Vol. 92 (1997) *ACTA PHYSICA POLONICA A* No. 1

Proceedings of the ICSC–F'96 Jaszowiec '96

HIGH QUALITY (100) AND (001) ORIENTED SUBSTRATES PREPARED FROM CZOCHRALSKI GROWN $SrLaGaO_4$ AND $SrLaAlO_4$ SINGLE CRYSTALS

M. Berkowski, J. Fink-Finowicki

Institute of Physics, Polish Academy of Sciences
Al. Lotników 32/46, 02-668 Warsaw, Poland

J. Sass and K. Mazur

Institute of Electronic Materials Technology, Wólczyńska 133, 01-919 Warsaw, Poland

The growth of $SrLaGaO_4$ and $SrLaAlO_4$ crystals on ⟨100⟩ and ⟨001⟩ oriented seeds was investigated. Various defects, which appeared in crystals grown on these two orientations, were observed in polarized light and by X-ray diffraction topography. It was found that to obtain a substrate of the best quality, the crystal should be cut along the growth directions. Therefore, crystals pulled along ⟨100⟩ direction are utilized for preparation of (001) substrates, whereas (100) substrates are better to cut from crystals grown on ⟨001⟩ seed. The quality of the prepared substrates was determined by high resolution X-ray diffraction study in terms of rocking curve and mean mosaic angle.

PACS numbers: 81.10.Fq, 68.35.Bs, 61.50.Ks

1. Introduction

Single crystals with tetragonal structure of K_2NiF_4-type ($I4/mmm$) were proposed for the first time as substrates for HTSC epitaxy [1] because of their suited dielectric properties and the lack of phase transitions. $SrLaAlO_4$ and $SrLaGaO_4$ are currently considered [2–6] as some of the best substrate materials for the epitaxy of high-T_c superconductors. Taking into account the small mismatch between the substrate and HTSC layers, the application areas include:

— (001) oriented $SrLaGaO_4$ for the deposition of YBaCuO [2, 3], and 1212 and 1223 phases of Hg based superconductors [4] with c-axis perpendicular to the substrate surface,

— (100) oriented $SrLaGaO_4$ for the deposition of YBaCuO [5], and 1212 mercury films with c-axis parallel to the substrate surface,

— (001) oriented $SrLaAlO_4$ [6] for the deposition of $La_{2-x}Sr_xCuO_4$.

2. Experiment and results

Single crystals of $SrLaGaO_4$ and $SrLaAlO_4$ were obtained by the Czochralski method using a modified Malvern MSR-4 device. The crucible weighing system was used for the automatic crystal diameter control. An iridium crucible of 50 mm in diameter was used. A long active afterheater placed directly on the crucible and covered with a ring disc was used to minimize the vertical temperature gradient. We investigated the growth of these crystals on ⟨100⟩ and ⟨001⟩ oriented seeds. Single crystals, obtained at low seed rotation rate and typical thermal configuration, keep convex crystal–melt interface during the growth. For both seed orientations, the central part of the crystal (core region — about 25% of the crystal diameter) has lattice parameters slightly different from that in the outer part (facets region) which result in the creation of internal stresses.

Single crystal obtained on a ⟨100⟩ oriented seed has almost elliptical cross-section. At its circumference, parallel to the longer axis of this ellipse two (001) facets occur. On the remaining part of circumference (101) and (103) facets appear. They are much less developed than the (001) planes. In the central part of the crystal grown on a ⟨100⟩ oriented seed two types of (101) planes appear on the crystal–melt interface. The boundary between these planes corresponds to the (001) cleavage plane. Various defects, which appear in crystals grown with this

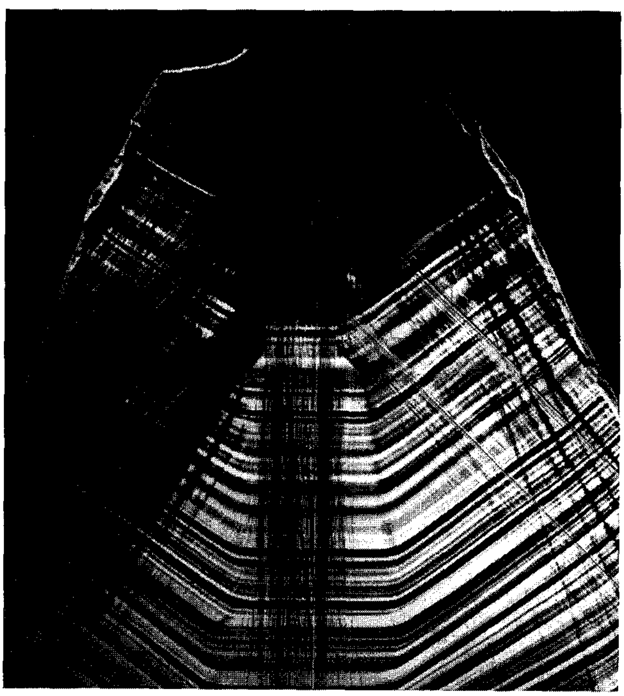

Fig. 1. X-ray diffraction topography. Slice cut parallel to the (001) plane from the initial part of $SrLaAlO_4$ crystal grown on ⟨100⟩ oriented seed.

orientation, were observed in polarized light as well as by X-ray diffraction topography. For the sample cut from the initial part of the $SrLaAlO_4$ crystal parallel to the (001) plane, the growth striations, indicating the shape of crystal–melt interface, are shown in Fig. 1. In the core region many dislocations, propagating from the seed along the crystal growth direction, are visible. Crystal quality in the core region is closely related to the seed quality and the procedure used to the start of the crystal growth. Dislocations and defects of the crystal structure in the seed used for crystal growth are very well visible in core region both, in samples cut parallel and perpendicular to the growth direction. X-ray diffraction topography of slices cut from the crystal perpendicularly to the growth direction shows the core region in the central part of the crystal, very often with well visible lines corresponding to stacking faults. Internal stresses resulting from the difference in the chemical composition of core and faceted regions sometimes cause small cracks parallel to the cleavage plane.

