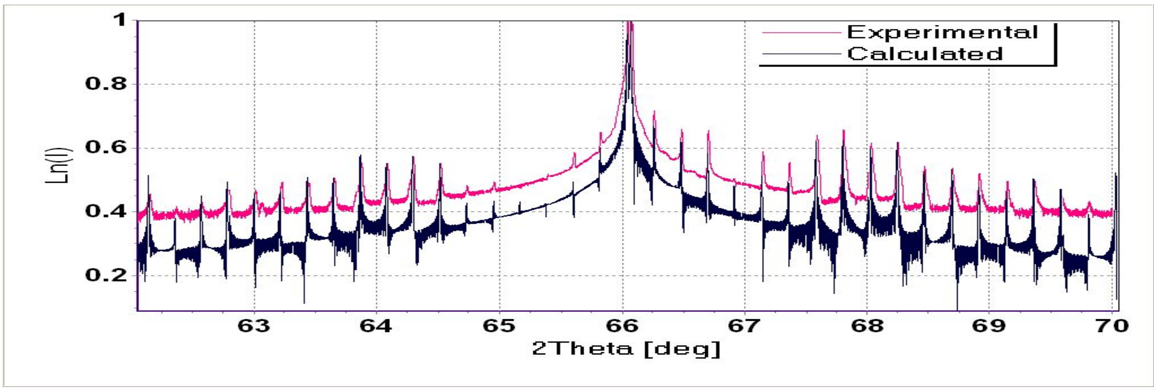


Fig. 5 Experimental and calculated rocking curves for heterostructure presented in fig. 4.

3.Results

The results of the HRXRD analysis of the AlAs/GaAs superlattices designed for DBRs, combined with the measurement of the optical reflectance and Rutheford backscattering allowed to answer the question how thickness variation and composition grading at the heterointefaces affect the DBR reflectivity [3,4]. We also hope to find the relationship between structure quality of the DBR and its reflectivity, especially in cases when the reflectivity is greater then 98%. HRXRD analysis of the heterostructures designed for quantum cascade lasers combined with numerical simulations allowed to determine their chemical composition profile in the growth direction and in this way to answer many questions concerning growth conditions, crystal quality, periodicity, structure of the interfaces and lattice coherence [5]. As a result it enabled to achieve an excellent quality of interfaces in the QCL structures and long term growth rate stability, necessary for obtaining strict periodicity of the structures and to draw a conclusion about the influence of the laser structure variation on the laser emission.

References

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