New functionalities for energy-efficient superconducting electronic devices

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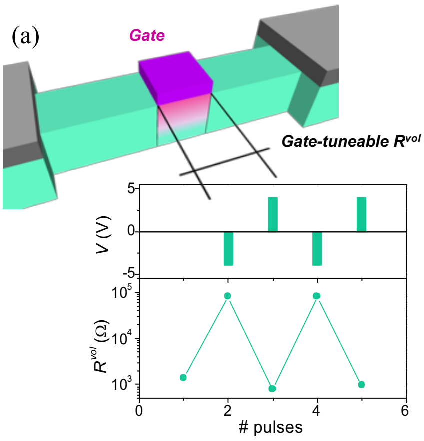
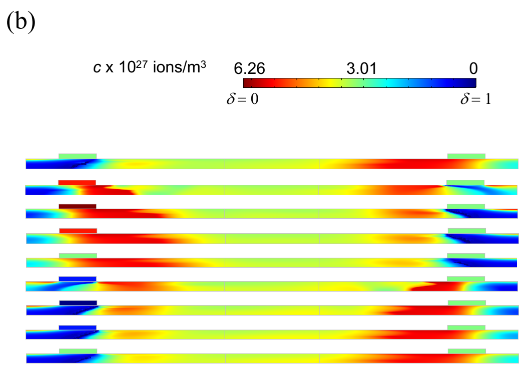
Next decade of research in condensed matter physics will be driven by the development of novel materials and hybrid systems for the design of new electronic functional devices featuring low energy dissipation. Strongly correlated metal oxides, showing metal-insulating transitions (MIT), appear as particularly interesting materials, offering the unique opportunity to induce large resistance variations with small tuning of their carrier concentration. The ability to continuously tune the electrical resistance through a field induced MIT modulation, as well as to obtain high nonlinear behaviour, positions them ideal candidates for memory and logic devices. In this context, one promising technology is indeed the use of superconductors, which could have a substantial impact by virtue of their inherent energy-efficiency. Field-effect tuning of the carrier density in strongly correlated superconducting cuprates, not only allows us to modulate the MIT but also enables to induce a reversible Superconductor-Insulator quantum phase transition (SIT), offering unique scientific and technological opportunities in this rapidly emerging field.

Here I will present the potential of the electric manipulation of the superconducting parameter in $YBa_2Cu_3O_{7-\delta}$ films, for the design for multi-terminal memristive transistor-like devices, with loss-less superconducting drain-source channels (Figure 1 (a)) [1]. Both normal state resistance and the superconducting critical temperature can be reversibly manipulated in confined active volumes of the film by gate-tuneable oxygen diffusion. The key advantage of these materials is the possibility to homogeneously modulate the oxygen vacancy diffusion not only in a confined filament or interface, as observed in widely explored insulating strongly correlated oxides, but also toward the whole film thickness, thus providing the basis for the design of robust devices. We analyse the experimental results in light of a theoretical model, which incorporates thermally activated and electrically driven volume oxygen diffusion (Figure 1 (b)).





(a) Scheme of a transistor-like device (top). Voltage pulses and volume bridge resistance evolution obtained for a 50 nm thick $YBa_2Cu_3O_{7-\delta}$ device. (b) Oxygen diffusion simulation at different stages of the switching process. Colors show the oxygen concentration.

References

[1] Palau et al. ACS Appl. Mat. & Interf. 10, 30522 (2018), Gonzalez-Rosillo et al, Adv. Electr. Mat, 1800629 (2019)

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