X-ray response of tunnel junctions with a trapping layer

J.B. le Grand¹, P. Valko^{1*}, M.P. Bruijn¹, M.J. Frericks¹, S. Patel¹, P.A.J. de Korte¹, J.G. Gijsbertsen², E.P. Houwman² and J. Flokstra²

¹ Space Research Organization Netherlands (SRON),
Sorbonnelaan 2, 3584 CA Utrecht, the Netherlands

² Low Temperature Group, University of Twente,
P.O.box 217, 7500 AE Enschede, the Netherlands

* On leave from Department of Physics, Slovak Technical University,
Ilkovičova 3, 812-19 Bratislava, Slovakia

1. ABSTRACT

The use of trapping layers in superconductive tunnel junctions may drastically improve their functioning as X-ray detectors¹. Information about these trapping layers can be obtained from I/V-curves and X-ray spectra. The application of a magnetic field causes a substantial reduction of the bandgap in the trapping layer.

2. EXPERIMENTAL SETUP

For this experiment a Nb/Al/Al₂O₃/Al/Nb junction with a barrier size of 100*100 μm^2 is used with a current density of 100 A/cm². The Al-layer of the base electrode is 25 nm thick and is functioning as a trapping layer for excess quasi-particles. The Al layer of the counter electrode is only 3 nm thick.

3. I/V-CURVES

I/V-curves can give direct information about the bandgap of the trapping layer (Δ_t) and the bandgap of the counter electrode (Δ_c) in two ways. At a bias voltage $\Delta_c + \Delta_t$ there is a large current increase and at $\Delta_c - \Delta_t$ there is a local maximum or at least the onset of a plateau in

the subgap current.

In figure 1a I/V curves are shown for $B = 0$ G and for $B = 500$ G. The magnetic field is applied in the plane of the junction. From these pictures it is clear that the magnetic field causes a reduction of $\Delta_c + \Delta_t$ of about 0.30 mV.

For determining $\Delta_c - \Delta_t$ the subgap currents have been measured. To eliminate non-thermal leakage currents, measurements at 1.25 K have been subtracted from measurements at 1.35 K. Figure 1b shows the results for magnetic fields of $B = 220$ G, 310 G, 400 G and 500 G. From the onset of the plateau one can conclude that the difference in bandgap between the trapping layer and the counterelectrode is 0.33 mV, 0.37 mV, 0.46 mV and 0.57 mV respectively. The decrease of the bandgap in the trapping layer is consistent with the increase of the plateau level.

Measurements on similar junctions with a 5 nm trapping layer do not show any magnetic field dependence up to 500 G.

4. X-RAY RESULTS

An example of a spectrum for ⁵⁵Fe (~5.9 keV) X-rays is shown in figure 2a. Of the three peaks, the right one is caused by a testpulse. Biasvoltage dependence indicates that the left

Fig. 1.a (insert) Half of total I/V-curve; 1.b Sub-gapregion of I/V-curve for a few magnetic fields.

Fig. 2.a (insert) X-ray spectrum and testpulse; 2.b pulseheight of base electrode as a function of bias voltage for a few magnetic fields.

one is caused by X-ray absorptions in the top electrode and the middle peak is due to absorption in the base electrode². The bias vol-

tage dependance of the signalheight of this peak is given by figure 2b for the same magnetic fields as in figure 1b. Here we see again maxima at about the same voltages as in the I/V curves: 0.35 mV, 0.44 mV, 0.51 mV and 0.57 mV.

5. DISCUSSION AND CONCLUSIONS

The X-ray peak and the subgap current depend in the same way on the magnetic field. This means that excess quasiparticles get thermalized on a timescale shorter than that of the signal, i.e. $\sim 0.7 \mu\text{s}$. This is in agreement with theory³.

From the measurements it is clear that the bandgap of the 25 nm Al-layer is reduced with magnetic field, while the counter electrode is not influenced. This may be explained by the fact that the thick Al-layer which is near the clean limit ($d_{\text{Al}} > \lambda_{\text{Al}}$), exhibits a far larger pair-breaking rate due to screening currents than the counter electrode which is effectively in the dirty limit⁴ ($d_{\text{Al}} < \lambda_{\text{Al}}$). d_{Al} is the thickness of the Al-layer and λ_{Al} the London penetration depth.

For $V_b > \Delta_c - \Delta$, the X-ray signal height is hardly dependant on the magnetic field. A detailed model with trapping, tunneling, loss and (self)-recombination time constants in the trap is in progress. This model is required to verify this independance as well as the absolute signal height and signal time constants.

REFERENCES

1. P.A.J. de Korte, proceedings of an ESA symposium on Photon Detectors for Space Instrumentation, ESA SP-356, 41 (1992).
2. D. Goldie et al., to be published in Superconductor Science and Technology.
3. A.A. Golubov and E.P. Houwman, Physica C, 205 (1993) 147.
4. A.A. Golubov, private communication.