Physical mechanisms associated in the formation and operation of memory devices based on a monolayer of gold nanoparticles-polythiophene hybrid materials

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SUPPORTING INFORMATION

1. Cluster analysis by TEM after the forming Process

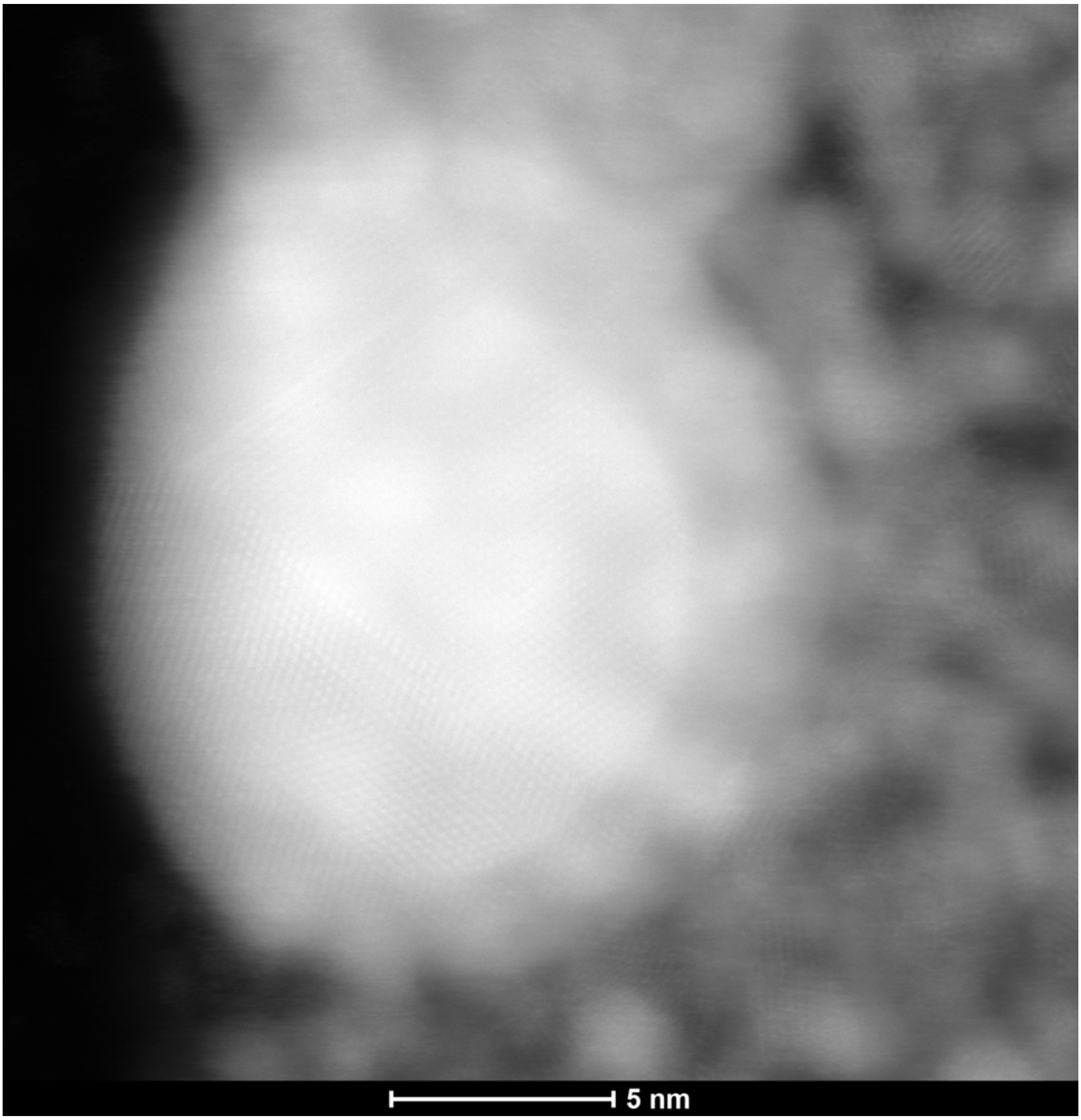


Figure SI-1. TEM images of a cluster of the P(TEDOT)-GNPs monolayer after the forming process in the OFF state.

