



**HAL**  
open science

## Investigation of the limit operating temperature of LiNbO<sub>3</sub> as substrate for SAW devices

Jordan Maufay, Thierry Aubert, Ninel Kokanyan, Cécile Floer, Sami  
Hage-Ali, Omar Elmazria

► **To cite this version:**

Jordan Maufay, Thierry Aubert, Ninel Kokanyan, Cécile Floer, Sami Hage-Ali, et al.. Investigation of the limit operating temperature of LiNbO<sub>3</sub> as substrate for SAW devices. IEEE International Ultrasonics Symposium, Sep 2020, Las Vegas (Virtual), United States. hal-03029837

**HAL Id: hal-03029837**

**<https://hal.science/hal-03029837v1>**

Submitted on 16 Dec 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## Background, Motivation and Objective

- SAW sensors are very good candidates to face the challenges of measurements in **harsh high temperature** environments
  - Wireless
  - Battery-free
- $\text{LiNbO}_3$ -based SAW Reflective Delay Lines (RDLs) operating up to  $400^\circ\text{C}$  have been on the market for more than ten years
- This temperature limitation is due to :
  - Degradation of the electrodes
  - Lithium triniobate ( $\text{LiNb}_3\text{O}_8$ ) segregation
- In this study, we suggest to re-explore :
  - The **segregation process** of congruent  $\text{LiNbO}_3$  crystals (cLN)
  - The **influence of the electrodes' nature**
  - Their impact on the SAW devices' performances

## Statement of Contribution/Methods

### Step #1:

- 150nm-thick aluminum or platinum films
- Y128 cLN** substrates
- Reflective delay lines (Fig.1) with connected interdigital transducers (IDTs) [1]
- Resonance frequency = 433 MHz

### Step #2

- Annealing in air atmosphere → **48 hours** at various temperatures ranging from  **$400$  to  $700^\circ\text{C}$** 
  - **Electrically characterized**
  - **X-ray diffraction** → Investigate the lithium triniobate ( $\text{LiNb}_3\text{O}_8$ ) formation and the phase evolution of the metallic IDTs.

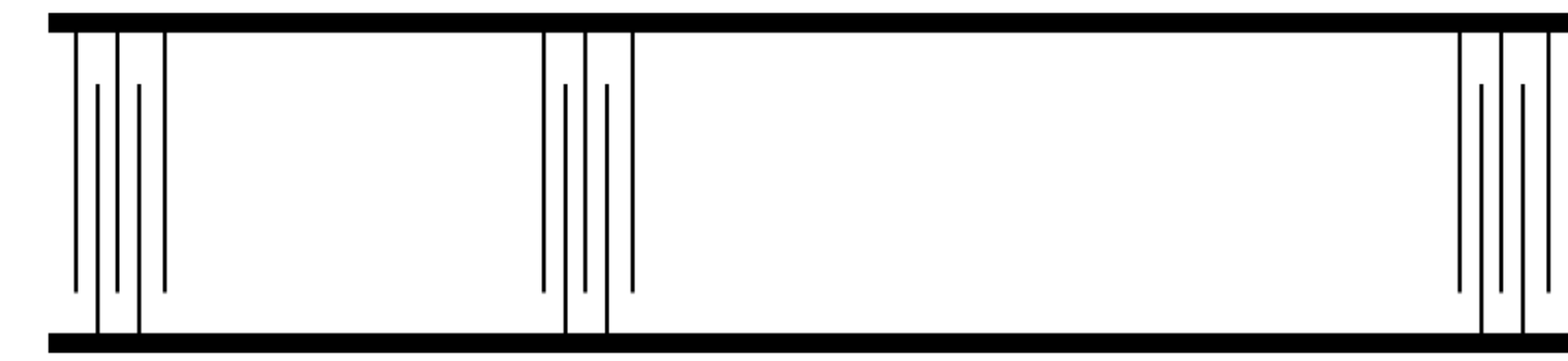


Figure 1: Reflective delay lines (RDL) with 3 connected IDTs design [1]

## Results, Discussion and Conclusions

- Formation of  $\text{LiNb}_3\text{O}_8$  observed after a 2-days annealing period at a temperature of  $500^\circ\text{C}$  (Fig.2).
- $\text{LiNbO}_3$  peak is not affected by the annealing process.

