Supercurrent and Coulomb blockade in multiwall CNTs with Nb contacts

M. Gaaß, E. Pallecchi, and Ch. Strunk

Institut für Experimentelle and Angewandte Physik,

Universität Regensburg, D-93025 Regensburg, Germany

(Dated: May 14th, 2007)

It has been shown that, under proper conditions, there can be dissipationless current flowing across nanotubes coupled to superconducting leads [1]. We present here first measurements of the characteristics of multiwall carbon nanotubes contacted to electrodes made of Niobium. We were able to reach critical currents of up to 20nA which are, to our knowledge, the highest currents reached so far.

Our samples are fabricated by standard lithographic and metal deposition means after locating the nanotubes with a SEM on either a SiO_2 or an Al_2O_3 substrate. In addition to the layer of Niobium with a thickness of around 40nm we cared for good electrical coupling between the contacts and the tube with a roughly 5nm thick layer of Palladium. This process resulted in typical room temperature resistances of around 10kΩ. The approximate contact spacing that we defined was between 250nm and 400nm, Fig. 1(a). A special feature of our design is that we defined rather long resistive leads made of AuPd and large enough bonding pads, Fig. 1(b). By this on-chip resistance and capacitance we are damping thermally activated switching of the junction into the resistive state which is equal to increasing the switching current towards the intrinsic value of the critical current [2]. Another important ingredient of the measurement setup are well filtered lines. In addition to the usual π- and Copper powder filters we use a two stage RC-filter setup following [1].

The measurements performed so far on a sample with a SiO_2 backgate include the investigation of the differential resistance over a wide gate voltage range and were all done in our dilution refrigerator at T = 25mK. The results showed that with gate voltage we are tuning the sample from a relatively weak Coulomb blockade regime into deep Coulomb blockade upon which, for even lower gate voltages, we reach a region where the sample only occasionally jumps back from the superconducting state into the normal state Fig. 2.

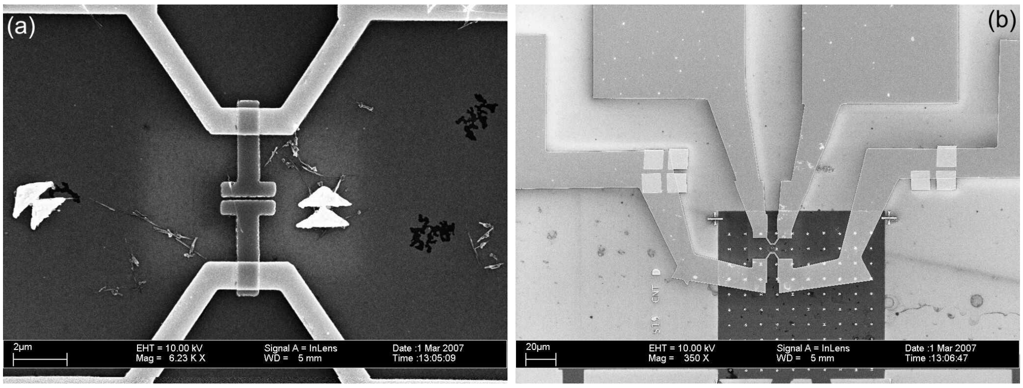

FIG. 1: (a) SEM image of a typical sample from this work. The superconducting contacts are clearly visible and are connected by a multiwall carbon nanotube which sits, barely visible, towards the left end of the contact electrodes. (b) The Nb contacts on top and bottom are connected to the resistive AuPd leads which help us achieving an appropriate on-chip resistance in order to damp together with the capacitance from the bonding pads the thermal activated switching of the junction into the resistive state.