2. Model of transport applied on I-V memory characteristics

2.1 Variable Range Hopping Model

In the case of a transport mechanism by variable range hopping, the dependence of the conductivity with the temperature is modeled by the following equation (from [[1]]):

$$\sigma(T) = \sigma_0 e^{\left[-\left(\frac{T_0}{T}\right)^{\alpha}\right]} \qquad \text{(Eq. SI-1)}$$

with σ the conductivity, σ_0 the conductivity prefactor, T_0 the characteristic temperature, T the temperature and α a constant equals 1/(D+1) where D is the dimensionality of the electrical conduction path.

[1] Nardes, A. M.; Kemerink, M.; Janssen, R. A. J.; Bastiaansen, J. A. M.; Kiggen, N. M. M.; Langeveld, B. M. W.; van Breemen, A. J. J. M.; de Kok, M. M., Microscopic Understanding of the Anisotropic Conductivity of PEDOT:PSS Thin Films. Advanced Materials 2007, 19 (9), 1196-1200.

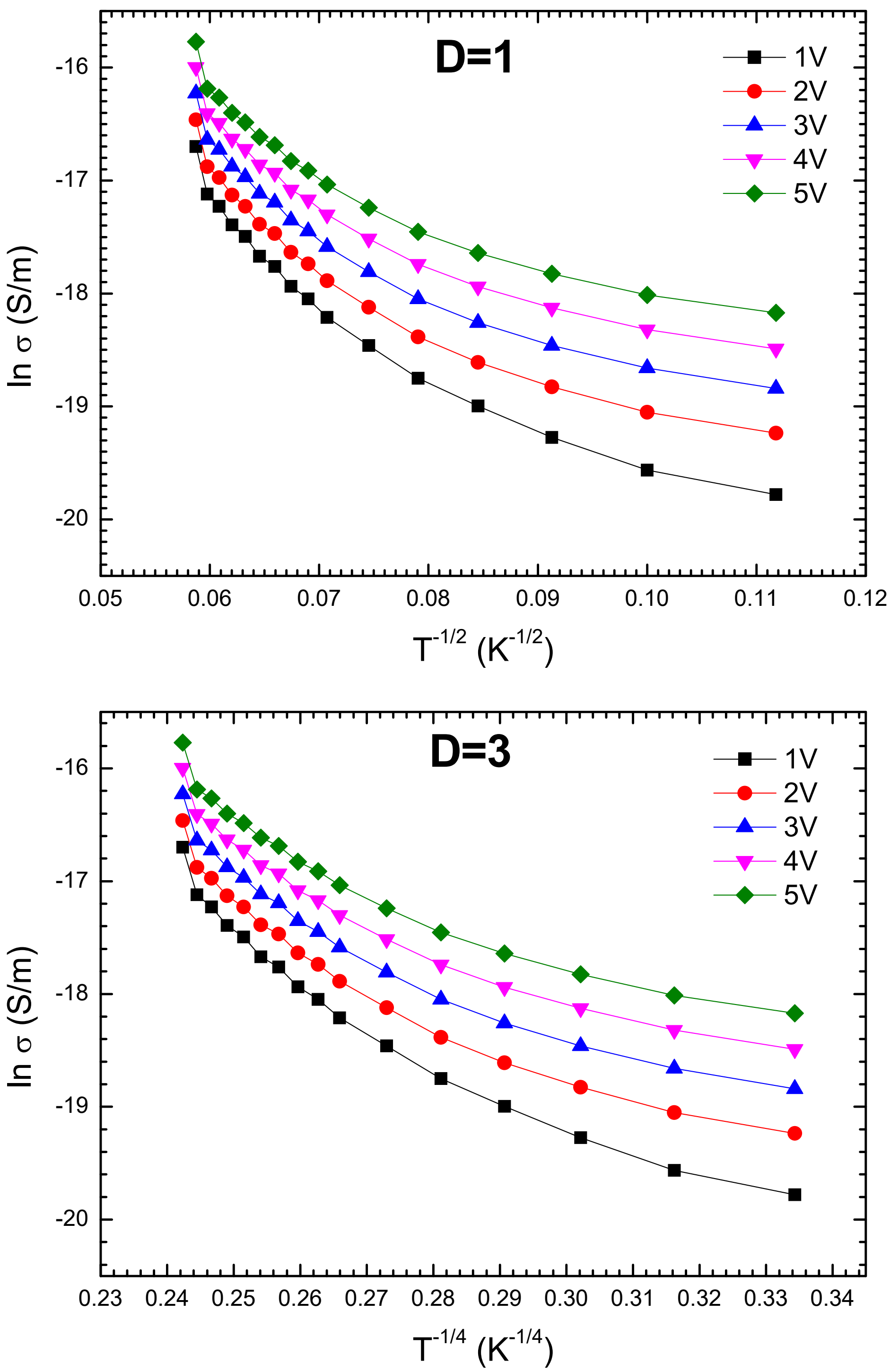


Figure SI-2. Temperature dependence of the conductivity measured in a Poly(TEDOT)-GNPs monolayer after the forming process in the OFF state for a 1D and 3D conduction path in top and bottom respectively. No linear