

Black Lithium Niobate

Chemically Reduced Lithium Niobate: Processing, Properties and Improvements in SAW Device Fabrication and Performance

Lithium niobate (LN) single crystals find wide application as substrates for surface acoustic wave (SAW) devices. This material's large piezoelectric coefficients enable fabrication of SAW filters with low insertion loss. The optical transparency and pyroelectric response of LN may, however, cause problems in its processing and application.

The high pyroelectric constant makes LN susceptible to charging upon undergoing temperature changes. These surface charges can spontaneously short, with the associated sparking causing processing or operational failures. Common processes such as photoresist baking or wire bonding can induce such discharges. For finished SAW devices, discharges due to changes in ambient temperature can produce undesired voltage spikes as seen in Figure 1.

Reduction processing generally is applied to LN after growth and poling. The degree of reduction depends on the reduction temperature and gas atmosphere, as well as the crystal's surface roughness, Li/Nb composition and sample size. For these experiments, lapped 128° RY LN wafers of congruent composition were reduced in an atmosphere of 10% H₂ and 90% N₂ for one hour at temperatures ranging from 400°C to 750°C. After reduction, wafers were polished on both sides and analyzed electrically and optically.

To test reduced LN wafers' susceptibility to pyroelectric charging, wafers were cooled on a hot plate from 120°C to 80°C at 10°C/min. while the surface charge was monitored using an electric field meter. For untreated LN wafers such a procedure typically generates a surface field of 2 kV/cm, which requires several hours to dissipate. As shown in Figure 2, none of the reduced wafers showed any measurable electric field.

SAW filters with a center frequency of 78 MHz were fabricated at Andersen Laboratories from several reduced as well as untreated wafers. Center frequency, insertion loss, SAW velocity and temperature coefficient of reduced LN were the same as untreated LN under normal operating conditions.

We gratefully acknowledge Ray Sawin and Jeff Galipeau of Andersen Laboratories for fabrication and testing of the SAW samples.

References:

Bordui, P.F. et al., J. Appl. Phys., (1999). 85(7): p. 3766-3769.
Standifer, E.M. et. al., Proceedings of the 1998 International Frequency Control Symposium. (1998).

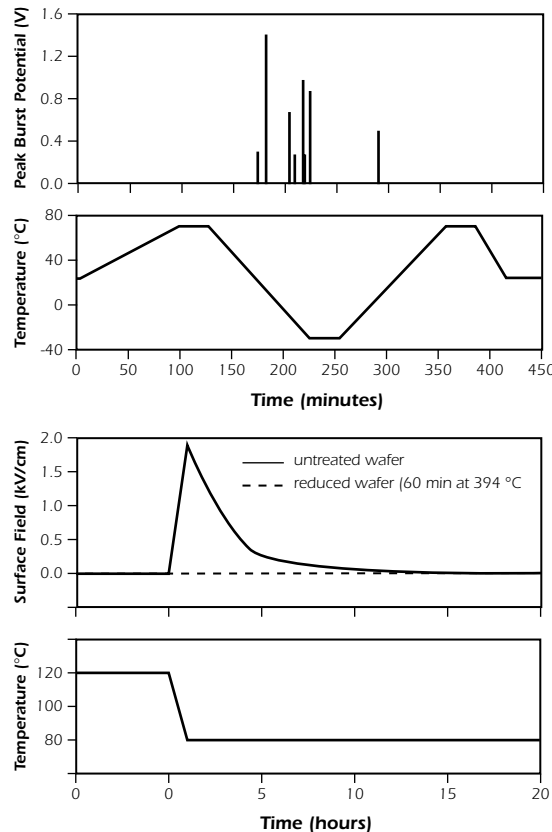


Figure 1. Pyroelectric test results for SAW devices fabricated on untreated LN. The lower graph shows the temperature ramp used for the test. The upper graph shows the peak burst voltages for the observed pyroelectric discharges. Eight burst were detected. On treated LN, no bursts were observed.

Figure 2. Surface electric field upon cooling such as is typical during processing. Solid line: untreated LN. Dashed line: LN reduced at 394°C for 1 hr.