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Report:

We report on the strain analysis of a $GaAs/Ga_{0.97}In_{0.03}As/GaAs$ [001] quantum well structure which was laterally patterned by a focused Ga^+ ion-beam implantation of $5 \times 10^{13} cm^{-2}$ ions. The Strain distribution in the samples was studied by means of X-ray grazing-incidence diffraction. In the as-implanted sample we found a nearly constant strain distribution of about 4×10^{-3} up to a maximum information depth Λ of about 500 nm. Rapid thermal annealing (RTA) during 60 s above $600^\circ C$ strongly reduces strain.

GID investigations were carried out at beamline ID10B using the vertical sample setup. For the definition of the reciprocal space we used a coordinate system rotated 45 degrees around the [001] surface normal. Scans were performed in reciprocal space at two symmetry equivalent in-plane reflections. Transverse scans, which keep the length of the scattering vector constant, were measured at (0-20) reflection. These scans provide information about the shape of the grating ridges. Longitudinal scans, where the length of the scattering vector, Q, changes, were measured at (200) reflection. These scans are sensitive for in-plane strains. Running line scans at different incidence angles, α_i, the strain distribution can be obtained for different depths Λ below the sample surface. High-resolution in reciprocal space was achieved by mounting an analyzer crystal in front of the scintillation detector which gave an in-plane resolution smaller than $2 \cdot 10^{-4}$ nm^{-1} for both scan types. Thus the resolution in reciprocal space was limited by the accuracy of the goniometer movement only. To separate the patterned and non-patterned sample areas we had to use 400 μm high and 10 μm wide slits in the incoming beam path.

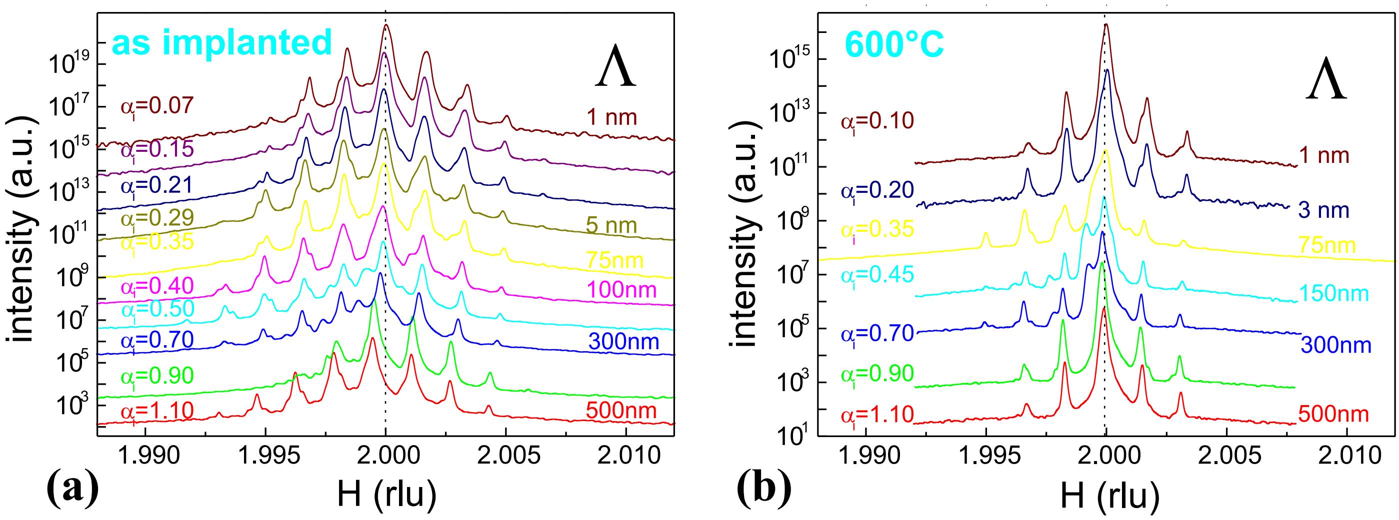

Figure 1: Strain sensitive scans for the as implanted (a) and after RTA at $600^{o}C$ (b).

Figure 1 shows the strain sensitive GID-scans of the as-implanted sample (fig 1a) and the sample annealed at $600°C$ (fig 1b). These longitudinal scans show several equally spaced grating peaks. Almost no grating peaks at the transversal scans were observed; thus peaks in the longitudinal scans can be interpreted by the appearance of a periodic strain field within the sample [1],[2] .

Taking the ratio 100 nm : 250 nm between the implanted and not implanted areas of the sample into account and assuming a sinusoidal strain profile without any residual strain, a strain amplitude, $\left\langle \frac{\Delta a_{[110]}}{a_{[110]}} \right\rangle$, for the as-implanted sample was estimated to be $3..5 \cdot 10^{-3}$. This amplitude remains approximately constant up to the maximum information depth ($\sim$ 500 nm). The corresponding positive and negative orders of the grating peaks have unequal intensity. The maximum of the envelope over the grating peaks is slightly shifted towards smaller H-values for the as implanted sample (fig 1a). This indicates on a defect structure causing a residual tensile strain of $\frac{\Delta a_{[110]}}{a} = 2.5 \cdot 10^{-4}$.

The GID-curves (fig 1b) of the sample treated by RTA at $600°C$ show a decrease of the grating peaks intensities for all Λ. The corresponding grating peak intensities are significantly smaller than those of the as-implanted sample. The strain amplitude was estimated to be $1..2 \cdot 10^{-3}$. At Λ between 150 nm and 350 nm an additional tensile strained layer peak appeared with a lateral lattice mismatch of $\left\langle \frac{\Delta a_{[110]}}{a_{[110]}} \right\rangle = 1 \cdot 10^{-3}$ indicating the stopping range of the implanted Ga^{+} ions.

References

[1] N. Darowski, K. Paschke, K.H. Wang, A. Forchel, D. Lübbert, T. Baumbach, *Physica* B **248**, 104 (1998).

[2] J. Grenzer, N. Darowski, U. Pietsch, A. Daniel, S. Rennon, J.P. Reithmaier, and A. Forchel, *Appl.Phys.Lett.* **77**, 4277 (2000).