The shape of the cross-section of a single crystal obtained on ⟨001⟩ oriented seed is a square with cut corners. The larger planes of the crystal surface correspond

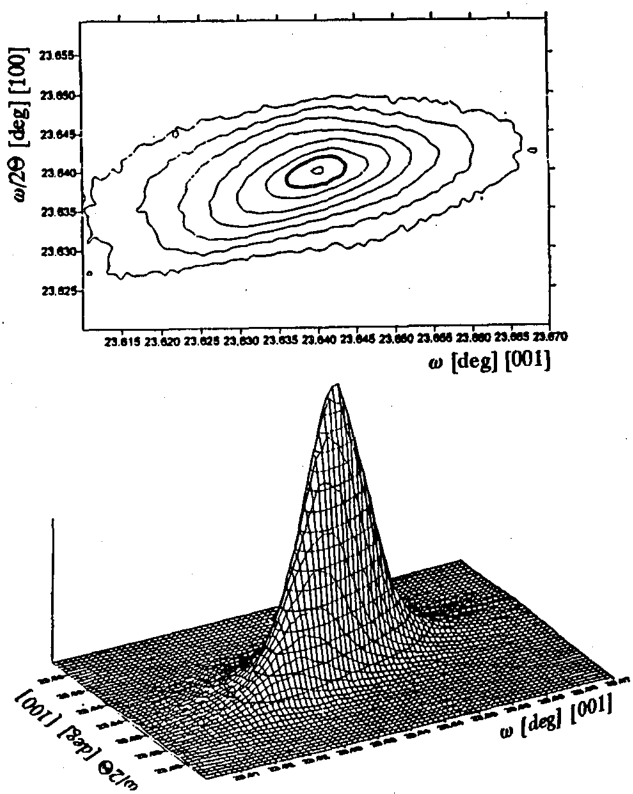

Fig. 2. Reciprocal lattice mapping of $SrLaGaO_4$ (100) oriented substrate, (200) reflection, Cu K_α radiation.

to the (100) planes and the smaller ones to (110). In the crystal grown on ⟨001⟩ oriented seed one (001) plane and four (103) type planes appear on the crystal–melt interface. In this crystal the core region is formed by the central part grown on the (001) plane whereas the outside faceted region consists of four (103)-type planes.

The quality of the prepared substrates was determined by high resolution X-ray diffraction study in terms of rocking curve and mean mosaic angle. Typical results, obtained on the $SrLaGaO_4$ crystal with the substrate orientation (100) are presented in Fig. 2. The theoretical value of the full width at half maximum of the rocking curve, obtained for the (200) reflex is 12.0 arcsec and for (006) reflex it is 9.3 arcsec, the experimental values measured on (100) substrates are in the range of 13 to 24 arcsec and on (001) substrates are 13 to 22 arcsec. The experimental values of mean mosaic angle for (100) and (001) substrates are in the range of 25 arcsec to 30 arcsec and 20.5 arcsec to 23 arcsec, respectively.

For single crystals with small core dimensions it was found that substrates of the best quality can be obtained when the crystal is cut along the growth direction from the faceted region. Therefore, crystals pulled along the ⟨100⟩ direction are used for preparation of (001) substrates, whereas the (100) substrates should be cut from crystals grown on ⟨001⟩ seed.

Acknowledgments

This work was partially supported by the Commission of the European Communities under contract CIPA-CT93-0032.

References

[1] M. Berkowski, A. Pajączkowska, P. Gierłowski, S.J. Lewandowski, R. Sobolewski, B.P. Gorshunov, G.V. Kozlov, D.B. Lyudmirski, O.I. Sirotinsky, P.A. Saltykov, H. Soltner, U. Poppe, *Appl. Phys. Lett.* **57**, 632 (1990).

[2] S. Hontsu, N. Mukai, J. Ishii, T. Kawai, S. Kawai, *Appl. Phys. Lett.* **64**, 779 (1994).

[3] A.W. McConnell, R.A. Hughes, A. Dąbkowski, H.A. Dąbkowska, J.S. Preston, J.E. Greedan, T. Timusk, *Physica C* **225**, 7 (1994).

[4] R. Gatt, E. Olsson, T. Cleason, R. Plewe, L.G. Johansson, A. Morawski, T. Łada, A. Paszewin, R. Moliński, H. Marciniak, M. Berkowski, in: *Applied Superconductivity 1995*, Ed. D. Dew-Hughes, Institute of Physics Publishing, Bristol 1995, p. 801.

[5] M. Mukaida, S. Miyazawa, *Appl. Phys. Lett.* **63**, 999 (1993).

[6] M.Z. Cieplak, M. Berkowski, S. Guha, E. Cheng, A.S. Vegalos, D.J. Rabinowitz, B. Wu, I.E. Trofimov, P. Lindenfeld, *Appl. Phys. Lett.* **65**, 3383 (1994).