UNDERSTANDING THE PHYSICS OF CONDUCTANCE SWITCHES

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With the ever decreasing size of electronic components, there is a continuous necessity to make ever smaller electronic switches. One of the approaches towards very small components lies in the use of solid electrolytes, which exhibit ‘memristive’ (memory resistive) properties.

In the correct configuration, these materials with highly mobile ions can form very small or even atomic contacts under the influence of an applied voltage. For example, the Ag_2S-based ‘atomic switch’ reported by Terabe et al. [1].

Using Ag_2S as the model material for such solid electrolyte devices, we have developed a method to grow Ag_2S thin films and to measure its memory resistive properties, in order to study the fundamental mechanism involved in resistance switching [2].

In different experiments, the Ag_2S thin films are contacted to electrodes: a Ag or Pt thin film as the bottom electrode and a Pt wire or Pt-coated AFM tip as the top electrode. Measurements at low bias voltages indicate semiconductor behavior, whereas they exhibit reproducible bipolar resistance switching at higher bias voltages (figure 1, left panel).
In the fully bipolar conductance switching regime, the device shows in the high conductance state several mutiples of quantum conductance (figure 1, right panel). We have found this conductance to be proportional to the applied bias voltage and to the size of the top electrode. By using a sharp, conductive AFM or STM tip, a few atoms contact can be achieved resulting in the observation of few multiples of the quantum conductance.

As a second approach to form atomic contacts with this solid electrolyte, we propose to use Ag_2S single crystalline whiskers. Under specific conditions, these whiskers are formed as a bi-product of our process to form Ag_2S thin films (figure 2).

By contacting and applying a voltage to these single crystalline wires, one should be able to directly observe material transport and deformation of the crystal due to Ag^+-ion diffusion, in the transition from high to low resistance states.

These observations will help us to have a complete understanding of the mechanism of conductance switching and possibly allow the direct observation of the formation of a single atomic contact.

References:

[1] K. Terabe, T. Hasegawa, T. Nakayama and M. Aono M, *Nature* **433** (2005) 47-50.
[2] M. Morales-Masis, S.J. van der Molen, W.T. Fu, M.B. Hesselberth and J.M. van Ruitenbeek, *Nanotechnology* **20** (2009) 095710.

Figures:

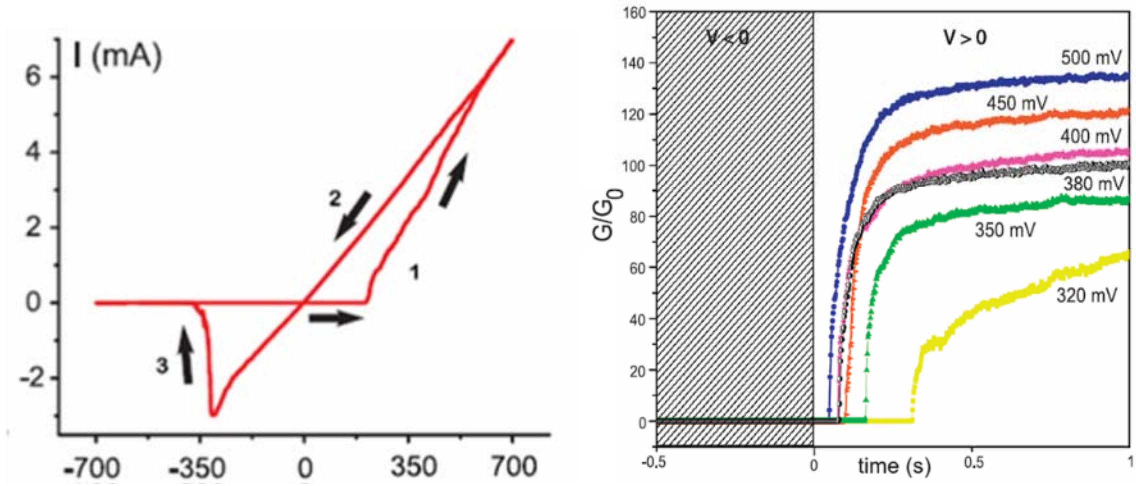

Figure 1 Left panel: IV characteristics of bipolar switching observed in Ag_2S thin films. The numbers 1 and 3 indicate the 'off' state (low conductance) and 2 indicates the 'on' state (high conductance). Right panel: Increase in the conductance as a function of time when different voltage steps are applied to the Ag_2S device.

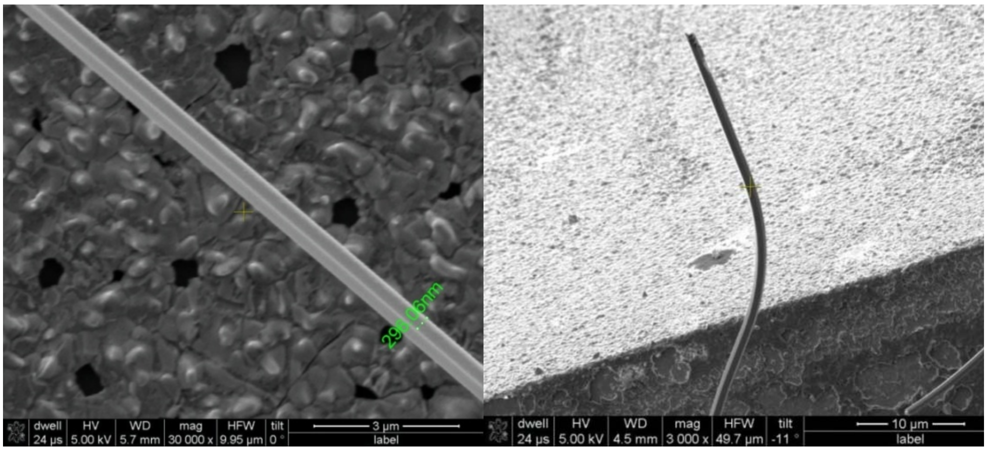

Figure 2 Single crystalline whiskers of Ag_2S. SEM images indicate the formation of wires with diameters in the range of 0.1 up to 1 mm and several microns long.