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

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## Background, Motivation and Objective

- SAW sensors are very good candidates to face the challenges of measurements in **harsh high temperature** environments
  - Wireless
  - Battery-free
- LiNbO<sub>3</sub>-based SAW Reflective Delay Lines (RDLs) operating up to 400°C have been on the market for more than ten years
- This temperature limitation is due to :
  - Degradation of the electrodes
  - Lithium triniobate (LiNb<sub>3</sub>O<sub>8</sub>) segregation
- In this study, we suggest to re-explore :
  - The **segregation process** of congruent LiNbO<sub>3</sub> 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°C**
  - **Electrically characterized**
  - **X-ray diffraction** → Investigate the lithium triniobate (LiNb<sub>3</sub>O<sub>8</sub>) formation and the phase evolution of the metallic IDTs.

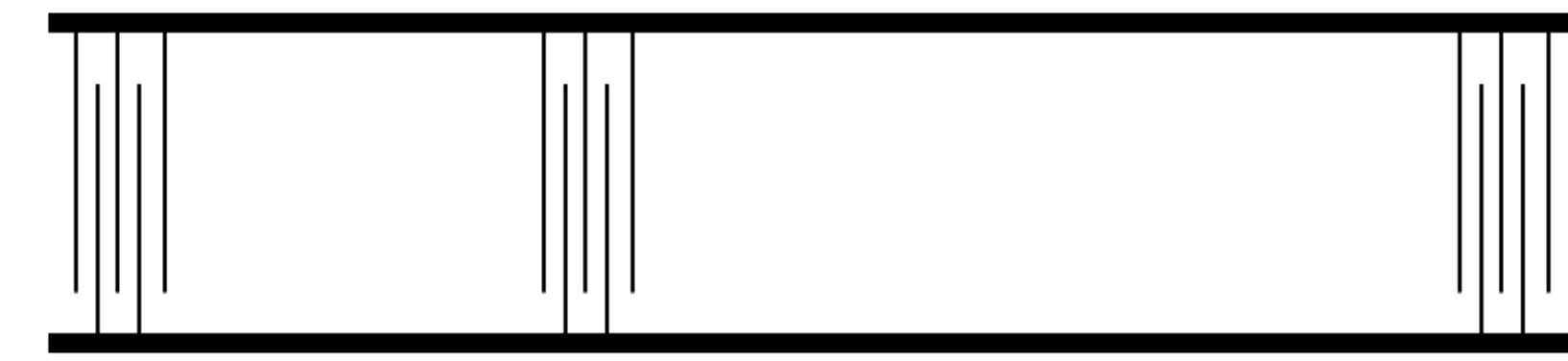


Figure 1: Reflective delay lines (RDL) with 3 connected IDTs design [1]

## Results, Discussion and Conclusions

- Formation of LiNb<sub>3</sub>O<sub>8</sub> observed after a 2-days annealing period at a temperature of 500°C (Fig.2).
- LiNbO<sub>3</sub> 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°C has almost no destructive effect on the device response (Fig.3). Whereas from 500°C onwards → Degradation due to :
  - Alumina (Al<sub>2</sub>O<sub>3</sub>) formation
  - **Dewetting effect**
- Annealing at 600°C :
  - Irreversible **frequency shift**
  - Strong **visual degradation** of the electrodes
- Limit for aluminum IDTs → Between 400 and 500°C for an operation period for several days

