Ellipsometric imaging of $LiNbO_3$ optical waveguides

S. Margueron[1], P. Thiesen[2]

[1] FEMTO-ST institute, UBFC-CNRS-ENSMM, 26 rue de l'épitaphe, 25000 Besançon France
[2] Accurion GmbH - Stresemannstraße 30 - 37079 Göttingen, Germany

Visible and ultraviolet ellipsometric imaging of $LiNbO_3$ of proton exchange waveguides are presented. Imaging of 8 µm waveguides with nanochromat x7 objective shows resolution of about 2 to 3 µm in deep ultraviolet. Dispersion analysis of doped and undoped regions shows high sensitivity near optical band gap with a widening of optical gap and a decrease of the dipole strength of the charge transfer transition $p^6d^0 \rightarrow p^5d^1$. The dispersion of optical transition decreases the optical index favoring the guiding effect in the visible to infrared domains.

The integrated optics requires negative variation of the index of refraction in the core of the waveguide $\Delta n<0$. Among materials, $LiNbO_3$ waveguides represents the most developed technology for opto-electronic modulators. Waveguides are patterned by severable techniques such as proton exchanges (PE) or diffusion of transition metals such as titanium. Microfabrication processes and heat treatments are essential to create guiding effects with germane thicknesses and index profile that generate low-loss waveguides. Meanwhile, the development remains empirical and the control techniques are usually realized by m-lines on fully diffuse surfaces or by controlling the final devices performances. In this context, the present paper analyzes the use of ellipsometric imaging technique for performing non-destructive and on-line characterizations.

Proton exchange waveguides of 8 µm wide were imaged with EP4 model (Accurion GmbH) from 200 to 400 nm with nanochromat x7 objective. The optical waveguides are analyzed in the visible and ultraviolet ranges in surface reflection with Knife-edge-illumination to prevent wafer back- reflection. No interferences are observed due to the waveguide as the Δn is weak and the ellipsometric data are supposed to originate only from the surface properties. Fig 1a presents psi contrast at 250 nm in false colors. The lateral resolution is of the order of 2 to 3 µm. Fig 1b present the refractive index calculated by direct converting delta and psi to n and k. The dispersion of the refractive index is more pronounce in deep ultraviolet with the band gap than in the visible range. One can observe a decrease of the dipole strength of absoprtion of p^6d^0 to the multiplet p^5d^1. The edge of the band gap broaden also below the band gap which may originate from defect and disorder induced by the proton exchange. Current work investigate the nature of the band such as Urbach tail (due to charged defects in non stoichoimetric sample) and indirect gap transition.

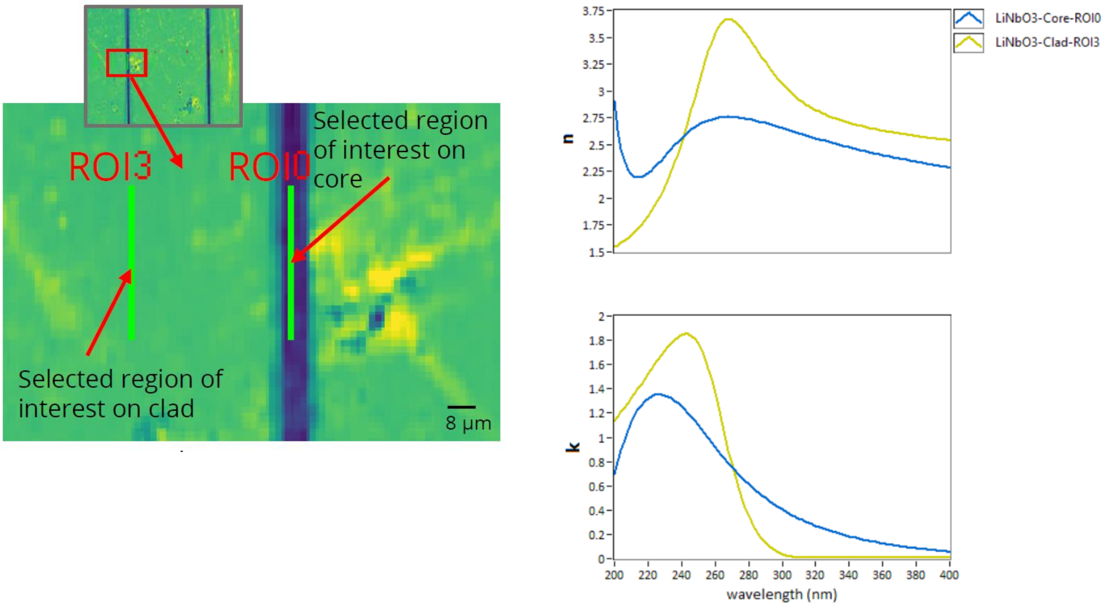

Fig 1 ellipsometric imaging with EP4_model of proton exchange waveguide a) Psi map at 250 nm b) refractive index between 200 and 400 nm