Low dimensional nanostructures by Electromigration

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XXXVI Cycle

Giuseppe Leonetti

Supervisors: Prof. Fabrizio Candido Pirri, Dr. Natascia De Leo, Dr. Gianluca Milano

Research context and motivation

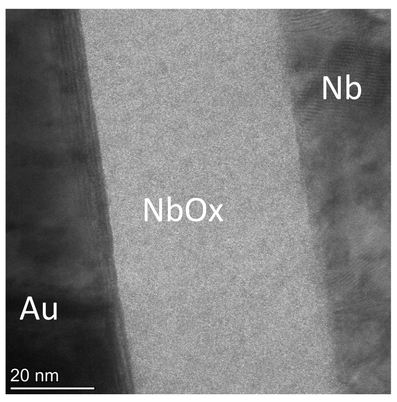
- Resistive switching (RS) devices fabricated as Metal-Insulator-Metal (MIM) nanostructures based on Nb, a superconducting material
- Fabrication of MIM devices and study of their resistive switching properties and formation of nanostructure exploiting the Electromigration (EM) in NbO_x
- Explore the superconducting phenomena in low-dimensional nanostructures obtained by EM
- Crossover: "Memristive Devices as Quantum Standard for Nanometrology" – JRP – f14, EMPIR 2020 (INRiM ft. Polito)

Addressed research questions/problems

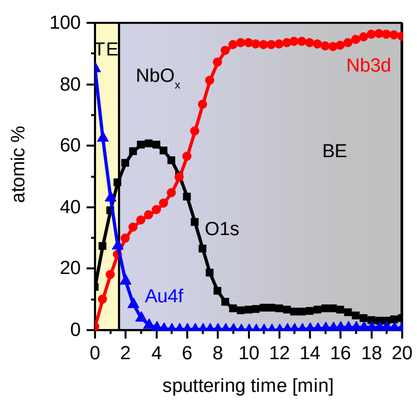
- No in-depth study of the superconducting material properties at extreme low dimensions
- Conventional fabrication techniques are not able to reach sub-10 nm to atomic scale features
- Resistive switching devices and Electromigration (EM) are never used for superconducting studies

Adopted methodologies

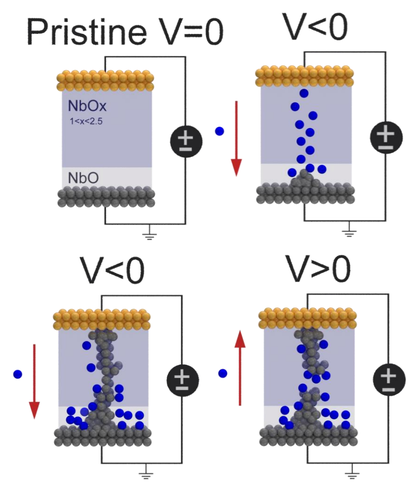
- Use of anodic oxidation to grow NbO_x on the top of Nb thin-films
- Thin-film technology in combination with standard optical lithography to develop the $Nb/NbO_x/Au$ resistive switching devices
- Material characterization to study the NbO_x structural and chemical properties
- Electrical characterization to induce EM in the fabricated devices, study the RS properties, and induce the formation of the Nb nanostructures.



