Optical Waveguiding in Ferroelectric $Na_{0.5}K_{0.5}NbO_3$ Thin Films

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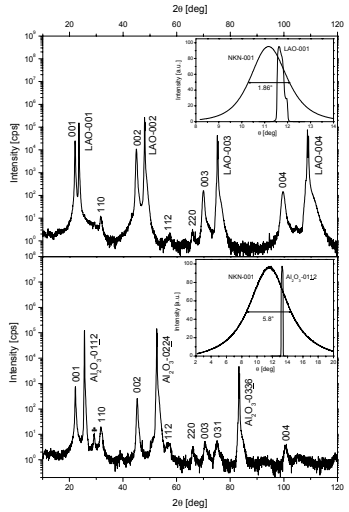
Rf-magnetron sputtering system

- High-density stoichiometric target.
- 60 W rf power and on-axis geometry.
- Substrate temperature 650 °C.

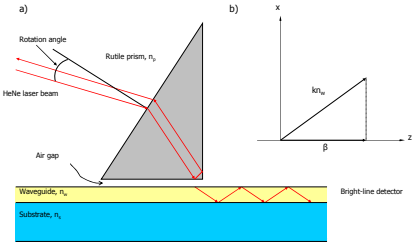
Objective

- High-quality ferroelectric thin films are promising materials for integrated optics applications, such as electro-optic waveguide modulators and frequency-doubling second-harmonic generators.
- Perovskite-structured $Na_{0.5}K_{0.5}NbO_3$ (NKN) films, which are in ferroelectric state at room temperature, have been investigated as an electrically tunable material for low loss rf and microwave applications [2], and the material should exhibit large electro-optic coefficients and high optical transparency.
- In this poster I show structural and waveguiding [1] results of NKN films grown by rf-magnetron sputtering on $LaAlO_3$(001) and Al_2O_3(01$\bar{1}$2) substrates.



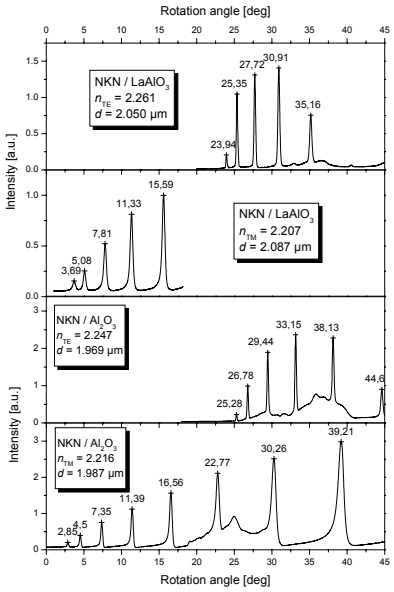
Structural properties by XRD

- Upper: 2.0 µm NKN/LAO, epitaxial growth
- Lower: 2.0 µm NKN/sapphire, preferential (00*l*)



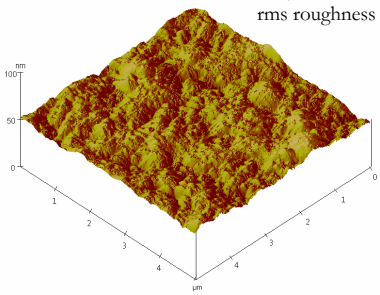
Prism-coupling technique

He-Ne laser focused on a rutile prism with high refractive index. The prisms is pressed against the thin film surface. When the horizontal component of the wave vector of the laser beam inside the prism matches the propagation constant of a waveguide mode in the film part of the light is coupled into the film. Measuring the light intensity at the edge of the waveguide and plotting it versus the rotation angle of the incident light, a bright-line mode spectrum is acquired, where the peaks corresponds to guided modes.
With two or more guided modes in the spectrum, a least mean square fit is used to calculate the thickness and refractive index of the thin film. Having the laser tilted at 45°, the beam can be polarized either with the electrical field in plane of the film (TE mode) or perpendicular to the film surface (TM mode).

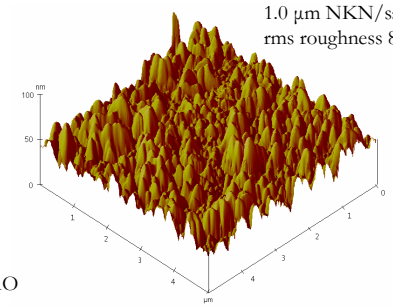


Bright-line spectra at λ=632.8 nm

- Transverse Electric (TE) and Magnetic (TM) modes.
- Birefringence Δn = -0.054 ± 0.003 for 2.0 µm NKN/LAO and Δn = -0.031 ± 0.003 for 2.0 µm NKN/sapphire. The disparity is attributed to the difference in crystalline quality.



1.0 µm NKN/LAO
rms roughness 2.5 nm



1.0 µm NKN/sapphire
rms roughness 8.0 nm

Surface morphology by AFM

References

[1] M. Blomqvist, S. Khartsev, A. Grishin, A. Petraru, and Ch. Buchal, "Optical waveguiding in magnetron-sputtered $Na_{0.5}K_{0.5}NbO_3$ thin films on sapphire substrates", *Appl. Phys. Lett.* **82**, 439-441 (2003).
[2] M. Blomqvist, J.-H. Koh, S. Khartsev, A. Grishin, and J. Andréasson, "High-performance epitaxial $Na_{0.5}K_{0.5}NbO_3$ thin films by magnetron sputtering", *Appl. Phys. Lett.* **81**, 337-339 (2002).

Conclusions

- Rf-magnetron sputtered $Na_{0.5}K_{0.5}NbO_3$ on $LaAlO_3$ and sapphire substrates were compared.
- XRD revealed epitaxial films on LAO and preferentially (00*l*) oriented films on sapphire.
- Planar waveguiding was shown by a prism-coupling technique, with refractive index of NKN films between 2.2 and 2.3.
- Birefringence as high as Δn = -0.054 for the epitaxial NKN/LAO film.
- Surface morphology by AFM showed lower rms roughness for the NKN/LAO structure.
- These results show the potential use of rf-sputtered NKN films as electro-optical material.

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