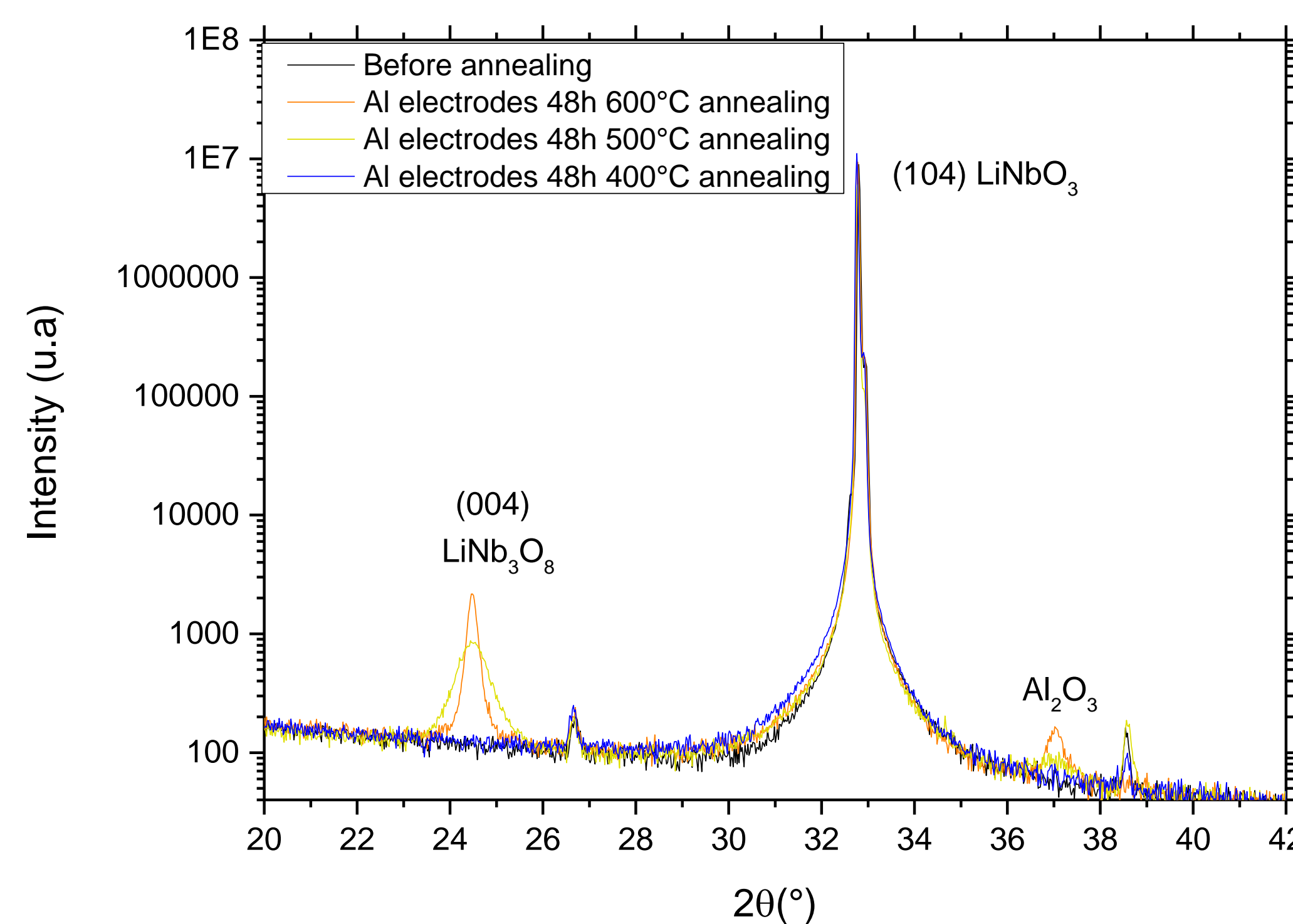


Figure 2 : X-ray diagram of LN Y-128, before and after annealing with and without Al IDTs on the top.

