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

G. Coiffard1, K.F. Schuster1, E.F.C Driessen1, S. Pignard2, M. Calvo3, A. Catalano4, J. Goupy5, A. Monfardini3,4
1IRAM, Institut de RadioAstronomie Millimétrique, 300 Rue de la Piscine, 38406 St Martin d’Hères, France
2LMGP / Université Grenoble Alpes & CNRS, F-38000 Grenoble, France
3LNCI / Université Grenoble Alpes & CNRS, F-38000 Grenoble, France
4Laboratoire de Physique Subatomique et de Cosmologie, Grenoble, France

**WHY TiN for KIDs?**

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 < \( 2\Delta < 330 \) GHz
- High value of the kinetic inductance \( L_{\text{kin,TiN}} \gg L_{\text{kin,Al}} \)
- High internal quality factor

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

**DEPOSITION PROCESS**

Reactive sputtering

\[ f_0 \propto \sqrt{\frac{E}{\Delta}} \]

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

Change \( Z_0 = R_0 + i\omega L_0 \)

\( f_0 \) is shifted

**Why TiN 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)

\( \text{N}_2 \) flow rate to determine the stoichiometry and the \( T_C \)

\( \text{N}_2 \) flow rate [sccm]

\( T_C \) 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 \( \text{N}_2 \) ring injection device improved uniformity

**Optical properties of TiN, change with x such as \( T_C \) (Vissers et al. 2013)**

- Ellipsometry measures the amplitude \( \Psi \) and phase \( \Delta \) change of a beam light reflected on a sample

**FIRST ARRAY MEASUREMENT**

Dry etching (\( \text{C}_4\text{F}_8 / \text{SF}_6 \) mixture)

Optical response 90kHz / pW

136-resonator array

**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)


**Why TiN for KIDs?**

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

Change \( Z_0 = R_0 + i\omega L_0 \)

\( f_0 \) 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 < \( 2\Delta < 330 \) GHz
- High value of the kinetic inductance \( L_{\text{kin,TiN}} \gg L_{\text{kin,Al}} \)
- High internal quality factor

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

**DEPOSITION PROCESS**

Reactive sputtering

\[ P_{\text{base}} = 2 \times 10^{-3} \text{ mbar} \]

**Why TiN 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)

\( \text{N}_2 \) flow rate to determine the stoichiometry and the \( T_C \)

\( \text{N}_2 \) flow rate [sccm]

\( T_C \) 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 \( \text{N}_2 \) ring injection device improved uniformity

**Optical properties of TiN, change with x such as \( T_C \) (Vissers et al. 2013)**

- Ellipsometry measures the amplitude \( \Psi \) and phase \( \Delta \) change of a beam light reflected on a sample

**FIRST ARRAY MEASUREMENT**

Dry etching (\( \text{C}_4\text{F}_8 / \text{SF}_6 \) mixture)

Optical response 90kHz / pW

136-resonator array

**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)