Uniform non-stoichiometric titanium nitride thin films for improved kinetic inductance detectors array

G. Coiffard[1], K.F. Schuster[1], E.F.C Driessen[1], S. Pignard[2], M. Calvo[3], A. Catalano[4,3], J. Goupy[3], A. Monfardini[3,4]

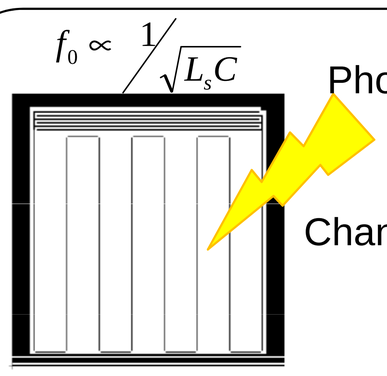
[1]*IRAM, Institut de RadioAstronomie Millimétrique, 300 Rue de la Piscine, 38406 St Martin d'Hères, France*

[2]*LMGP / Université Grenoble Alpes & CNRS, F-38000 Grenoble, France*

[3]Institut Néel & Université Joseph Fourier, CNRS, BP 166, 38042 Grenoble, France

[4]Laboratoire de Physique Subatomique et de Cosmologie, Grenoble, France

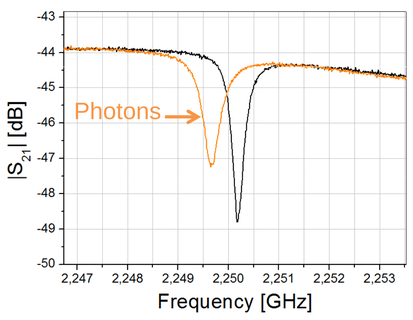
WHY TiN for KIDs?



Photons with $E = h\nu > 2\Delta = 3.52 k_B T_C$

Change $Z_S = R_S + i\omega L_S$

f_0 is shifted



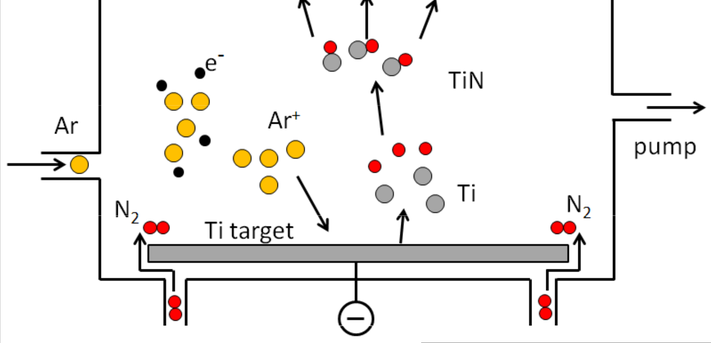
TiN is suitable for KIDs (*LeDuc et al. 2010*)

- T_C tunable between 0,5 K < T_C < 4,5 K
  → We can choose the cutoff 36 GHz < 2Δ < 330 GHz
- High value of the kinetic inductance $L_{kin,TiN} >> L_{kin,Al}$
- High internal quality factor

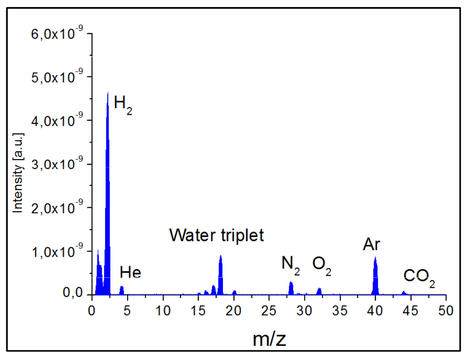
Challenges : Uniform films over large area in term of thickness and nitrogen content are required

