

Quasiparticle loss rates in Ta-based superconducting tunnel junctions

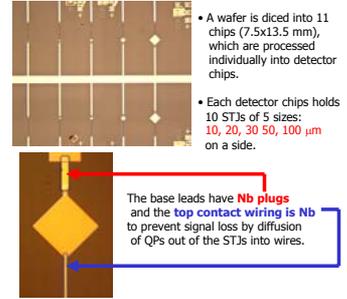
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Introduction

Superconducting Tunnel Junctions (STJs) are being developed as spectro-photometers in wavelength bands ranging from the NIR to X-rays. The ability to handle high event rates is ultimately limited by the pulse decay time, which is a measure of the lifetime of the photon induced excess quasiparticle distribution in the device. In our Ta-based STJs this life time is usually not found to be limited by intrinsic Ta recombination rates (at sufficiently low temperature), but rather by other loss processes. These unintentional loss processes are associated with traps at the perimeter or the surfaces of the devices, or with contact leads to either of the electrodes. Consequently, the pulse decay time is dependent on the fabrication process as well as the device geometry. In this paper we investigate how the pulse decay time can be manipulated by the introduction of layers of different superconductors in Ta based devices.

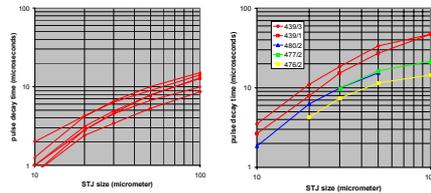
Device description

- Ta-based detectors have been fabricated by the former Oxford Instruments Superconductivity Group (Cambridge, UK).
- Ta-Al-AlOx-Al-Nb-Ta multilayers on 2" superpolished sapphire wafers.
- The Ta layers are 100 nm thick. The base Ta layer is epitaxial with the sapphire (RRR~30-40), whereas the other layers are poly-crystalline.
- The barrier resistivity is typically 2-3 $\mu\Omega \text{ cm}^2$.
- 2 series of devices:**
 - Al layers thickness varied from 5-265 nm
 - Nb capping layers (0,5,20 nm) on top and below the STJs (fixed Al thickness 5 nm).



Reproducibility

In spite of a tight control on all parameters and settings involved in the manufacturing of the detector chips, a considerable variation in the measured QP lifetime, and hence in the responsivity, is observed among nominally the same detectors.

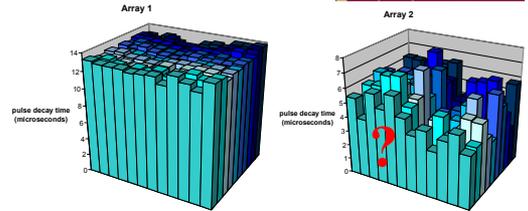


For a given size, the measured decay time may vary from chip to chip by a factor 2

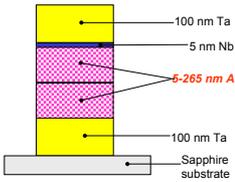
For a given size, the measured decay time may vary from chip to chip by a factor 2-3

Uniformity of pulse decay times across 10x12 pixel arrays:

- Usually very uniform: $\pm 5\%$ (array 1)
- Occasionally large variations: $\pm 50\%$ (array 2)

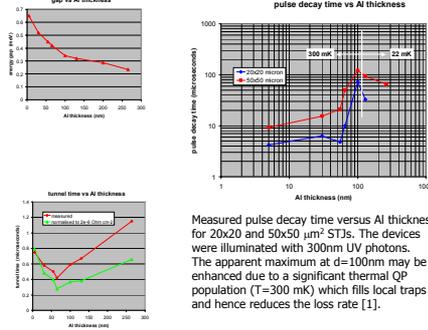


Variation of Al trapping layer thickness



Variation of the Al thickness has a strong effect on the energy gap in the devices. In order to exclude effects from thermally excited QPs, the thick Al devices need to be measured at sufficiently low T

Variation of the Al thickness also affects the tunnel time (here derived from the IV-curves as average over top and base electrodes) of the devices. The highest tunnel rates in this configuration are achieved for 50-100 nm Al

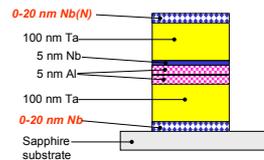


Results:

Clearly, increasing the Al layer thickness can be used to increase the pulse decay time by about an order of magnitude.

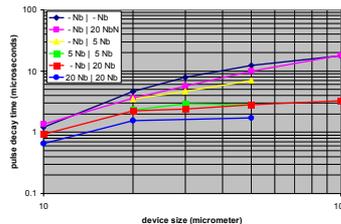
This enhances the number of tunnels per QP and, together with the reduced energy gap and higher tunnel rate, yields a strongly enhanced responsivity.

Nb capping layers on top or below Ta-STJs



	capping layers		average gap (meV)
	base	top	
reference	-	-	0.655
NbN	-	20	0.657
Nb	-	5	0.654
Nb	5	5	n.a.
Nb	-	20	0.664
Nb	20	20	0.724

5 different capping configurations are compared with a reference chip. The energy gaps (measured from the IV-curves as average over top and base electrodes) show little deviation from the reference value. Only for the 20 nm cap in the base film the gap is enhanced, due to the longer range of the proximity effect in the epitaxial Ta.



Results:

- The introduction of more and thicker Nb layers clearly enhances the QP loss rate progressively, in agreement with the higher loss rates which are generally observed in Nb-based devices [2].
- Depending on device size, the pulse decay time can be reduced up to an order of magnitude
- Addition of a NbN cap has no significant effect on the QP life time in the present Ta devices. (Different from Nb-based devices, where the addition of a NbN cap on top of the device significantly enhanced the pulse decay times [2])

[1] A.G. Kozlov, J. K. Wigners, A. Peacock, A. Poelaert, P. Verhoeve, R. den Hartog, and G. Brammertz, Appl. Phys. Lett. **78**, p3654-3656 (2001).

[2] N. Randó, P. Verhoeve, A. Poelaert, A. Peacock and D.J. Goldie, J. Appl. Phys. **83**, p5536-5542 (1998).