Experimental evidence of quantum phase slip phenomena in ultra-narrow superconducting channels

M.Zgirski, **K.-P.Riikonen, M.Savolainen, V. Touboltsev and K.Yu.Arutyunov**

University of Jyväskylä, NanoScience Centre, Department of Physics,
PB 35, 40014, Jyväskylä, Finland
E-mail: zgirski@phys.jyu.fiT

A superconducting wire can be considered as quasi-one dimensional (1D) if its characteristic transverse dimension is smaller than the coherence length ξ. The shape of the bottom part of the resistive transition *R(T)* of a not too narrow 1D strip is well described by the model of thermally activated phase slips [1,2]. However, if the wire width falls into a ~ 10 nm range, there are predictions that a new phase slip mechanism due to quantum tunneling should be observed [3,4,5]. Early experiments on 'one size' In and InPb ultra-narrow wires [6] did show up evidence of quantum phase slip phenomena. Recent experiments [7] on MoGe films evaporated on top of an insulating carbon nanotube also revealed qualitative deviations from orthodox thermal activation mechanism. The motivation of this work was to trace the evaluation of the R(T) dependences as a function of the cross-section of a same 1D wire. We have developed a method of progressive reduction the transverse dimensions of e-beam lift-off fabricated nanowires by ion-beam sputtering (Fig.1.). Sputtering can be thought as an erosion of the structure due to bombardment of primary ions. The method is very promising, for it lets us directly follow changes in superconductive transition in 1D superconductor along with successive reduction of its cross-section. Aluminum wires with effective diameter < 35 nm did show up a low temperature 'foot' at *R(T)* dependencies, which can be associated with quantum phase slip mechanism (Fig.2.).

References:

[1] J.S. Langer, V. Ambegaokar, Phys. Rev. 164, 498 (1967)
[2] D.E. McCumber, B.I. Halperin, Phys. Rev. B 1, 1054 (1970)
[3] A. Zaikin, D. Golubev, A. van Otterlo, and G. T. Zimanyi, PRL 78, 1552 (1997)
[4] A. Zaikin, D. Golubev, A. van Otterlo, and G. T. Zimanyi, Uspexi Fiz. Nauk 168, 244 (1998)
[5] D. Golubev and A. Zaikin, Phys. Rev. B 64, 014504 (2001)
[6] N. Giordano, Physica B 203 (1994) 460-466
[7] C.N. Lau, N. Markovic, M. Bockrath, A. Bezryadin, and M.Tinkham, Phys. Rev. 87, 217003 (2001)

Figures:

Fig.1. *Effect of sputtering: left picture – a wire fabricated with e-beam lithography method, right picture – the same wire after sputtering (4-probe measurement setup is depicted schematically). Pictures are captured with AFM.*

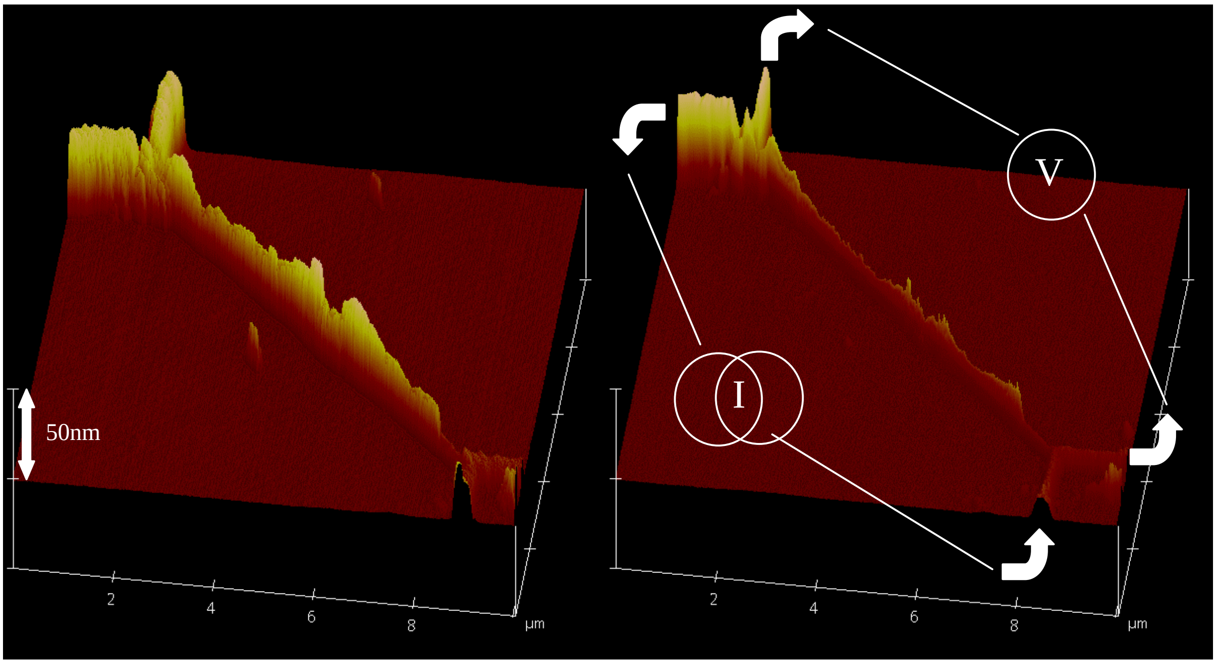

Fig.2. *Shape of superconducting transition R(T) of the wire fabricated with e-beam lithography (left) can be described within LAMH theory [1, 2]. After sputtering the qualitative change in the transition is observed (right). 'Foot' is believed to appear due to quantum tunneling phenomenon [3, 4, 5].* R_N *denotes normal state resistance.*