GAMMA-RAY DIFFRACTOMETRY STUDY OF CaF_2/Si(111) HETEROSTRUCTURES GROWN BY MBE

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Heterostructures CaF_2/Si(111) grown by molecular beam epitaxy (MBE) method on single crystal Si substrates of $\approx 0.5\times5\times15\ mm^3$ and $0.5\times10\times15\ mm^3$ sizes at the growth temperature $T \approx 650 - 750^oC$ have been studied.

With the purpose of the independent study of various effects causing a distortion of the crystal structure of the heterosystems, the γ-ray diffractometry experiments have been carried out in several stages. In the first place the initial Si specimens, on the second stage the same crystals which had undergone high temperature treatments in the MBE reactor without MBE process carried out, then the specimens after MBE of CaF_2 layers of different thicknesses on Si and those after the CaF_2 films having been removed from the surface of Si specimens had been investigated.

The measurements were carried out with the γ-ray diffractometer at LNPI. The method of investigation, described in detail at [1], uses Bragg diffraction of monochromatic γ-rays ($\lambda = 0.03$ Å). We have measured angular distributions of intensity (reflection curves) by ω-steps scanning in transmission Laue geometry in the central part of Si specimens. Results of the measurements are reported in [2—4].

The typical scattering curves of the (111) reflection are shown in fig. Curve *1* is used as a standard. It was measured with the high quality Si specimen. FWHM of this curve ($\approx 10''$) characterizes the angular resolution of the γ-ray diffractometer.

Curve *2* was measured with the initial specimen of Si.

For clarification of the influence of high temperature treatments in the MBE reactor by the thermal conditions analogous to ones by MBDE, the initial Si specimens had undergone various regimes of heat treatments. Curves *3* and *4* characterize specimens without CaF_2 films that have been thermally treated in the MBE reactor at temperatures of $\leq 800^o C$ and $\approx 1200^o$ C, respectively. For the specimens, having undergone heating to a temperature less than 800^o C, no decrease of the structural perfection is found. Contrary situation is observed with the crystals heated to 1100—1200° C. A strong broadening of the reflection curves and a distortion of their shapes indicates to the generation of the dislocations, non-homogeneously distributed in the volume of the specimen.

Curve *5* represents Si specimen with a CaF_2 layer of 6 *nm*, grown at about 790^o C.

Curves *6*, *7* and *8* were measured after removing the CaF_2 film. Curve *6* was measured with the same Si crystal, that curve *5*, curves *7* and *8* were measured with the specimen with the film thicknesses 18 *nm* and 30 *nm* respectively.

From the comparison of curves *6*, *7* and *8* with curve *2* and *5* we can make the following conclusions. On the specimens with minimum thicknesses of CaF_2 films $\leq 10\ nm$, their influence upon the structure perfection of the heterostructures tells upon the elastic bending of the Si substrate only. After removal of the CaF_2 layers the specimens return to the initial state completely. With the crystals with the CaF_2 films thicknesses $\approx$10—20 *nm* we observe the residual effects. Nevertheless, we can infer that with these thicknesses the main effect of CaF_2 film influence upon the CaF_2/Si(111) heterostructure is the elastic bending of the Si substrate.

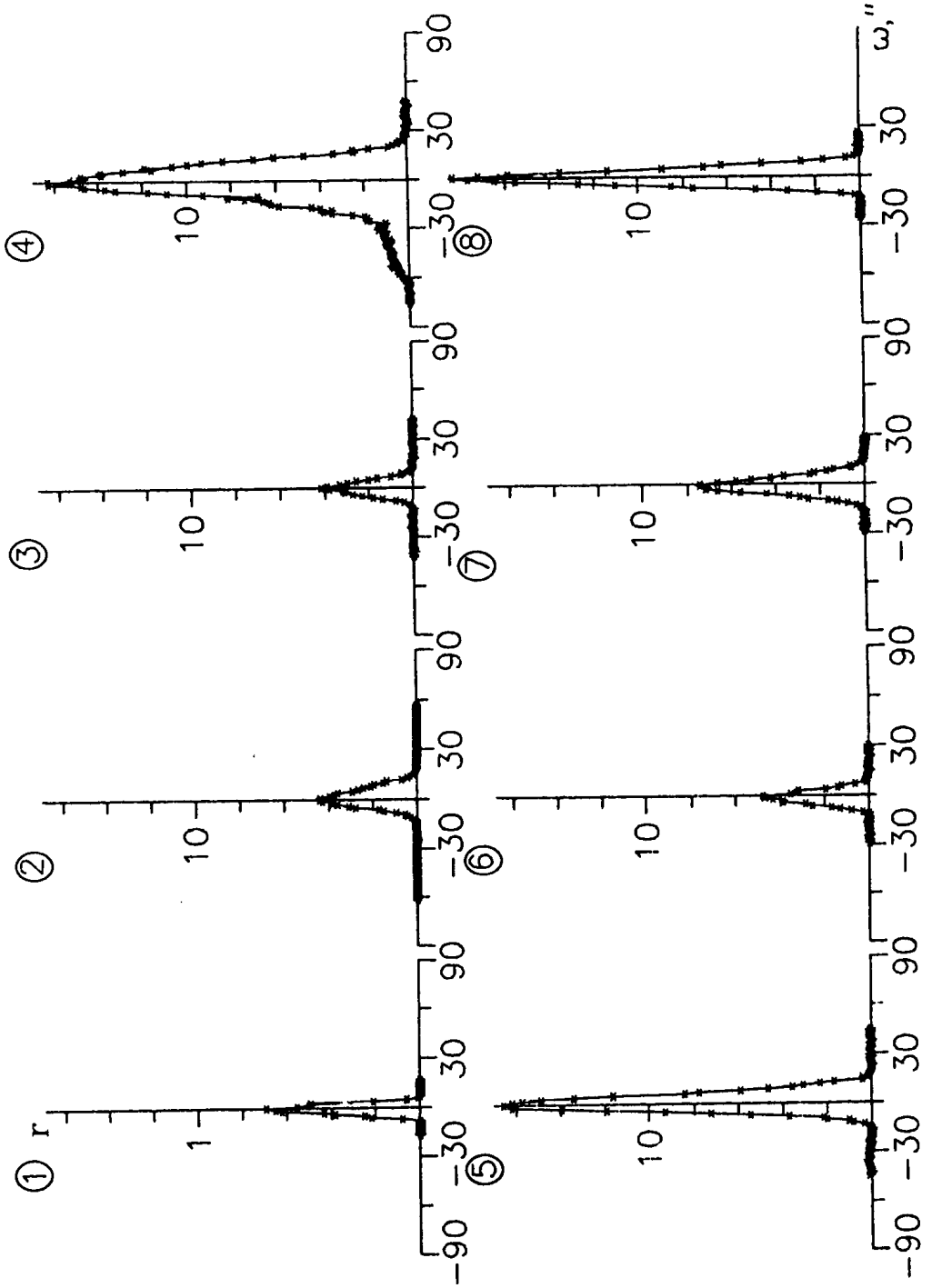

Fig.

On the contrary, the effect of bending was not principal for the specimen with the CaF_2 layer thickness 30 *nm*. After the film removal rocking curve does not change in practice. Thus with the CaF_2 layer thicknesses more than critical the process of the defect generation in the Si substrate is prinsipal.

References

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