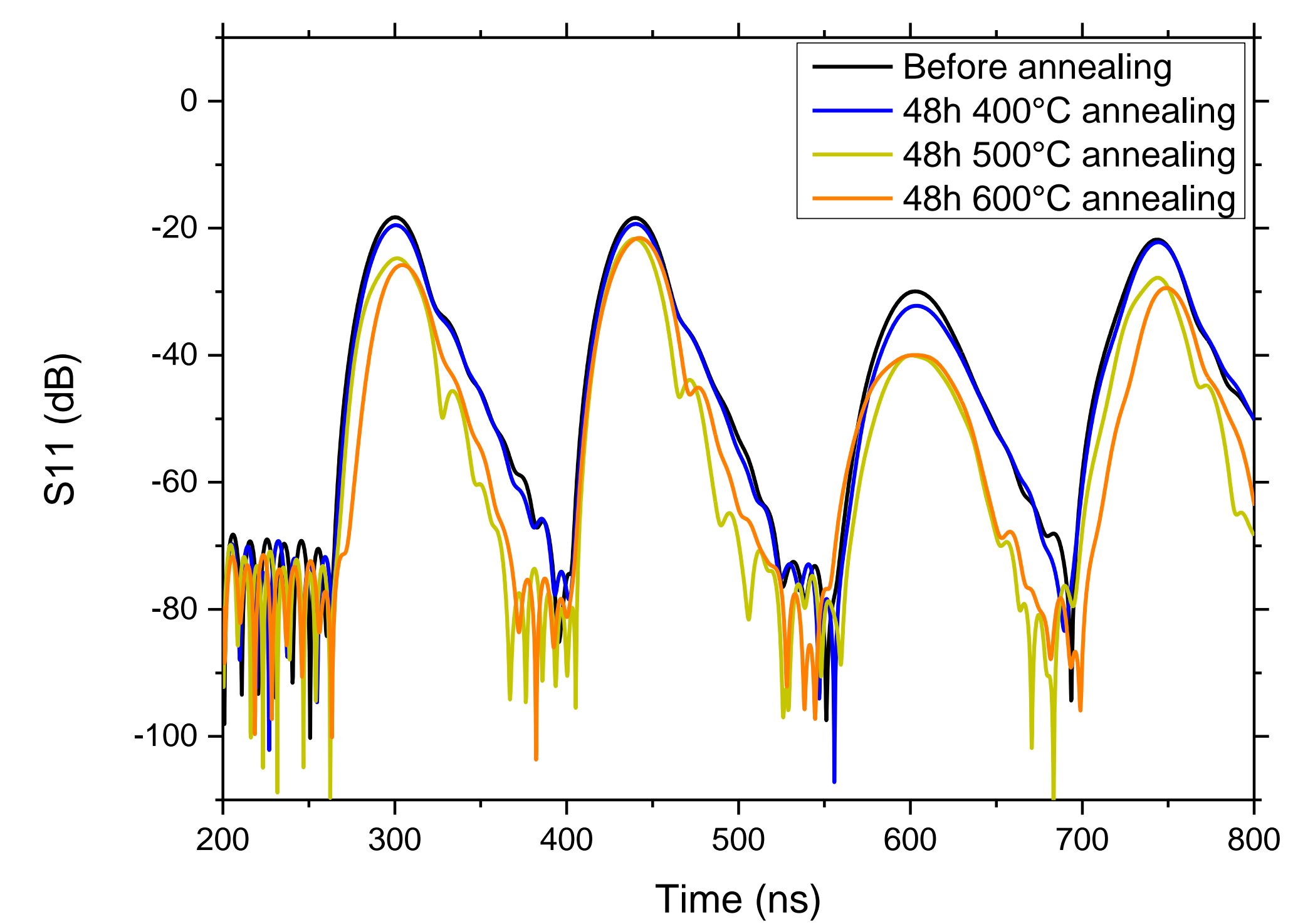


Figure 3 : Time domain reflection coefficient of RDL devices with aluminium IDTs

### Platinum electrodes

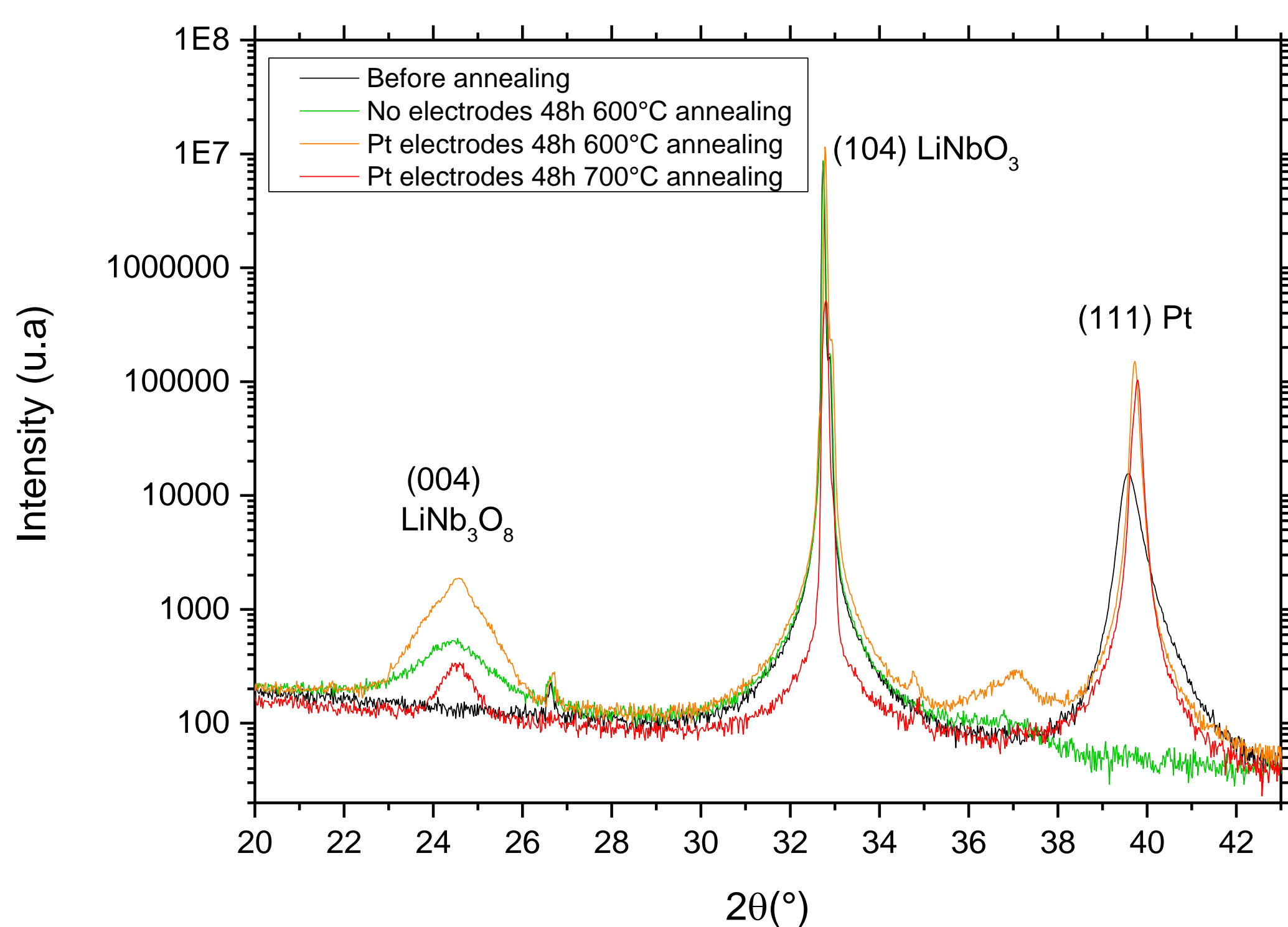


Figure 4 : X-ray diagram of LN Y-128, before and after annealing with and without Pt IDTs on the top.

- Aluminum-like LiNb<sub>3</sub>O<sub>8</sub> formation kinetics for platinum
- LiNb<sub>3</sub>O<sub>8</sub> less crystallized for the same annealing period (Fig.4)
- Increase in annealing time → LiNb<sub>3</sub>O<sub>8</sub> more crystallized
- LiNb<sub>3</sub>O<sub>8</sub> formation reaches a limit even with **extension of the annealing time or temperature**
- After a 48-hours annealing process at 600°C (Fig.5)
  - Time domain response is not degraded
  - Even improved → **Platinum IDTs recrystallization** (Fig.4).