behavior is observed. Thus, the transport model by variable range hopping is not consistent with the electrical properties measured on the Poly(TEDOT)-GNPs monolayer after the forming process in the OFF.

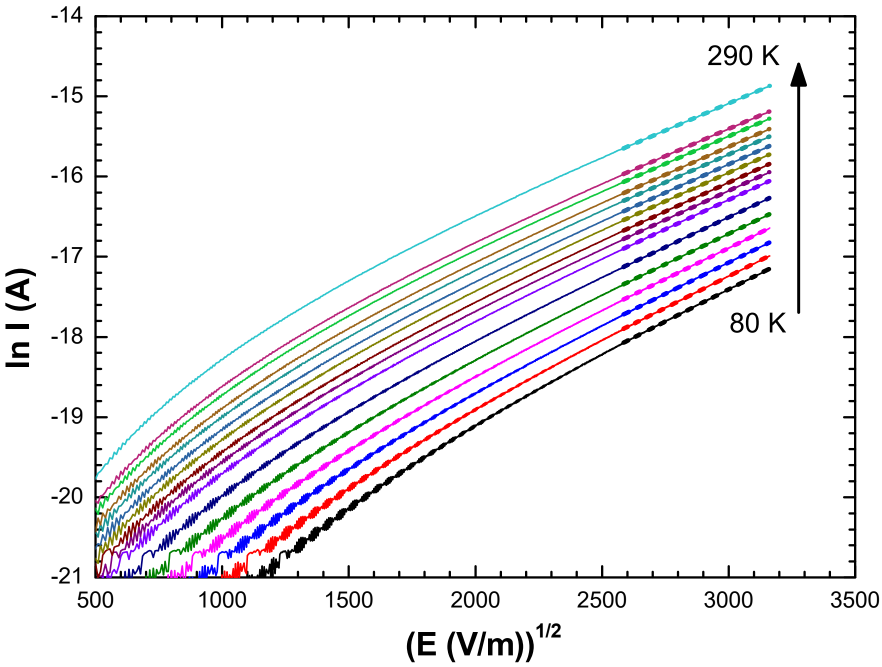
2.2 Thermionic emission limited conduction (TELC) Model

In the case of a transport mechanism by TELC, the expression of the current is given by the following equation (from [2]):

$$I(V,T) = 120\frac{m^*}{m_0}T^2\,S\,e^{-\frac{\phi_0}{kT}}\,e^{\frac{\beta_S E^{\frac{1}{2}}}{kT}} \qquad \text{(Eq. SI-2)}$$

with J the current density, m^* the effective mass of the electron, m_0 the electron mass, T the temperature, ϕ_0 the barrier height, k the Boltzman's constant, E the electric field and $\beta_S = \left(\frac{e^3}{4\pi\varepsilon\varepsilon_0}\right)^{1/2}$, with e the electronic charge, ε permittivity relative, ε_0 permittivity of vacuum and S the cross section.

2 Hesto, P., The nature of electronic conduction in thin insulating layers. In Instabilities in silicon devices, Barbottin, G.; Vapaille, A., Eds. Elsevier: Amsterdam, 1986; Vol. Vol. 1, pp 263-314.