DEPOSITION PROCESS

Reactive sputtering



$P_{base} \approx 2\times10^{-8}\, mbar$

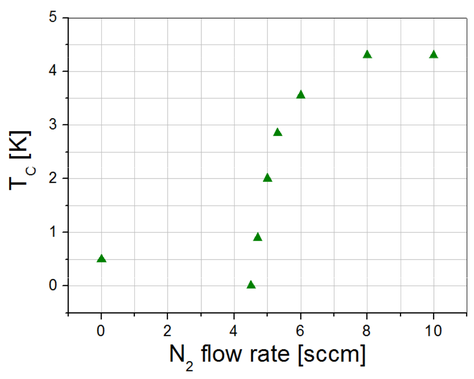


ring injection for N_2

Very good vacuum + cleaning process with sputtering of pure Ti (getter effect) to reduced contaminants in the chamber

- Qualitative analysis with mass spectrometer
- Pure TiN films (confirmed by chemical analysis - RBS)

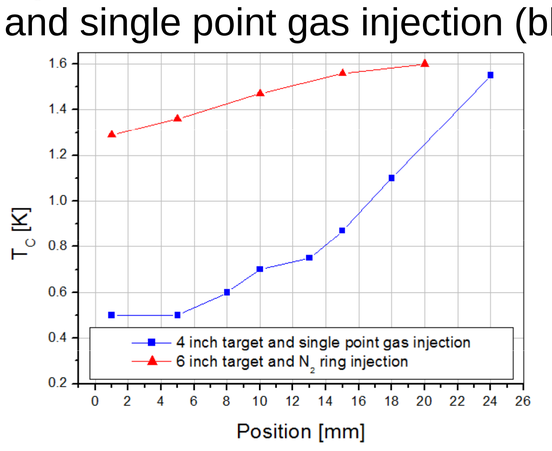
N_2 flow rate to determine the stoichiometry and the T_C

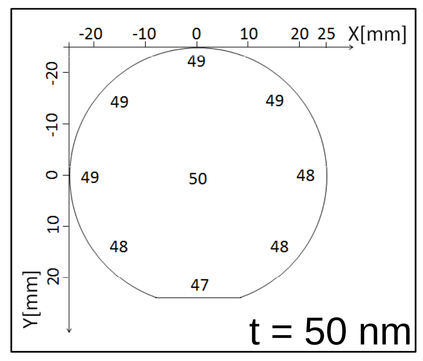


Very sharp transition near the required T_C ≈ 1-2 K
→ Difficult to control the value of T_C

CHARACTERIZATION

T_C varies strongly with 4 inch target and single point gas injection (blue)

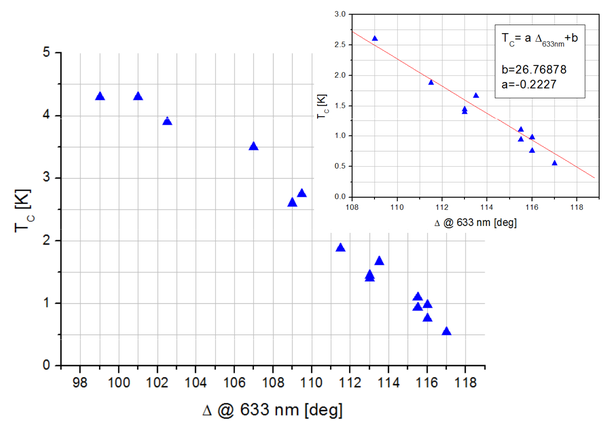




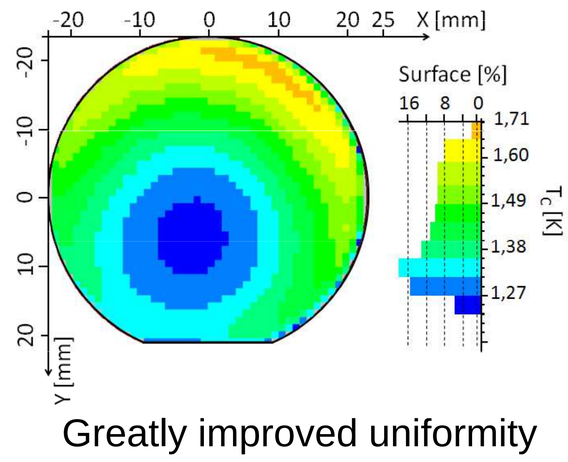
Thickness is uniform with 6 inch Ti target

