Random telegraph noise as a signature of metal-insulator crossover in self-assembled mesoscopic systems: experiment and modeling

K. O. Vicaro*[1]*, H. R. Gutierrez*[1]*, J. R. R. Bortoleto*[1]*, L. Nieto*[1]*,
***A. G. G. von Zuben*[1]*, A. C. Seabra*[2]*, P. A. Schulz*[1]*, M.A.Cotta*[1]**

[1] *UNICAMP – IFGW, CP 6165, 13081-790, Campinas, SP, Brazil*
[2] *LSI-PSI-EPUSP-USP, Av. Prof. Luciano Gualberto, trav.3, 158, 05508-900 - São Paulo-SP, Brazil*

Vertical and in-plane electrical transport in InAs/InP semiconductors nanostructures —mainly wires and dots, Fig. 1— have been investigated by conductive atomic force microscopy (C-AFM)[1] and electrical measurements at low temperatures in processed devices. Spatially resolved current images and localized *I-V* curves are obtained with C-AFM technique in a controlled atmosphere at room temperature and provide information about vertical transport across the nanostructures. The devices were processed by electron-beam lithography in order to access the in-plane conductance of an assembly with a reduced number of nanostructures. On these devices, fluctuations on *I-V* curves at low temperatures (<40K) are observed in subsequent acquisitions, see Fig. 2. At these low temperatures and for a suitable range of constant applied voltages the signature of random telegraph noises (RTN)[2] in the current behavior with time is observed (Fig. 3). For dot assemblies a RTN with two levels was observed in the electrical current. In this case, up and down times vary with the temperature and applied voltage. For the wire-and-dot system large RTN times were observed. These levels for electrical current can be associated to electrons removed from the wetting layer and trapped in dots and/or wires. This behavior is consistent with the energy values for the onset of current fluctuations and correlate well with C-AFM and *I-V* results for individual nanostructures.[3] The RTN evidences the relevance of a relatively small number of structures (dots and/or wires) in the transport for a certain range of temperatures. The amplitudes of the noise, as well as the time scales can be associated to other sample characteristics, e.g. energy levels and structure sizes, by means of phenomenological models.

A crossover from conduction through the continuum, associated to the wetting layer, to hopping within the nanostructures is observed with increasing temperature. For low temperatures, semiconductor or metallic-like transport behaviors can be seen at low and high applied voltages, respectively (Fig. 4). For larger temperatures, however, a $T^{-1/2}$-activated behavior can be observed: this dependence is usually attributed to constant range hopping transport[4] and suggests an important contribution of carriers trapped in localized states of the nanostructures for the current in the device.

FIGURES:

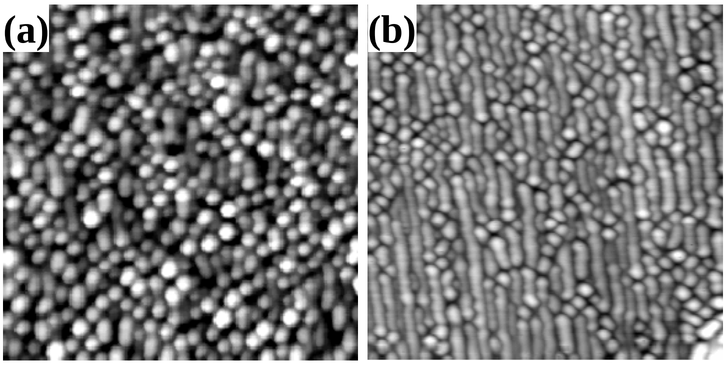

Fig. 1: Topographical AFM images of InAs grown nanostructures (a) dots. (b) wire-and-dot. Images sizes are 1x1µm^2.

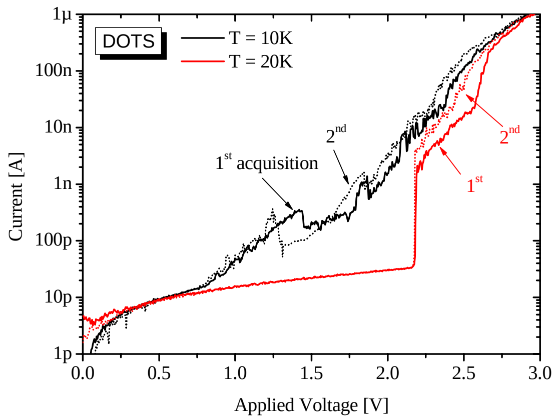

Fig. 2: *I-V* curves at low temperatures for processed devices with dots. Fluctuations are observed in subsequent acquisitions.

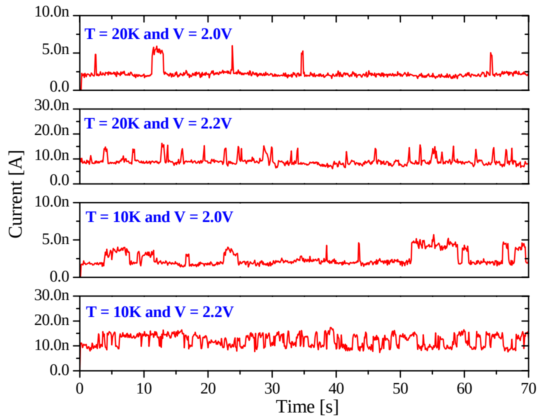

Fig. 3: Current vs time behavior for dots in a processed device. Switching between high and low levels indicates a signature of RTN.

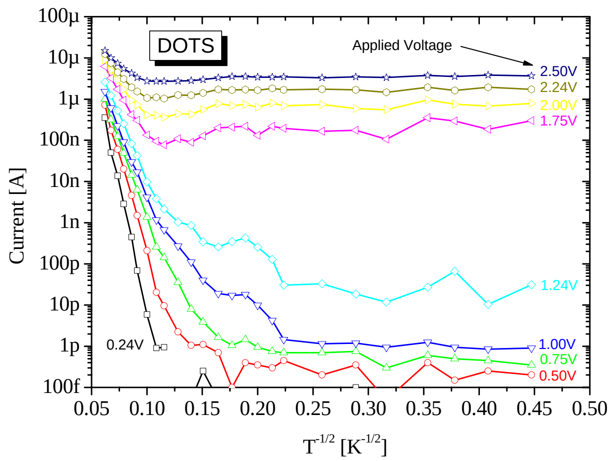

Fig. 4: Temperature dependence of the current for the processed devices (with dots) for a set of applied voltages.

REFERENCES:

[1] S. A. Landau, N. Junghans, P.-A. Weiß, B. O. Kolbesen, A. Olbrich, G. Schindler, W. Hartner, F. Hintermaier, C. Dehm, C. Mazure, Appl. Surf. Sci. **157**, 387 (2000).
[2] M. B. Weissman, Rev. Mod. Phys. **60**, 537 (1988).
[3] K. O. Vicaro, M. A. Cotta, H. R. Gutiérrez, and J. R. R. Bortoleto, Nanotechnology **14**, 509 (2003).
[4] N. F. Mott, *Metal-Insulator Transitions*, London: Taylor & Francis Ltd., (1974). P. Sheng, B. Abeles and Y. Arie, Phys. Rev. Lett. **31** (1), 44 (1973).