TOMOGRAPHY OF POLARON LUMINESCENCE IN LiNbO_3 : APPLICATION TO THE CHARACTERISATION OF OPTICAL GUIDES AND INTEGRATED OPTICAL DEVICES

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LiNbO_3 (LN) is now considered to be the best dielectric materials for integrated optics because of its wide transparency range from visible to IR, its large electro-optic and acousto-optic coefficients, and its unique capability to achieve low-loss optical waveguides (~ 0.1 dB/cm) in the telecom bands. In LN optical waveguides, the titanium diffusion is known as the more suitable technique to obtain waveguides that support both TE and TM propagation. The reproducibility of titanium distribution and its uniformity along guiding axis are key points for achieving low-loss LN:Ti waveguides of constant characteristics.

Figure 1 : Raman spectra and luminescence band in LN congruent crystal.

These optical guides are usually fabricated on commercially available LN crystal of congruent composition (48.38 mol% Li_2O + 51.62 mol% Nb_2O_5) grown by the conventional Czochralsky method. Li deficiently in this congruent composition corresponds to a proportional amount of intrinsic point defects. Some Nb ions occupy Li sites (antisite defects Nb_{Li}) and for the charge compensation cationic vacancies are always present [1]. The quality and the electro-optical properties of the modulators, in particular the Mach-Zehnder Integrated modulators (MZI), depend to a large amount of these defects.

The studies carried out in particular on these LN MZI showed that the conditions of diffusion annealing are also of a great importance on the electric drift of these components.

The origin of this DC drift is probably linked to the gradient of electrical conductivity in the waveguides and their

surrounding area. We show that in LN crystal the electrical conductivity is closely related to the chemical reduction of the material. It is known that the antisites Nb_{Li} are able to trap electrons, this trapping of only one electron by the antisites gives the simple polaron (SP) $\text{Nb}_{\text{Li}}^{4+}$. The trap of a second electron by the simple polaron gives the bipolaron (BP) $\text{Nb}_{\text{Li}}^{4+}\text{-Nb}_{\text{Nb}}^{4+}$. The total concentration of trapped electron gives the degree of chemical reduction of material. It is the concentration of the polarons and bipolarons which, in the absence of impurities, is only responsible for absorption in the visible and near-IR ranges, as well as for electrical conductivity. In LN materials, excepted for the strict stoichiometric composition, the polarons give a very intense and broadband luminescence, extending from 700 to 950 nm (see figure) [2].

We propose in this paper a fast, sensitive and reliable technique of characterisation based on micro-spectroscopy (Raman and polaron luminescence), which allows at the determination of the chemical reduction profile after titanium diffusion or other high-temperature annealing treatments, and thus to the electrical conductivity, in the section of the waveguides. This profile allows us to predict the DC drift of active components using the electro-optical effect. Moreover, coupled with confocal microscopy, this technique can give 2D and 3D maps of a waveguide at micro scale.

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