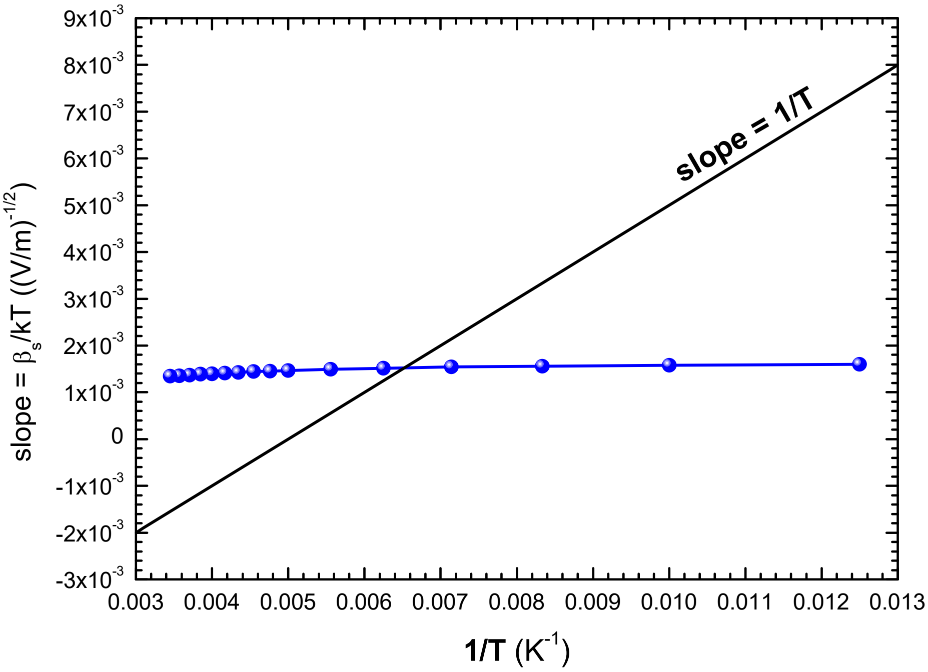


Figure SI-3. Top: Electric field dependence of the current, measured in a Poly(TEDOT)-GNPs monolayer after the forming process in the OFF state. From the linear dependence, linear adjustments give the slope of the curves at different temperature. Bottom: the fitted slopes values from the top graphic are plotted in function of 1/T. No linear behavior is observed for this slope with 1/T. Thus, the transport model by TELC is not consistent with the electrical properties measured on the Poly(TEDOT)-GNPs monolayer after the forming process in the OFF.

3. I-V memory characteristics on shorter inter-electrode gap

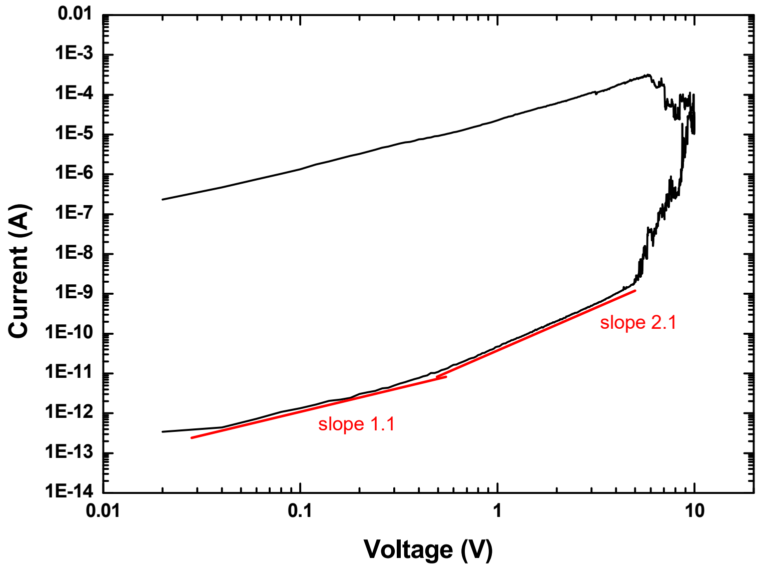


Figure SI-4. Typical current I versus voltage V curves (log-log scale) for the memory behavior measured on a formed-pTEDOT-C10-S-GNPs device with a gap length of 500 nm. Dots correspond to experimental data and red lines to the fitting adjustments before switching regions; i.e. in region 1 (0.1 to 1 V) and Region 2 (1 to 10 V) for the OFF state, and from 0.1 to 7 V for the ON state.