INSULATOR–TO–METAL SWITCH IN CORRELATED INSULATORS VIA THE FIELD–DRIVEN COLLAPSE OF THE MOTT GAP

Giacomo Mazza
École Polytechnique & Collège de France @ Paris

w/ Adriano Amaricci, Massimo Capone, Michele Fabrizio
International School for Advanced Studies @ Trieste

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Control of the conductive properties of materials

Building block of almost every electronic device

Semiconductors

Quantum tunneling

Chemical doping
Why Correlated Materials?

Extremely tunable materials with rich phase diagram (doping, temperature, pressure)

Mott insulators ↔ “unsuccessful metals”

electronic correlation

electric-field

Unlock a huge number of frozen carriers

Huge potential for Mott based microelectronic devices!

see Inoue & Rozenberg Adv.Func.Mat ‘08
Insulators-to-Metal switch in correlated insulators

Resistive switch experiments

Electric-Double-Layer-Transistor

Abrupt switch at fields much smaller than the gap

Guiot et al NatComm ’13
Stoilar et al AdvMat ‘13

cf. E. Janod talk

bulk delocalisation beyond the electrostatic screening length

Nakano et al Nature ‘12

Insulators-to-metal switch beyond semiconductor physics
Breakdown in Mott–Hubbard Insulators

Simplest description of a correlated insulator phase behave not differently to semiconductors

Tunnel across the Mott-Hubbard gap

T. Oka et al PRL ’03
S. Okamoto PRB ’08
M. Eckstein et al PRL ’10
M. Eckstein et al. PRB ’14
G. Mazza et al. PRB’15

Possible alternative route to the dielectric breakdown

Mott insulator coexisting with a metastable metal

Eckstein et al PRL 105,146404
Two bands model w/ crystal field splitting

**Effects of e-e correlation**

Shrinking coherent quasiparticles

Enhancement of the crystal field

\[ W \rightarrow ZW \]

\[ \Delta \rightarrow \Delta + Um \]

**First-order MIT (DMFT)**

Metal-Insulator Coexistence
Insulating slab w/ applied electric field

Ground state evolution across the field driven insulator-to-metal transition (real space DMFT)

Different mechanisms in and out the metal/insulator coexistence region
Field-induced insulator-to-metal transition

\[ U \gg U_c \]

increasing Electric Field

Rigid tilt of the insulating gap

inhomogeneous metal charge redistribution

“equilibrium” formation of tunnel-like conductive channel
Field-induced insulator-to-metal transition

\[ U \gtrsim U_c \]

increasing Electric Field

Abrupt closing of the gap

Homogenous conductive states

First-order insulator-to-metal transition!
INS–MET hysteresis loop VS electric field

Energy gain within the linear response regime!

\[ \delta \langle H \rangle \propto E^2 \]

Relatively small electric field is able to induce the switch between the two coexisting phases!

The electric field reduces the effect of the correlation
Different routes for the Mott insulator metallisation

Switch between two competing phases

Rigid modification of the insulator (only one stable phase)

Qualitative and quantitative different IMT!
Different routes for the Mott insulator metallisation

Switch between two competing phases

Qualitative and quantitative different IMT!

Non-equilibrium description needed!