ESRF	**Experiment title:** X-ray topography of optical wave guide strips in Zn:$LiNbO_3$ grown epitaxially on $LiNbO_3$ substrates	**Experiment number**: MA-745
Beamline: BM05	**Date of experiment**: from: 22-06-2009 to: 26-06-2009	**Date of report**: 03-10-2010
Shifts: 9	**Local contact(s)**: Dr. Jürgen Haertwig	*Received at ESRF:*

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Report:

Due to its outstanding optical and electro-optical properties, LiNbO3 is a suitable material to optical waveguide devices (such as modulators and switches) and to second-harmonic generation devices for integrated optical applications. Optical waveguides demand a well-defined modification of the local refractive index. For this purpose, Zn-doped LiNbO3 thin films with a thickness up to 4 µm were grown on standard x-cut LiNbO3 single crystal substrates by means of the liquid phase epitaxy (LPE) method. Zinc-substituted stoichiometric Zn:LiNbO3 shows an increased refraction index and also an enhanced damage threshold. However, a lattice mismatch of the epitaxial films to the substrate is the consequence of the Zn-substitution. It was assumed and also with the recently taken measurements experimentally verified [1, 2] that this lattice mismatch causes an additional inherent strain in the grown films with influence on the required refraction index.

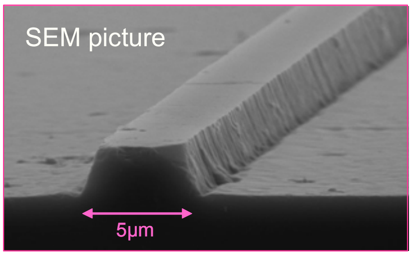


Fig. 1: Zn:LiNbO3 rib waveguide, produced by ICP-RIE etching technique

[1] J. Kraeusslich et al. Report to the ESRF experiment SI-1346 at BM20

[2] J. Kraeusslich, C. Dubs, A. Tünnermann: phys. stat. sol. (a) 204, No. 8, 2585 (2007)

The original aim of the planned experiment was to characterize, with lateral two-dimensional resolution, epitaxially grown and subsequently structured Zn:LiNbO3 thin films (Fig. 1) by using the high resolution plane wave X-ray topography (double-crystal topography). X-ray transmission topograms taken up at different working points of the rocking curve should give direct information about the in-plane strain components because the diffraction vectors are parallel to the lateral deformation vector components, quite contrary to topograms recorded in the reflection mode.

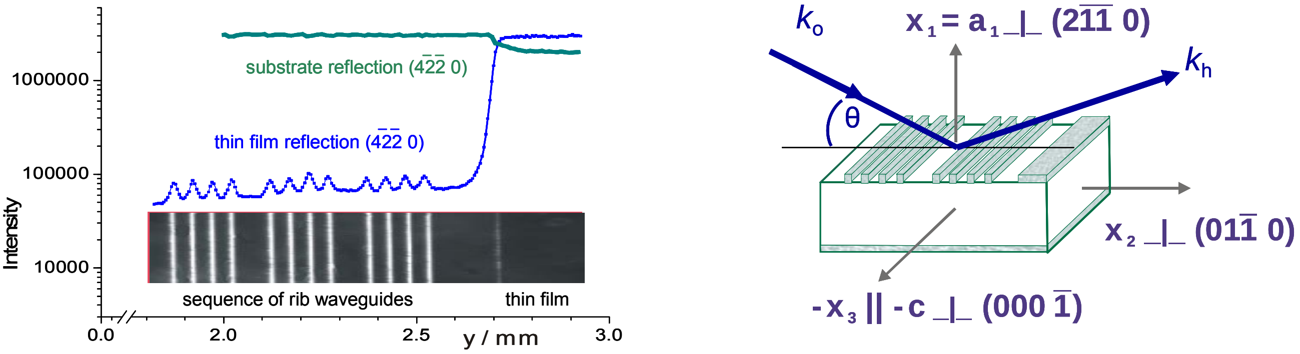


Fig. 2: Lateral y-scan taken with the symmetric 4-2-2 0 thin film and substrate reflection, respectively. A real dimension photo of the sample is shown in the insert. On the left side sequences of rib waveguides are seen whereas on the right side still the homogeneous thin film is still there.

To generate a nearly perfect plane wave across the whole sample for the plane-wave X-ray topography, the divergence of the x-ray beam, oncoming from the point source, must be compensated by a suitably bended monochromator crystal. In principle this possibility is given at beamline BM 05 of the ESRF because there is only there a such unique high-resolution plane-wave double-crystal X-ray topography device. Unfortunately this equipment was not operational during our stay. Our topograms had to be taken up with slight divergent X-ray waves which scan the whole rocking curve. Therefore we have a modulation of the intensity and the restriction of the visual field and also an alteration of the sensitivity.