Finally, for gate voltages below $V_G = -15V$ the sample remains completely superconducting. In the superconducting state we investigate the dependence of the critical current on gate voltage, temperature and magnetic field. While the first two show the expected behavior, the magnetic field dependence remains unclear. This we attribute to trapped flux in the superconducting electrodes. The next series of measurements will be done in

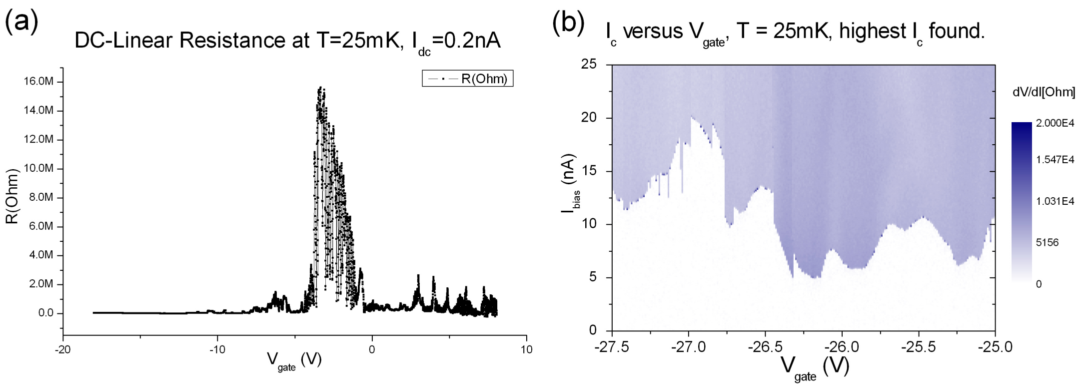

FIG. 2: (a) Differential resistance collected over a wide gate voltage range. The transport properties change from slight Coulomb blockade to clear Coulomb blockade before it switches into the superconducting state. (b) Dependence of the critical current on the gate voltage around $V_G = -27V$. A maximum value of $I_c = 20nA$ could be reached.

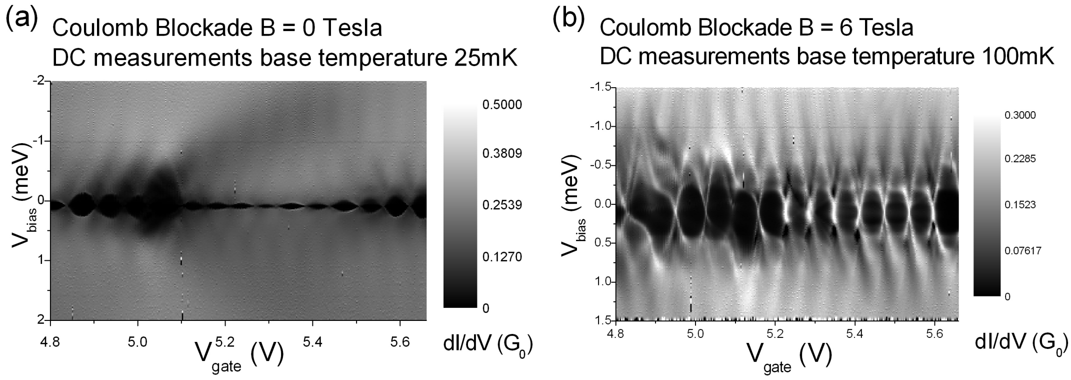

FIG. 3: (a) Differential conductance at zero magnetic field with superconducting electrodes. (b) Differential conductance for the same gate voltage region as in (a) but with a magnetic field of B = 6T in order to drive the electrodes into the normal state.

parallel field to minimize this effect.

One focus in the gate voltage regime of zero resistance was set on trying to correlate the size of the supercurrent and the normal state resistance which was measured at B = 6T. The results of this measurements still need further interpretation.

Furthermore we investigated the Coulomb blockade regime for any signature of the superconducting leads at low temperature for different magnetic fields. The results of these measurements are shown in Fig. 3.

---

[1] P. Jarillo-Herrero, J. A. van Dam, L. P. Kouwenhoven, Nature **439**, 953 (2006).

[2] M. F. Goffman, R. Cron, A. Levy Yeyati, P. Joyez, M.H. Devoret, D. Esteve, and C. Urbina, PRL **85**, 170 (2000).