

SIS technology development to serve Next Generation receivers for ALMA

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GARD **SIS Junction Fabrication Process** to serve Next Generation Receivers for AI MA



GARD standard SIS fabrication process status before ALMA Wideband Sensitivity Upgrade

- Mature process with high yield (typically above 90%)
- In-house microfabrication facility with dedicated Nb-SIS deposition system
- Track record:
 - ALMA Band 5 full production
 - APEX SHeFI Band 1, 2, 3 (=ALMA Band 6, 7, 8)
 - APEX SEPIA Band 5
 - Novel Nb-SIS frequency multiplier





GARD SIS fabrication process: limitations and motivation for the upgrade



GARD SIS process upgrades

AIN-barrier SIS junctions process

lower specific capacitance and lower specific resistivity supported by ESO study 2017 – 2020

✓ Smaller SIS junctions process
 ≤ 1 µm²
 supported by ESO study 2021 – 2024

Strategy:

- Do not change overall process integration to preserve reliability of the process and its high yield
- Modify only one key step at a time:
 - <u>Tunnel barrier plasma nitridation</u> instead of thermal oxidation
 - Direct laser writing instead of contact photo lithography

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• Standard Nb-SIS process, but with a **plasma nitridation** instead of thermal oxidation

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- Stable Nb/Al-AlN/Nb junctions process had been developed.
- R_nA between
 5 to 120 Ω·μm²
- All with low subgap current (high R_j/R_n ratio)



- Stable Nb/Al-AlN/Nb junctions process had been developed.
- $R_n A$ between 5 to 120 $\Omega^{-}\mu m^2$
- All with low subgap current (high R_j/R_n ratio)
- Stable for aging and annealing, somewhat more stable than standard Nb/Al-AlOx/Nb junctions





- Specific capacitance C_s vs R_nA of GARDmade AlN-barrier SIS characterized (cryogenic S-parameter measurements)
- The specific capacitance of Nb/Al-AlN/Nb junctions is proved to be significantly lower than that of Nb/Al-AlO_x/Nb junctions.
- Independently confirmed by measurements done at NAOJ (cryoprobe station, T. Kojima, S. Masui)
- **Compared and is consistent** with the C_s vs R_nA numbers reported by other groups for other AIN-SIS processes.



- Nb/Al-**AlOx**/Nb junctions (measured at GARD)
- Nb/Al-**AIN**/Nb junctions (measured at GARD)
- ✗ Nb/AI-AIN/Nb junctions (measured in NAOJ, T. Kojima, S. Masui)
- Nb/Al-AIN/Nb junctions (data of Kojima 2018, Kawamura 2000, Kooi 2020, Khudchenko 2016, Lodewijk 2009)

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Smaller SIS-junctions

Standard Nb-SIS process, but with **Direct Laser Writing** instead of contact photolithography:

- Avoiding changes to other process component, i.e., preserving the stable fabrication process
- Keeping the process within existing budgetary framework
- Quick writing
- Backup equipment present







Smaller SIS-junctions

- Demonstrated to be possible to define as small as ≤1µm², and quite smaller as well;
- Extraction of true junction area (along with the RnA) was used instead of measuring of the junction area on micrograph.





IVCs of Nb/AI-AIN/Nb SIS junctions with the R_nA product of 8.4 Ohm· μ m² with the area of ca. 0.85 μ m² (above), and ca. 0.25 μ m² (below).



Demonstrator SIS devices: Band 9 mixer

- Nb/AIN/Nb SIS junctions
- $R_n A \simeq 13 \Omega \cdot \mu m^2$
- SIS area $0.8 \ \mu m^2$
- Yield after dicing and lapping at NOVA ca. 80%



ALMA Wideband Sensitivity Upgrade - ESO Garching, 24 - 28 June, 2024 A. Pavolotsky

with GARD-made Nb/AIN/Nb SIS demo devices -

baseline SIS devices (TUDelft-made)

All ALMA Band 9 ever produced – with the

SIS devices for GARD Band 6 and 7 CCA demonstrator

- Nb/AIN/Nb SIS junctions
- $R_n A \simeq 13 \Omega \cdot \mu m^2$
- SIS twin junction, area 2 μm^2 each



Design and performance:

see the talk

V. Belitsky "Exploring boundaries for wider RF and wider IF bands for ALMA SIS receivers" on *Thursday, June 27 at 9:55*



GARD SIS fabrication process to serve ALMA Wideband Sensitivity Upgrade

- The ALMA 2030 Roadmap: up to 4x bandwidth compared to today's receivers
- GARD SIS fabricating process:
 - Junctions with lower specific capacitance and specific resistance (AIN-barrier SIS junctions)
 - Smaller SIS junction area $(\leq 1\mu m^2)$





GARD SIS technology team

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François Joint

Seems, ready and prepared for the ALMA WSU adventure...