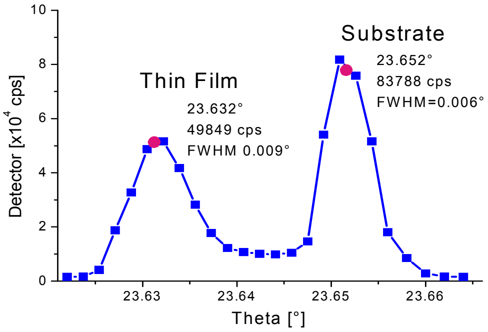
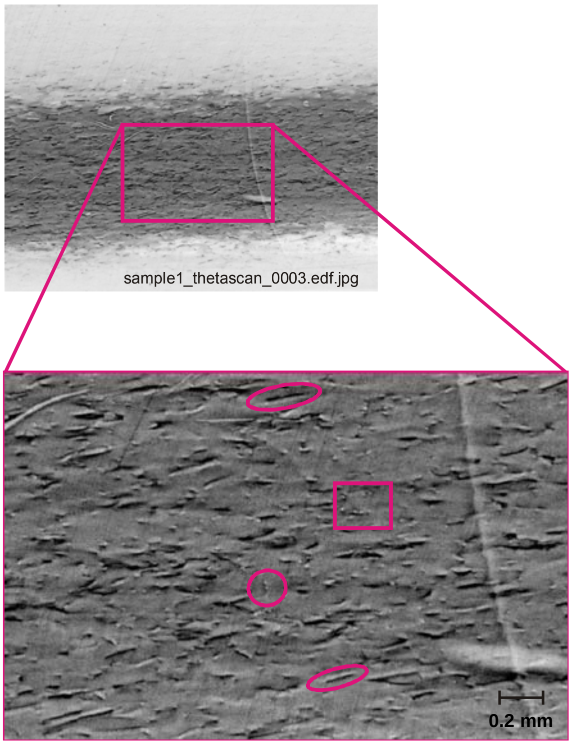


Fig. 3: Rocking curve of Zn:$LiNbO_3$ thin film homogeneously grown on x-cut $LiNbO_3$ substrate

● this flags the used operating points



In the magnified detail of Fig. 4 are to be seen:

→ dislocation lines running through the crystal (⬭)

→ image contrast reversal due to the rising and sloping part of the rocking curve (⬭)

→ high-contrast breaking points of the dislocations running nearly perpendicular through the crystal (○)

→ density of dislocations: nearly 250 cm^{-2} (□)

Fig. 4: High resolution XRD topogram of Zn:$LiNbO_3$ thin film homogeneously grown on x-cut $LiNbO_3$ substrate, symmetric 6-3-3 0 reflection, λ=0.062nm. The vertical intensity modulation is caused by the X-ray beam divergence.

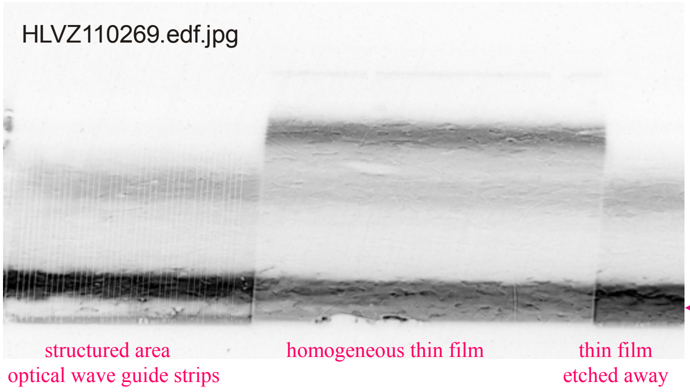


Fig. 5: High resolution XRD topogram of the epitaxially grown (in the middle) and subsequently structured (left side) Zn:$LiNbO_3$ thin film recorded with the symmetric 6-3-3 0 reflection (λ=0.062nm). Here the sample adjustment fulfils the operating point lying on the substrate maximum of the rocking curve (Fig. 3).

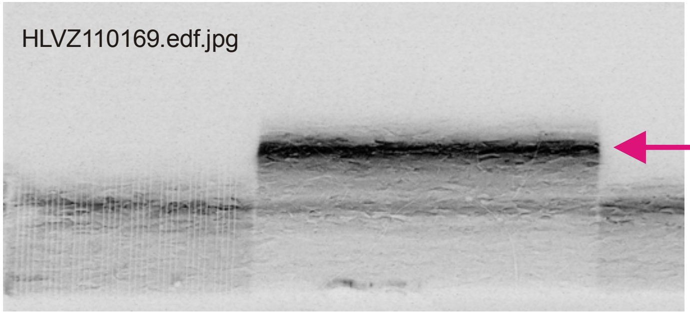


Fig. 6: High resolution XRD topogram recorded with operating point lying on the thin film maximum of the rocking curve (Fig. 3). The optical wave guide strips (left side) should show a dark contrast similar to the contrast of the homogeneous thin film.

→ The bright contrast of the wave guide strips could be caused by an additional ´self-absorption´ of the strips and/or by a local breakdown of the diffraction conditions.

Unfortunately, the desired strictly plane waves for X-ray diffraction topograms at differently operating points could not be used during our stay.

We thank all members of the beamline team BM 05 for the helpful support at the time of realization this experiment.