

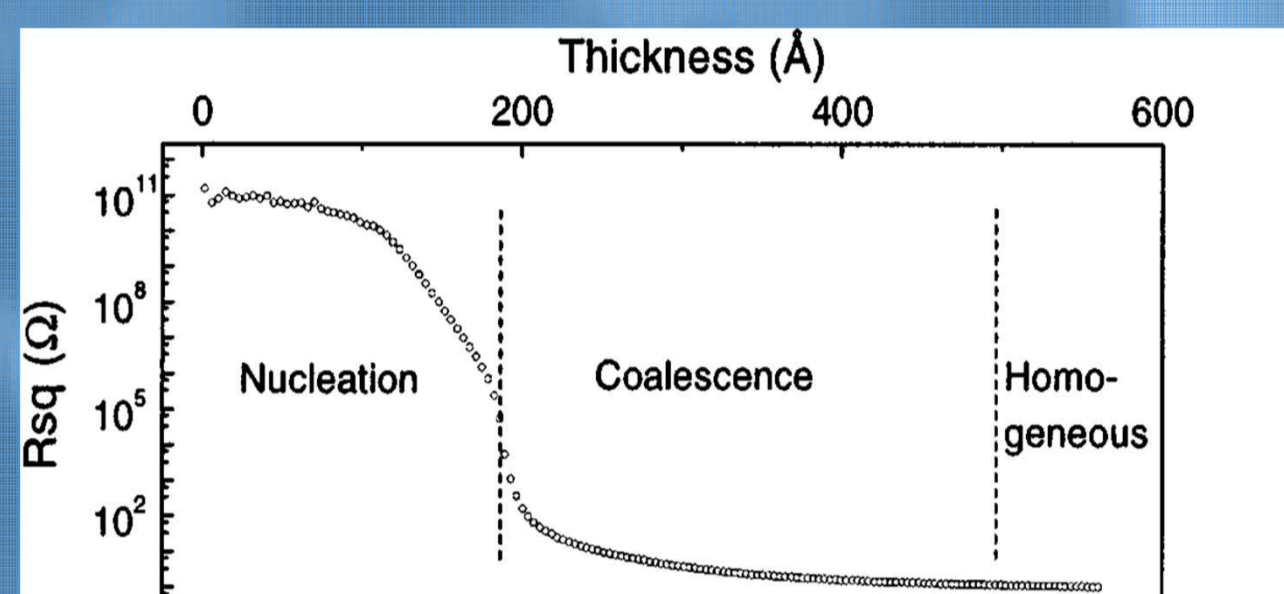
Characterization of the transport electrical properties in nanostructured metallic granular films

M. Mirigliano, C. Minnai, A. Bellacicca, S. A. Brown, P. Milani

Abstract - Thin films show interesting and anomalous physical properties often different from the bulk materials ones [1]. A peculiar class of thin films is that assembled by clusters [2]. We analysed the electrical properties and the morphology of the cluster assembled materials fabricated through the Supersonic Cluster Beam Deposition [3]. By means of this technique we realized devices composed by two metallic electrodes connected by a region of deposited gold clusters. Measuring the current flowing through the device under the bias of voltage sweeps, a variable electrical resistance and a switch behaviour controlled by the applied voltage were observed. We also investigated the morphological properties of the cluster region through the analysis of the digital images obtained by a Scanning Electron Microscope. The study revealed a structure at the nanoscale characterized by the presence of metallic islands connected through nanojunctions. This suggests that electromigration processes can be responsible for the observed electrical properties [4]. The switch behaviour makes suitable the studied devices for the fabrication of memristors [5, 6].

Background

Electrical properties of thin metallic films

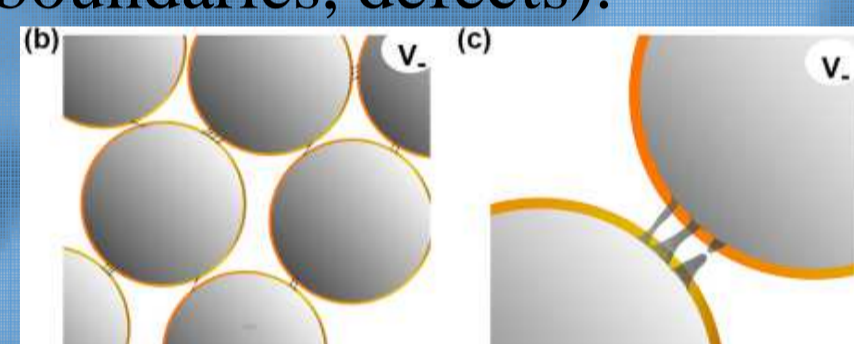


Reprinted from [1].

