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Study of Cr₅Si₃ Electrodes on Langasite Surface Acoustic Wave Resonators for High Temperature Sensing

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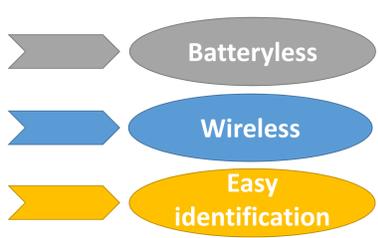
Abstract

Many piezoelectric materials are viewed as potential candidates for high temperature SAW applications, including langasite (LGS) and AlN. Only a few metals or alloys can withstand such temperatures, among them platinum and iridium based alloys or nanocomposites. These materials cannot be considered when high quality factors are required, due to their higher resistivity and density. The (Cr, V)-Si system was previously studied, but has never been proposed as a solution for SAW electrodes, in spite of its high thermal stability, lower density (about 6 g/cm³) and decent resistivity. This study focuses on the development of Cr₅Si₃ alloy deposition for its use in LGS-based resonators, aiming at wireless applications.

Context for High Temperature Sensing

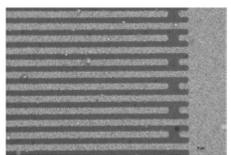
Reaching trade-offs for IDT electrodes

High temperature, harsh environments



Development of SAW resonators as compliant candidates to fulfill these requirements

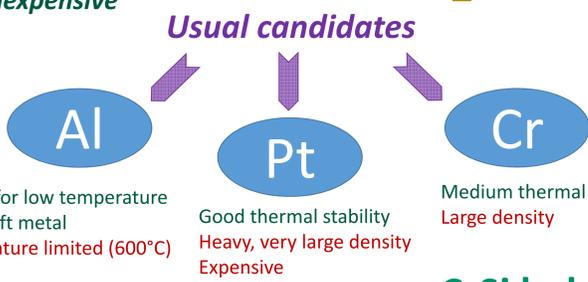
- Relying on High Temperature compatible piezoelectric substrates
 - Langasite LGS (High stability perovskite, parabolic temperature behavior)
 - Aluminum nitride (Large bandgap, high resistivity semiconductor, linear TCF)
- Looking for trade-off for the choice of IDT electrodes
 - Low resistivity, decently stable with temperature
 - High thermal stability / Passivation
 - Low density, low hardness
 - Inexpensive



Typical Aluminum IDTs

Other candidates to explore: Cr-Si alloys

Lower density than most metals / semi-metal alloys
More resistive than Pt...
...But more steady with temperature than Al
Might be prone to diffusion...
...But expected to have good thermal stability



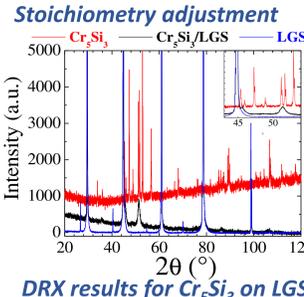
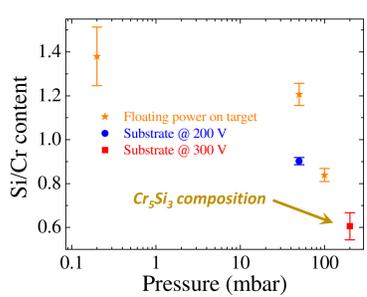
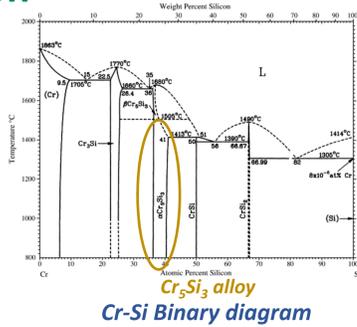
Trade-off to be investigated

Cr₅Si₃ thin film elaboration

First investigations on bulk alloys

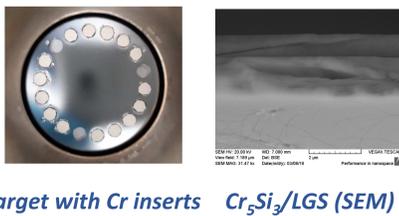
- Investigated system: Cr-Si
- Alloys prepared in electric arc furnace
- Samples followed by Thermogravimetry