- New horizons are possible regarding the use of LiNbO<sub>3</sub> for high-temperature applications up to 600°C
- Aluminum electrodes are a good alternative for medium lifetime devices up to 400°C
- Devices with platinum IDTs look stable up to 600°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

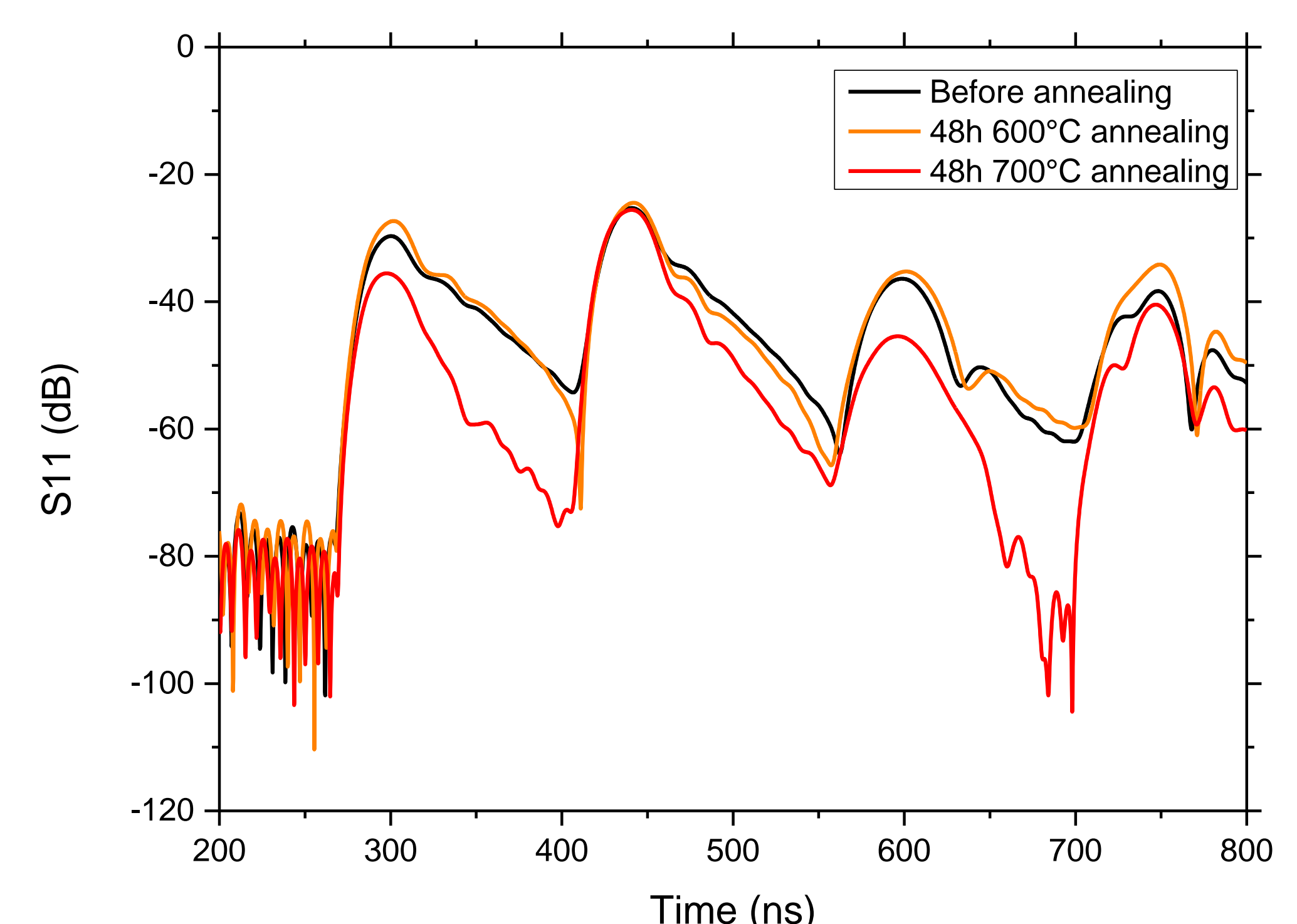


Figure 5 : Time domain reflection coefficient of RDL devices with platinum IDTs