→ new 6'' Ti target and N_2 ring injection device improved uniformity

Optical properties of TiN_x change with x such as T_C *(Vissers et al. 2013)*
→ Ellipsometry measures the amplitude Ψ and phase Δ change of a beam light reflected on a sample



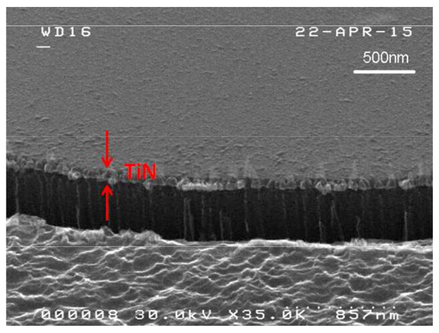
Measured T_C (4-wire sensing) scales optical parameter Δ



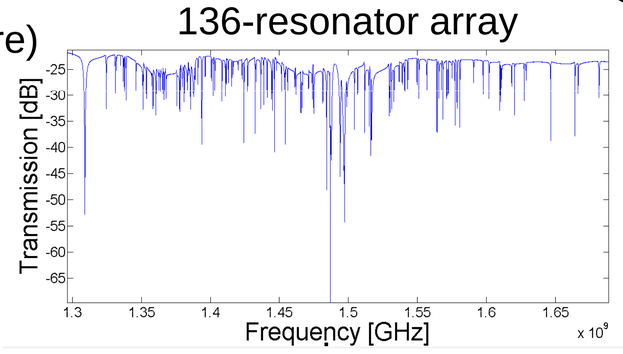
Greatly improved uniformity over a 2'' substrate with our new N_2 injection

FIRST ARRAY MEASUREMENT

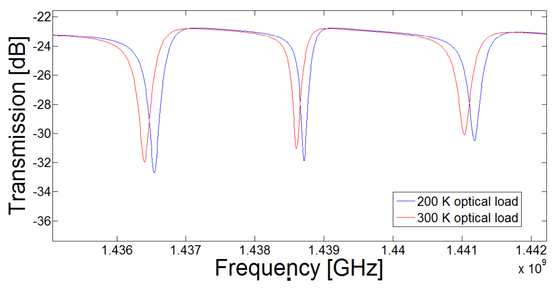
Dry etching (C_4F_8 / SF_6 mixture)

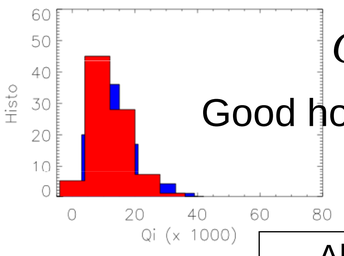


136-resonator array



Optical response $90 kHz / pW$





$Q_i \approx 15000$

Good homogeneity

	Al	TiN
Response [kHz/pW]	16	90
Noise [Hz/Hz$^{0.5}$]	1	30
NEP [W/Hz$^{0.5}$]	6x10^{-17}	3x10^{-16}

Good optical response but high noise that has to be understood

CONCLUSION & PERSPECTIVE

- The uniformity of the nitrogen content in our TiN thin films is greatly optimized. We are still working to further increase the homogeneity
- Pure TiN thin films thanks to a very clean deposition chamber without any leak + cleaning procedure before each deposition
- Uniform sub-stoichiometric TiN films with required T_C are deposited with high reproducibility
- Several arrays were fabricated and are currently investigated (electrical noise, optical response, absorption spectrum)

References: H. G. LeDuc et al. Appl. Phys. Lett., 97(102509), 2010
M. R. Vissers et al. Thin Solid Films, 548:485 488, 2013