Cr₅Si₃ selected as trade-off between low density and high temperature stability



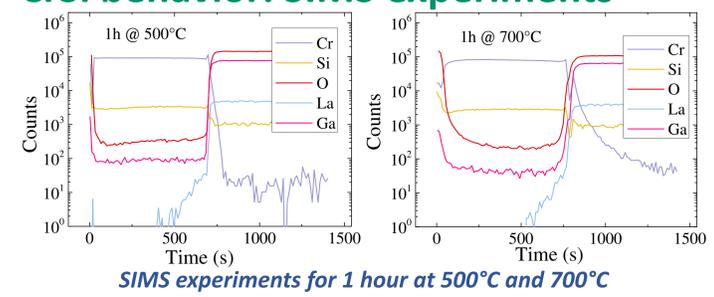
Investigation of Cr₅Si₃ for thin films

- Prepared by DC sputtering from Cr-Si target
- Optimization of parameters:
 - Power on target
 - Floating / Set potentials on substrate
 - Chamber pressure...



Si target with Cr inserts Cr₅Si₃/LGS (SEM)

CrSi behavior: SIMS experiments



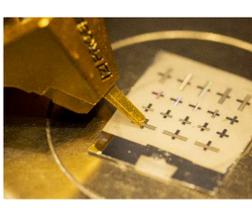
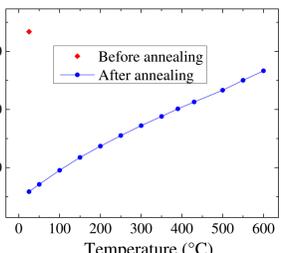
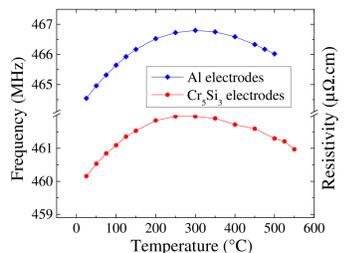
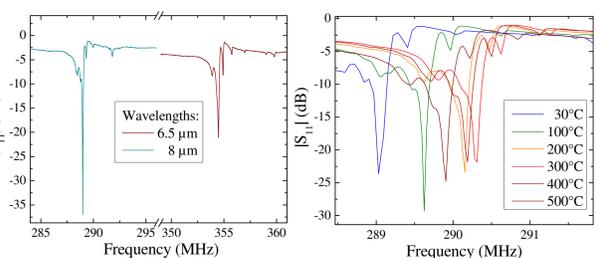
- SIMS experiments after 1 hour
 - Diffusion into LGS is very limited, up to 600°C
 - Slight surface oxidation
- SIMS experiments after 6 hours
 - No further diffusion into LGS
 - Oxidation layer is strongly slowed down

Good potential for light, stable electrodes up to 600°C

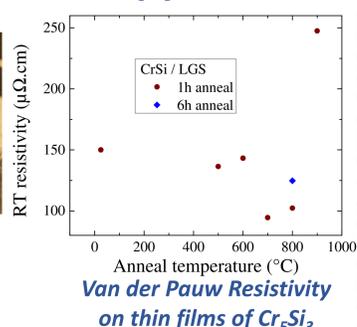
High Temperature SAW characterizations

Resonator design for first HT experiments

- Synchronous design
- Wavelengths between 5 and 16 μm
- Aperture = 40·λ, 100 pairs, 2 x 200 reflectors
- Electrodes choice: Cr₅Si₃, 200 nm



RF characterizations



Conclusion and perspectives

Exploration of Cr₅Si₃ for SAW resonator electrodes

- Approach: reaching a good trade-off between temperature range, low resistivity, low density, thermal stability...
- Cr₅Si₃ shows good thermal stability up to 600°C
- Resistivity remains high, but rather steady with temperature

Future strategies for the improvement of Cr₅Si₃ electrodes

- Initial anneal of electrodes, for better thermal stability
- Integration of a passivation layer
- Study of Cr₅Si₃ with substrates less prone to interdiffusion (AlN / Sapphire...)
- Extension to Cr-V-Si ternary alloys

Future work on integration of Cr₅Si₃ electrodes

- Optimization of LGS-based and AlN-based resonators equipped with Cr₅Si₃ electrodes
- Further work on Cr₅Si₃ aging behavior

Other study on AlN / Sapphire optimization for wireless HT SAW sensors (IUS 2018 Poster)

Optimization of Al/AlN/Sapphire Acoustic Wave Sensors for High Temperature Wireless Applications