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Examinations of High-Temperature Properties of Stoichiometric Lithium Niobate

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Non-stoichiometric lithium niobate has lithium contents of 46 – 49 % Li_2O and can be applied for surface acoustic wave devices and guided-wave optics because of its excellent piezoelectric and optical properties, respectively. However, when non-stoichiometric lithium niobate is heated to higher temperatures, the lithium content in the crystal decreases leading to its decomposition. Lithium niobate with stoichiometric ratios of lithium and niobium was prepared by different research groups [1,2]. Several companies supplied samples for the experiments, all of which promised a lithium content of 50 % Li_2O; DelMar Photonics (USA), Crystal Technology (USA), OXIDE (J) and Hungarian Academy of Sciences (H).

An analysis of the lithium content in the different samples is performed using UV-Vis spectroscopy. The absorption edge for the absorptivity of lithium niobate at $\alpha = 20\ \mathrm{cm}^{-1}$ is known to give information about the lithium content in the sample [3,4]. Fig. 1 shows the results for the different samples and their lithium content determined from the absorption edge. For the analysis of lithium loss from high-temperature treatment, the crystals were heated to 900 °C in ambient air for 24 h. Absorption measurements and secondary ion mass spectroscopy indicate no lithium loss within the accuracy of the instruments [5].

Samples with 49.0 % Li_2O (Del Mar) and 49.7 % Li_2O (CrysTech) are analyzed using impedance spectroscopy in order to determine the electrical conductivity. Fig. 2 shows the temperature dependent conductivity graph and the different activation energies of the lithium niobate samples. The sample containing less lithium has an activation energy 0.29 eV greater than the samples with higher lithium content (for $T \leq 750$ °C). The difference in conductivity might be related to oxygen vacancies in the lattice and explained by the following equation involving antisite defects:

$$\mathrm{Nb_{Nb}} + 2\mathrm{O_O} + \mathrm{Li_3NbO_4} \rightleftharpoons \mathrm{Li}_{\mathrm{Nb}}^{\prime\prime\prime\prime} + 2\mathrm{V}_{\mathrm{O}}^{\bullet\bullet} + 2\mathrm{LiNbO_3}$$

The preliminary results underline the potential of stoichiometric $LiNbO_3$ for high-temperature applications. Detailed investigations of transport phenomena, defect chemistry and electromechanical properties will be performed as subject of an ongoing research project.

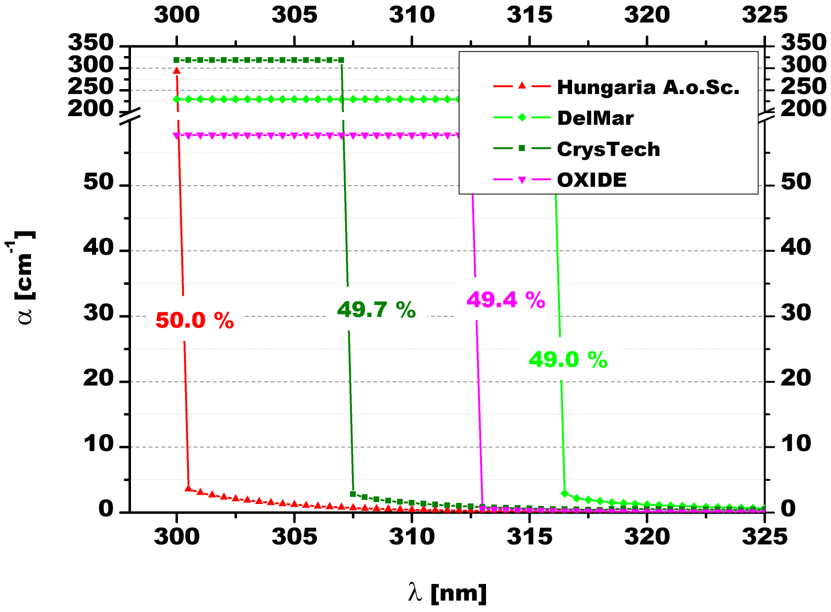

Fig. 1 Li$_2$O content of different lithium niobate samples determined from the absorption edge (α = 20 cm^{-1}).

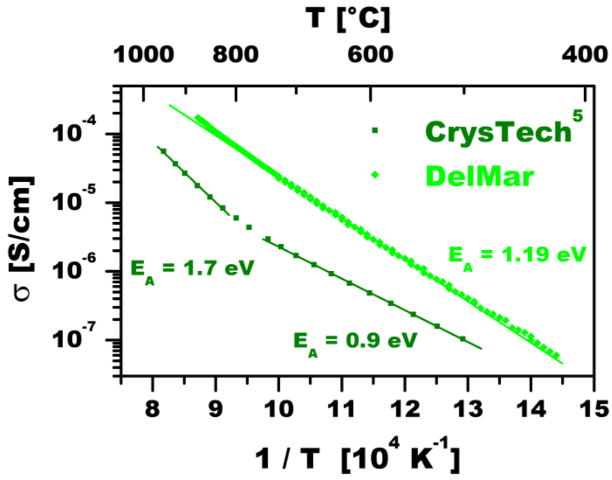

Fig. 2 Temperature dependence of the ionic conductivity for LiNbO$_3$ with different Li$_2$O contents.

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