- Segregation kinetics depends on :
  - **The annealing temperature**
  - **The nature of the electrodes.**

### Aluminum electrodes

- Annealing at  $400^\circ\text{C}$  has almost no destructive effect on the device response (Fig.3). Whereas from  $500^\circ\text{C}$  onwards → Degradation due to :
  - Alumina ( $\text{Al}_2\text{O}_3$ ) formation
  - **Dewetting effect**
- Annealing at  $600^\circ\text{C}$  :
  - Irreversible **frequency shift**
  - Strong **visual degradation** of the electrodes
- Limit for aluminum IDTs → Between  $400$  and  $500^\circ\text{C}$  for an operation period for several days

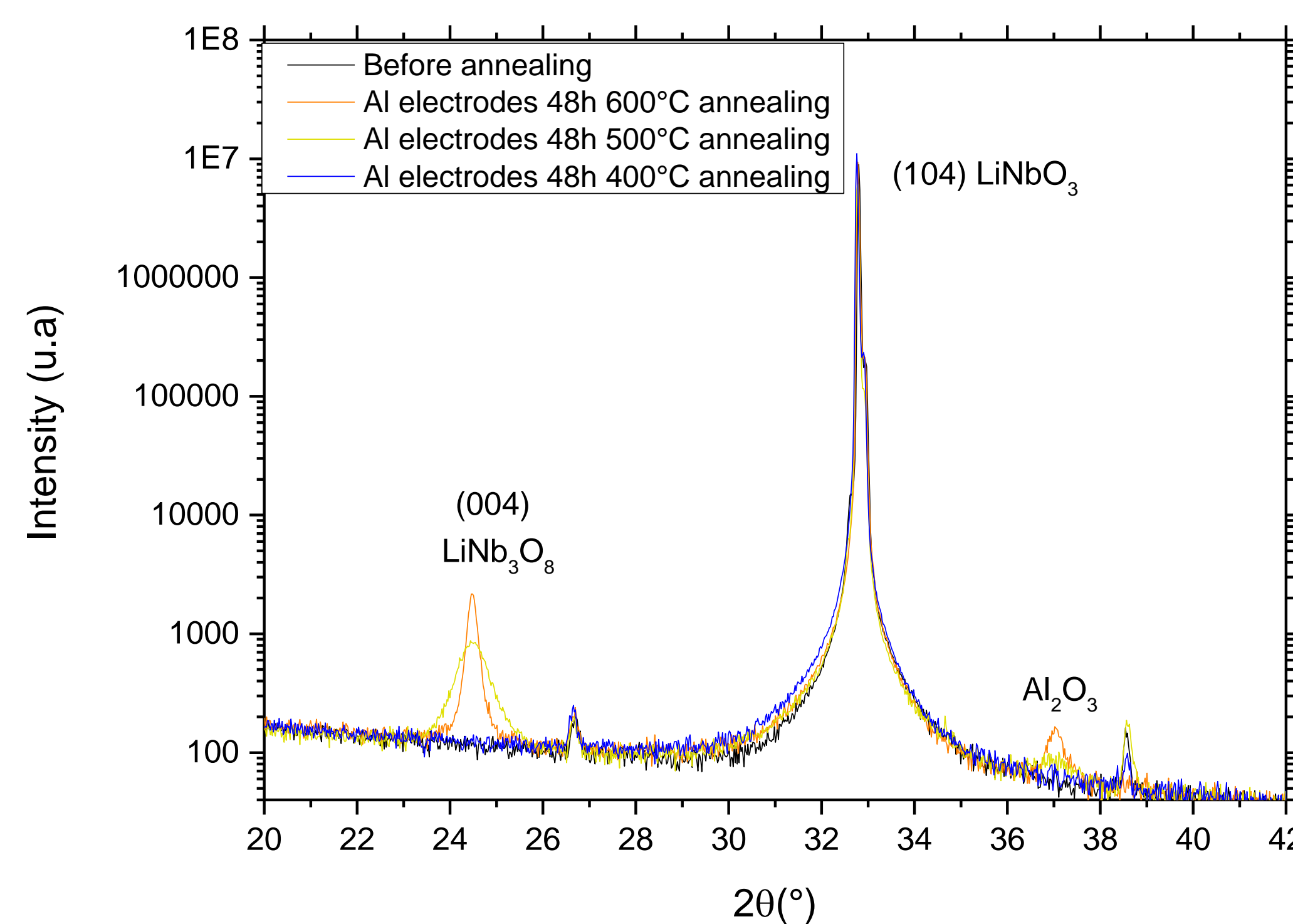


Figure 2 : X-ray diagram of LN Y-128, before and after annealing with and without Al IDTs on the top.