Metallic films with thickness comparable to the electron mean free path, have anomalous resistivity values. The electric properties of these systems are influenced by their microstructure (grain boundaries, defects).

Cluster assembled materials

Thin metallic films obtained using atomic clusters as building blocks.

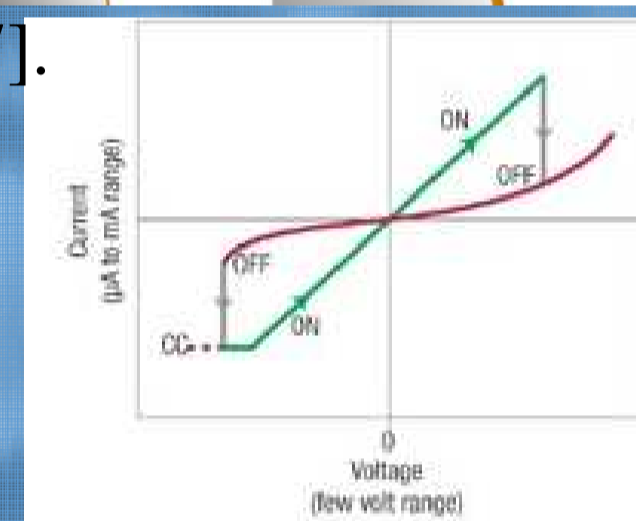


Memristor

Reprinted from [7].

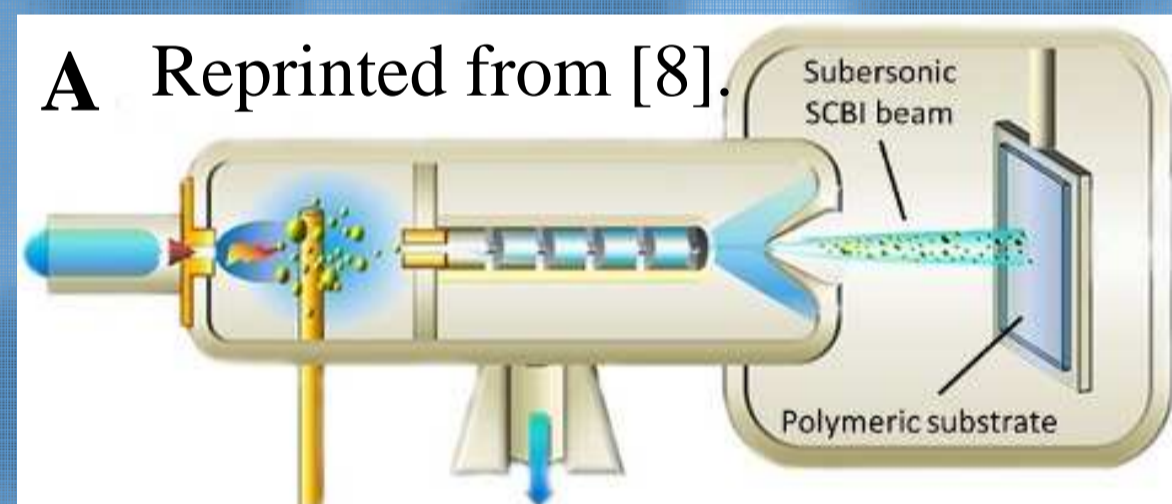
Metal-insulator percolated cluster systems are suitable for the fabrication of memristive devices