HR-TEM

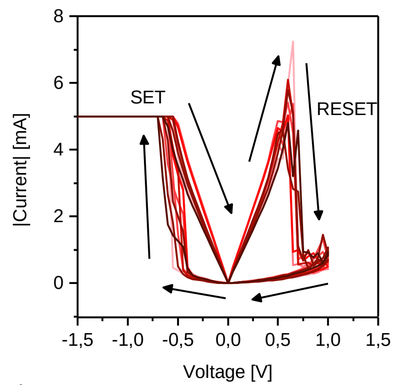


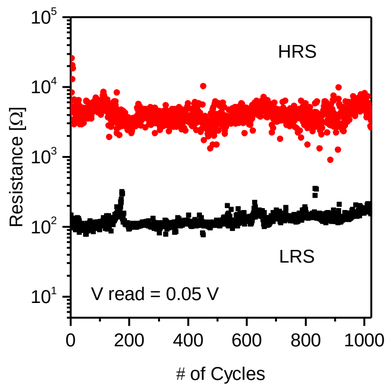
XPS – depth profile

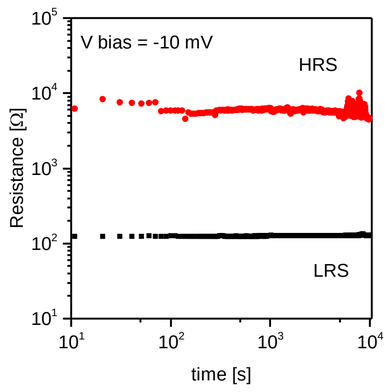


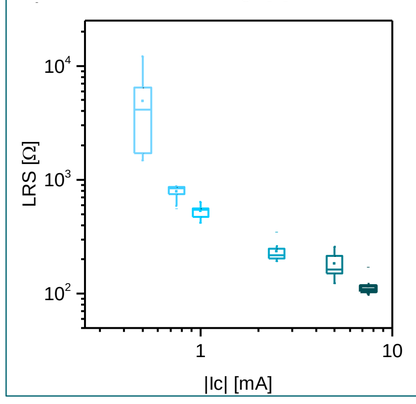
Novel contributions and results

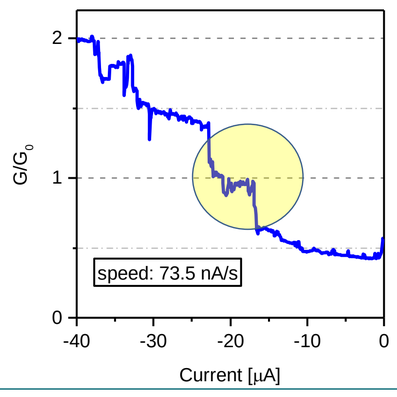
- Study of resistive switching properties of $Nb/NbO_x/Au$ devices through *IV* measurements of Endurance and Retention
- Study of the electrical conductivity of the conductive EM-formed channel by tuning the Compliance Current *Ic*
- Fine tuning of the channel conductance through slow Current and Voltage sweep measurements and observation of
- the Conductance Quantization

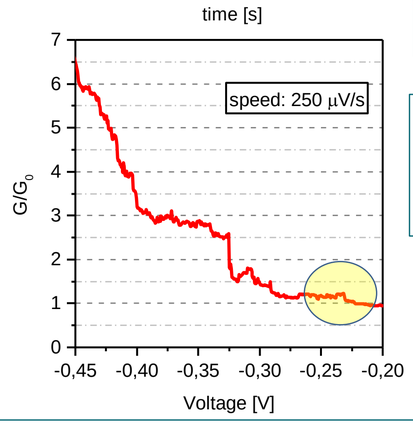


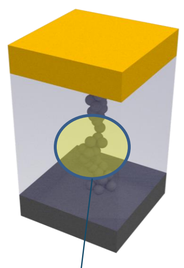










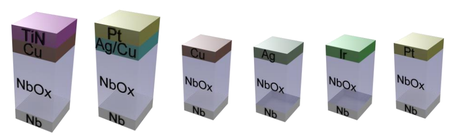


$$G_0 = \frac{2e^2}{h} = 7.74809173 \times 10^{-5}\ S$$

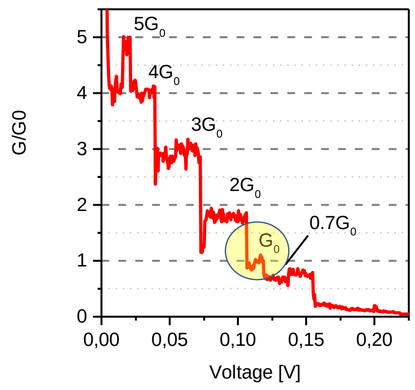
Approaching
The QuantumPoint Contact
(QPC)

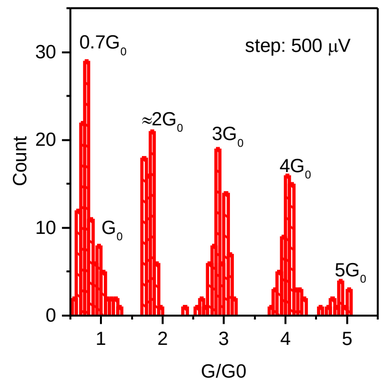
Measurements at IWE2
RWTH of Aachen

Department of Physics | RWTH AACHEN UNIVERSITY



- Fabrication of new RS devices based on NbO_x, different thicknesses and top electrodes
- Use of slow voltage sweep measurement for the observation of Integer multiple of G_0 during the RESET phase in Controlled Moisture *IV* measurements*





*Measurements referred to the Pt terminated device

Future work

- Study the superconducting properties of the conducting channel realized in the MIM as studied devices as soon its conductance approaches the quantum Conductance G_0
- Find the correct operating conditions for reproducible conductance steps
- Realization of cross-point devices for better control of the quantized steps

Acknowledgments

- Part of this work has been carried out at Nanofacility Piemonte INRiM, a laboratory supported by the ''Compagnia San Paolo'' Fondation and at the QR laboratories, INRiM

Submitted and published works

List of attended classes

- 02UKHKI – Applied spectroscopic methods (16/06/2021, 30 hours)
- 02LWHRV – Communication (3/12/2020, 5 hours)
- 02LCRKG – Fisica di superfici ed interfacce (2/04/2021, 15 hours)
- 01VFNRV – High Temperature Superconductors for Electrical Applications (Didattica di eccellenza vp) (25/01/2021, 12 hours)
- 01DMLKG – Introduzione alla microscopia ottica – Scienza e Tecnologia (Didattica di eccellenza vp) (24/03/2022, 20 hours)
- 01TCPRV – Nano and molecular electronics (15/09/2021, 40 hours)
- 01UNVRV – Navigating the hiring process: CV, tests, interview (10/03/2022, 2 hours)
- 02SFURV – Programmazione scientifica avanzata in matlab (27/04/2021, 30 hours)
- 08IXTRV – Project management (7/12/2020, 5 hours)
- 01RISRV – Public speaking (2/12/2020, 5 hours)
- 01SYBRV – Research integrity (23/12/2020, 5 hours)
- 01SWQRV – Responsible research and innovation, the impact on social challenges (21/12/2020, 5 hours)
- 01UKGKI – Synthesis methods to tailor the surface and the structure properties (3/05/2021, 25 hours)
- 01QSXRU – The measurement of the electrical impedance (10/03/2021, 10 hours)
- 01UNXRV – Thinking out of the box (11/03/2022, 1 hour)
- 01QOPRV – Writing scientific papers in English (18/02/2021, 15 hours)