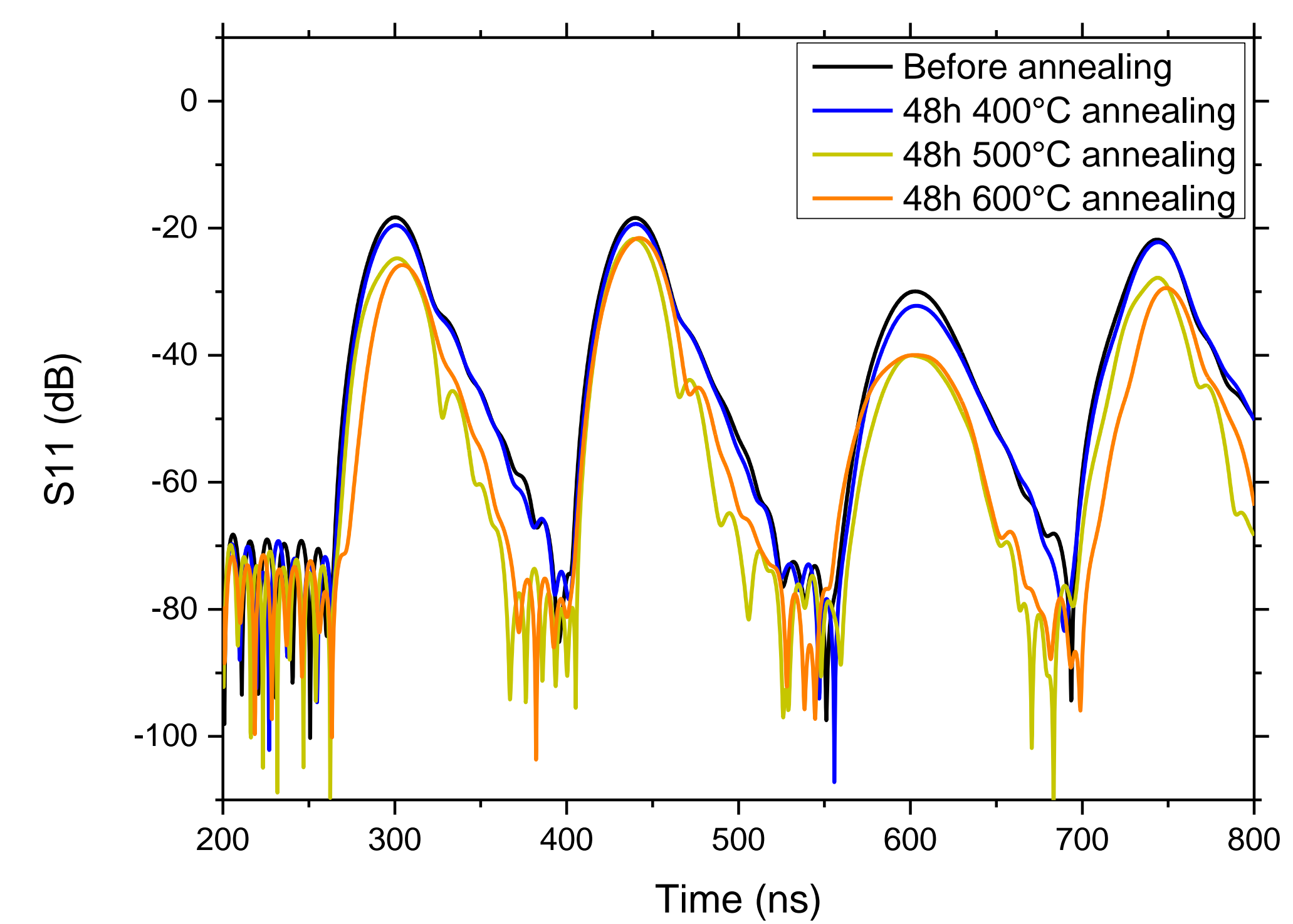


Figure 3 : Time domain reflection coefficient of RDL devices with aluminium IDTs

### Platinum electrodes

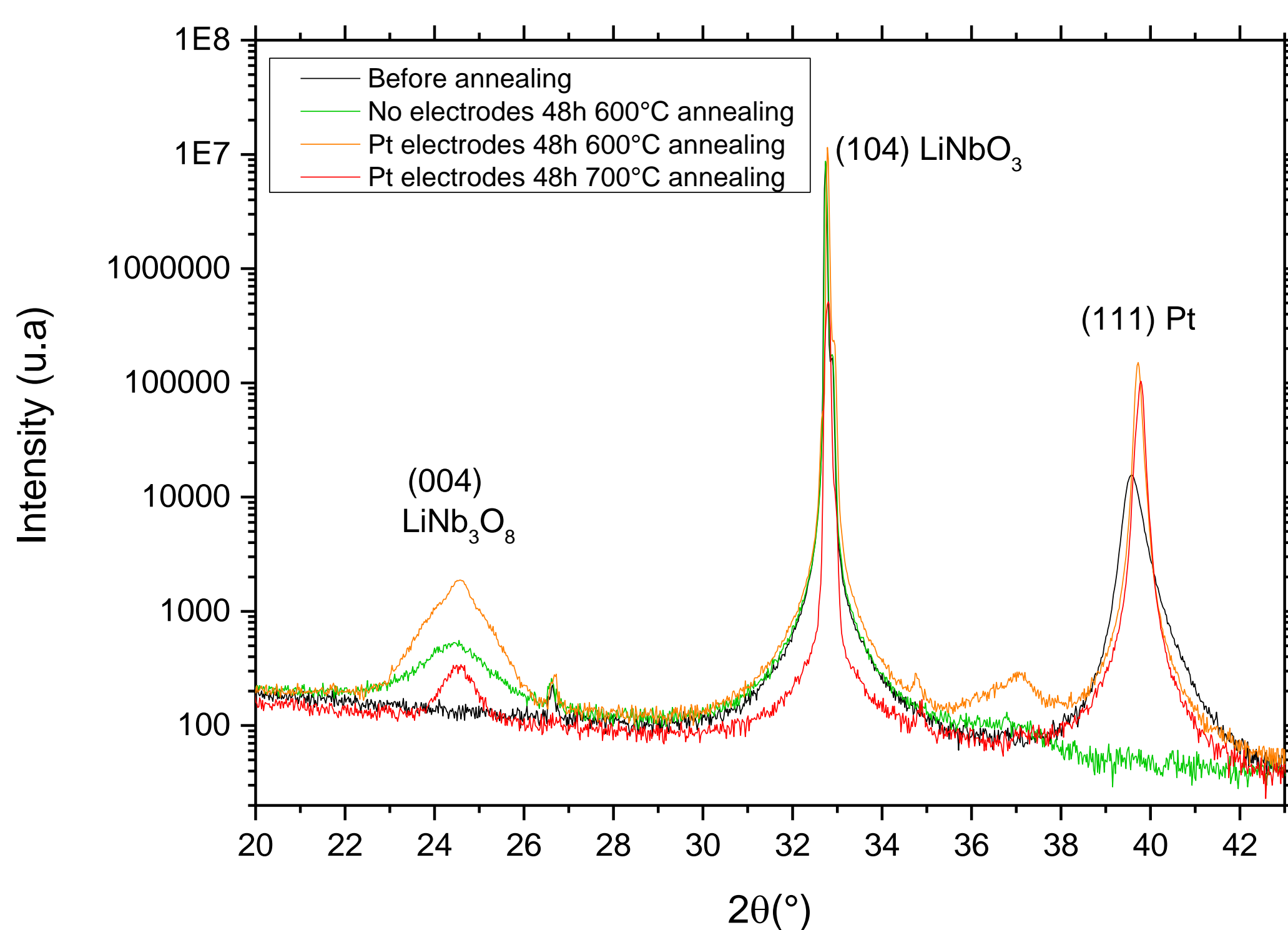


Figure 4 : X-ray diagram of LN Y-128, before and after annealing with and without Pt IDTs on the top.

- Aluminum-like  $\text{LiNb}_3\text{O}_8$  formation kinetics for platinum
- $\text{LiNb}_3\text{O}_8$  less crystallized for the same annealing period (Fig.4)
- Increase in annealing time →  $\text{LiNb}_3\text{O}_8$  more crystallized
- $\text{LiNb}_3\text{O}_8$  formation reaches a limit even with **extension of the annealing time or temperature**
- After a 48-hours annealing process at  $600^\circ\text{C}$  (Fig.5)
  - Time domain response is not degraded
  - Even improved → **Platinum IDTs recrystallization** (Fig.4).