- Switch resistive behaviour
- Non linear current-voltage relation

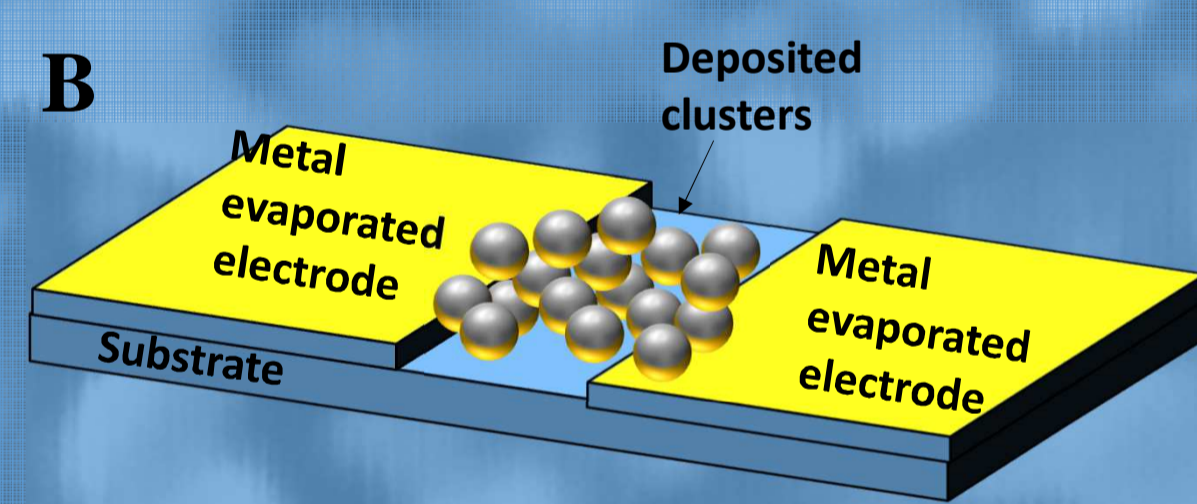


Methodology

Supersonic Cluster Beam Deposition (SCBD)



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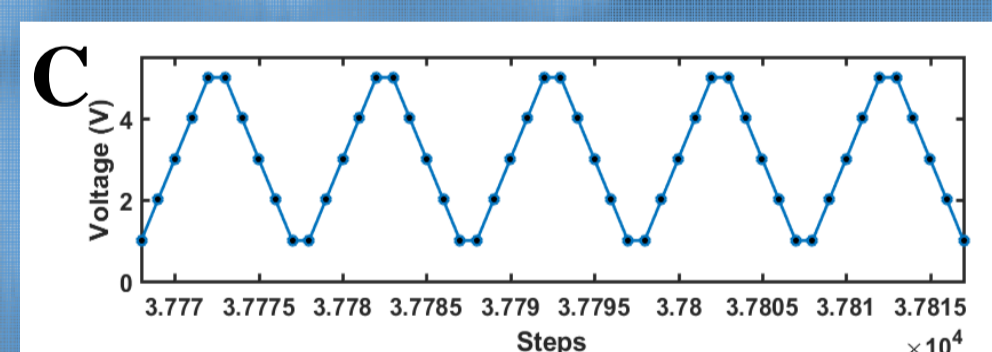
A thin cluster film is fabricated by the SCBD (A):

- Cluster production and supersonic beam expansion
- Aerodynamically focused beam
- Deposition on a substrate

Device design (B): two metal electrodes connected by a gold cluster film on a substrate.

Electrical and morphology characterization

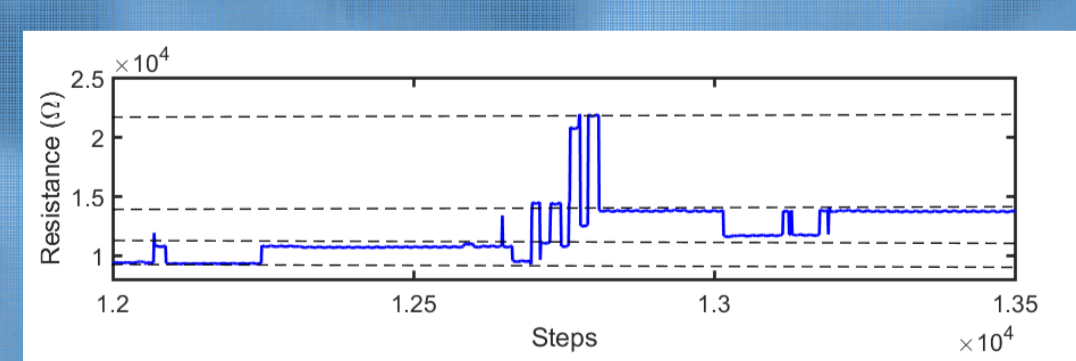
- SEM images analysis (background image)
- Voltage ramps; current measure for each ramp point (C)



Results

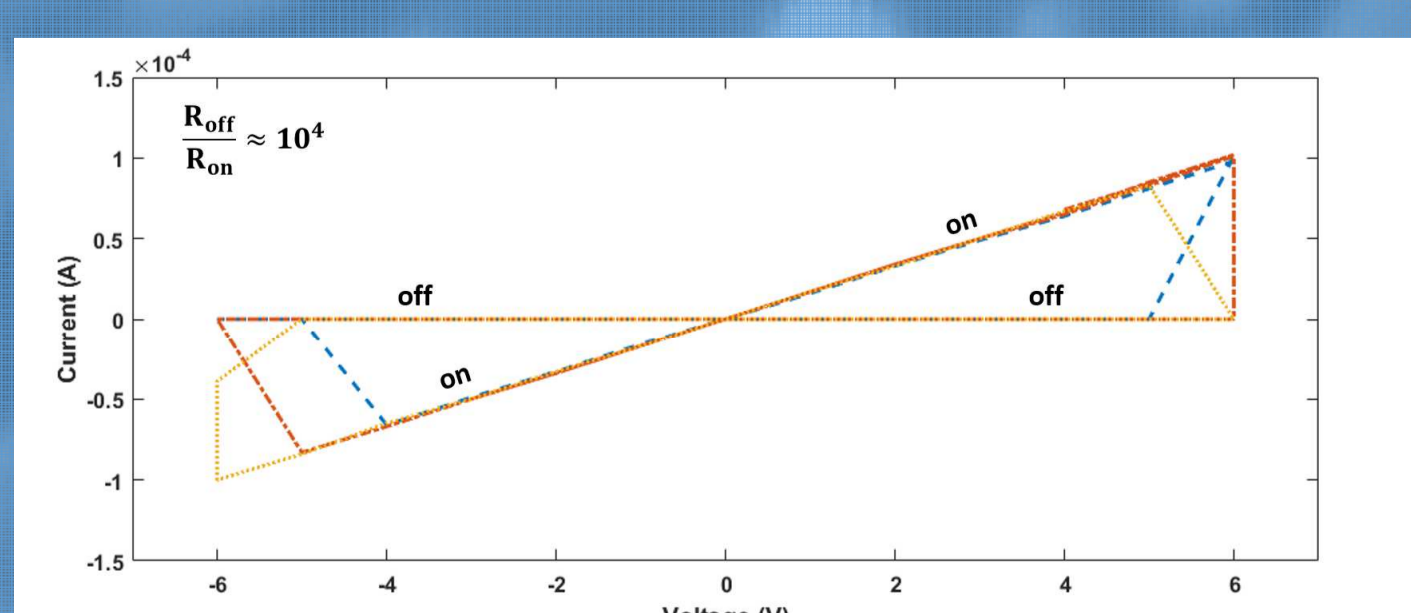
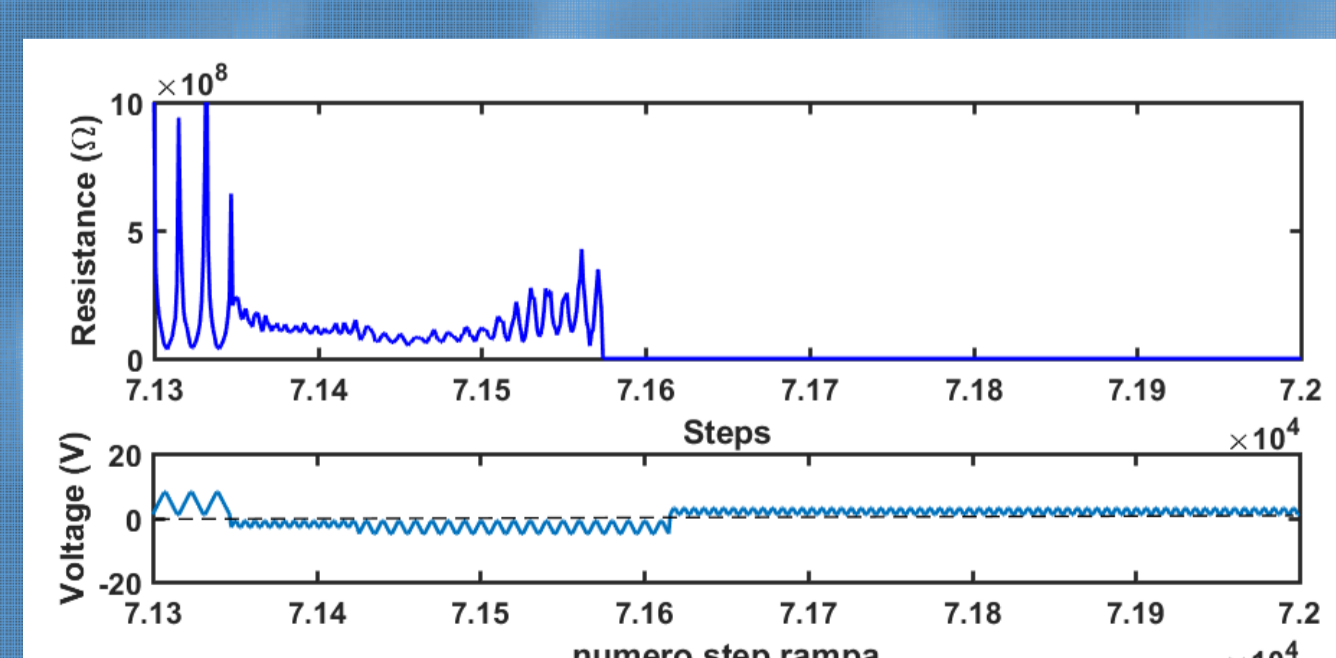
Electrical characterization