- New horizons are possible regarding the use of  $\text{LiNbO}_3$  for high-temperature applications up to  $600^\circ\text{C}$
- Aluminum electrodes are a good alternative for medium lifetime devices up to  $400^\circ\text{C}$
- Devices with platinum IDTs look stable up to  $600^\circ\text{C}$
- These deductions were made with devices designed at 433MHz
  - For higher frequencies, platinum electrodes would be less performant
- In order to push back the limits of cLN-based high-temperature SAW sensors, we need to find an innovative solution in terms of electrodes' nature:
  - Need to withstand high temperatures without too many physical transformations and ionic exchanges with the substrate
  - Need to have a low density

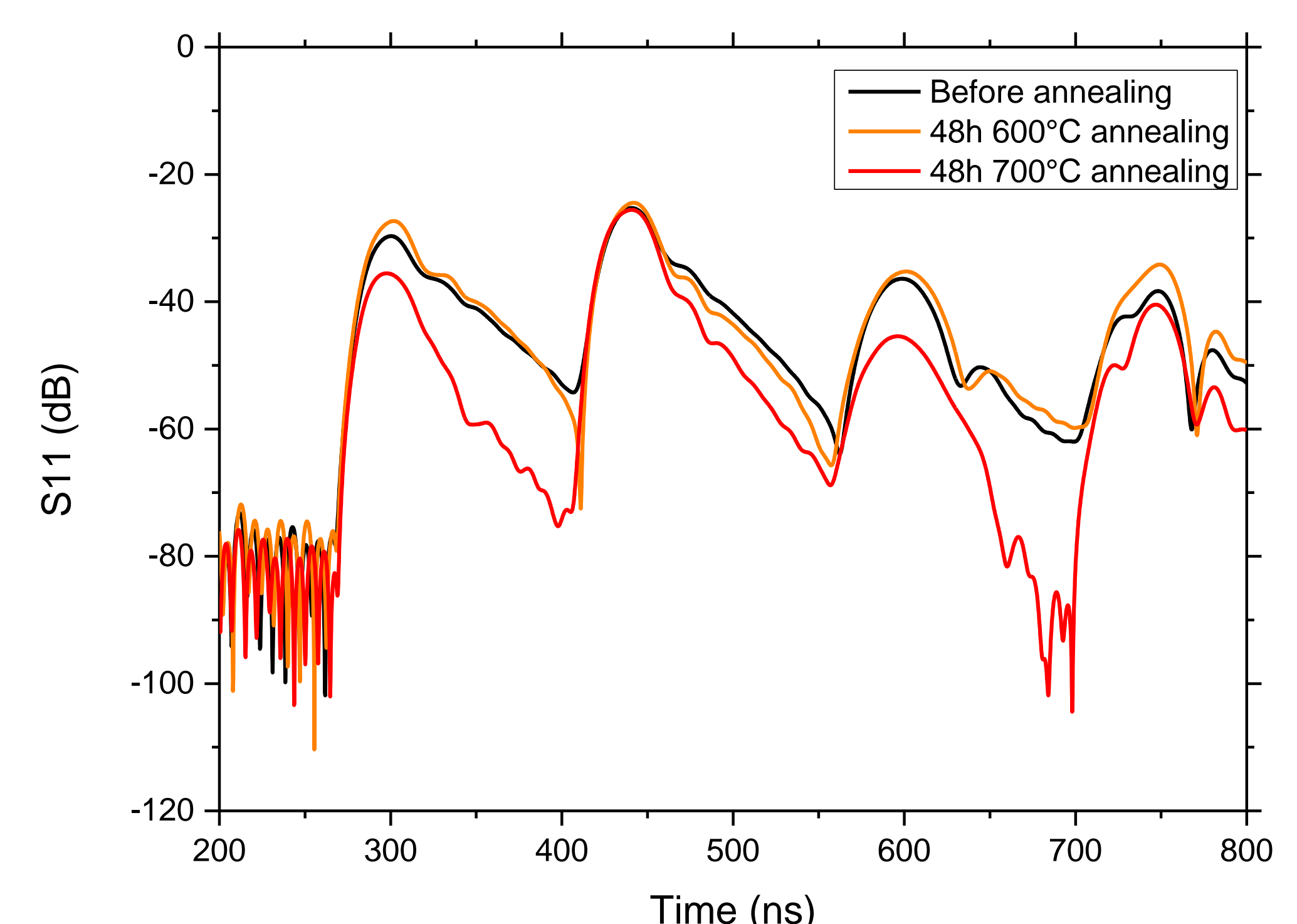


Figure 5 : Time domain reflection coefficient of RDL devices with platinum IDTs