Resistive switching behaviour!



R_{off} : high resistance value
 R_{on} : low resistance value

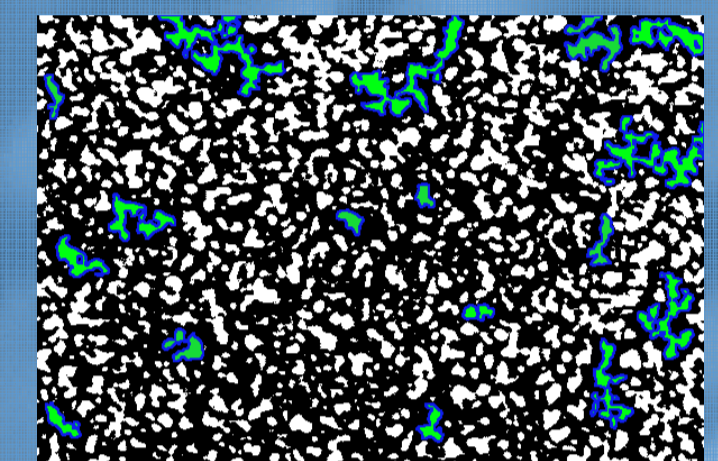
Voltage controlled on-off transition



Non linear current-voltage relation

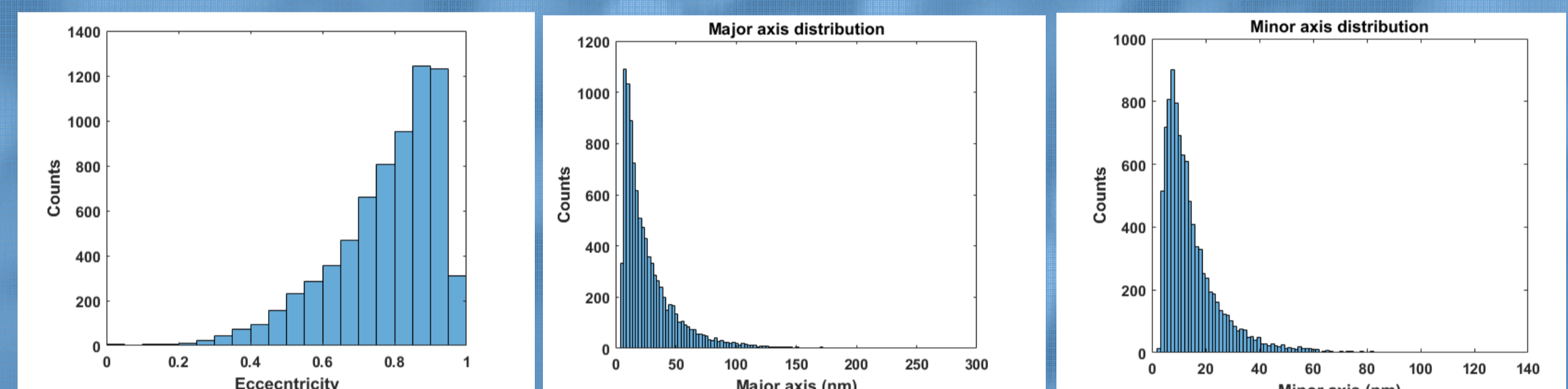
Morphology characterization

Binarized SEM image

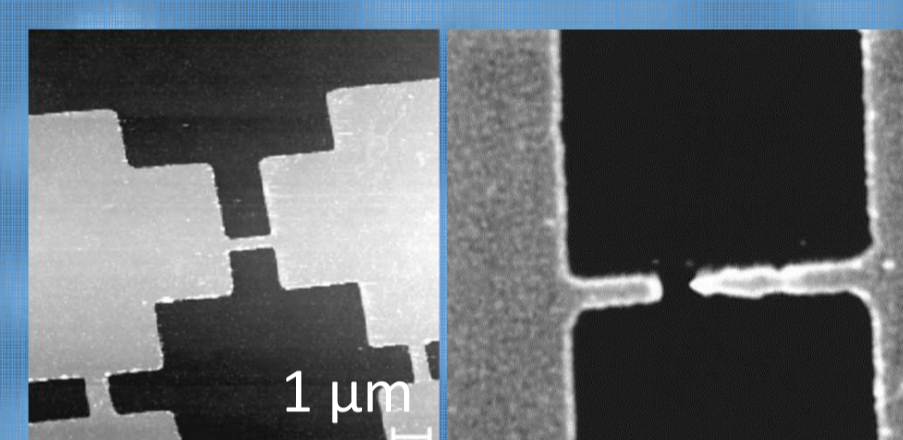


The SEM image analysis shows:

- Ramified shape
- Large distribution of island dimensions



Discussion

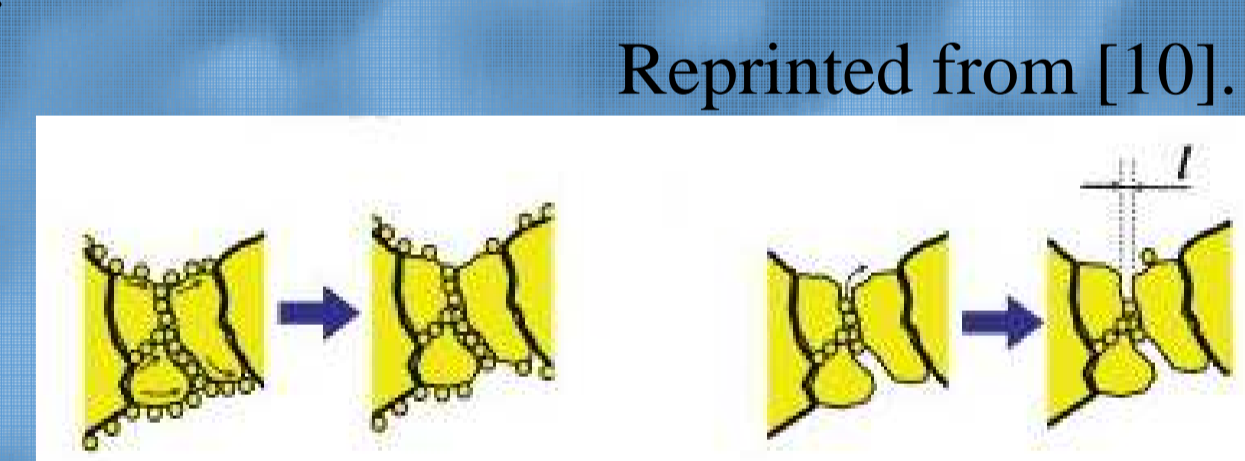


The ramified shape and the presence of several island dimensions, suggest the formation of nanojunctions between the aggregates.

Reprinted from [4].

The **electromigration processes** [9] play an important role for the overall electrical properties of the films. In fact, the current can cause the breaking of a nanojunction, changing the conduction capacity.

In addition, the migration of atoms at the cluster boundaries because of the current flow, is the origin of the switching behaviour, for the percolated films.



Reprinted from [10].

Conclusions and perspectives

The main results concern the correlation between the electrical and the morphologic properties of the cluster assembled materials. The main features for the metallic cluster assemblies is the loss of the ohmic behaviour in a wide voltage range. Thanks to phenomena like electromigration one, the samples show a switching resistive mechanism and an on-off voltage controlled transition. So, the SCBD represents an optimal and flexible solution for the fabrication of memristive device, only starting from the deposition of metallic nanoparticles.

References

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