Charge Transport in van der Waals Thin Films, the case of Reduced Graphene Oxide from single flake to thin film

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Large area van der Waals (vdW) thin films are assembled materials consisting of a network of randomly stacked nanosheets. The multiscale structure and the two dimensional (2D) nature of the building block mean that interfaces naturally play a crucial role in the charge transport of such thin films. While single or few stacked nanosheets (i.e., vdW heterostructures) have been the subject of intensive works, [1-3] little is known about how charges travel through multilayered, more disordered networks. [4] Here, we report a comprehensive study of a prototypical system given by networks of randomly stacked reduced graphene oxide 2D nanosheets, whose chemical and geometrical properties can be controlled independently [5], permitting to explore networks ranging from a single nanosheet to some billions forming thin films, with room temperature resistivity spanning from 10^{-5} to 10^{-1} $\Omega\cdot$m.

Most studies give an ambiguous interpretation of charge transport phenomena by qualitative plot of resistance vs temperature, while a univocal interpretation of the charge transport phenomenon is still object of debate: Efros-Shklovskii variable-range hopping (ES-VRH) or 2D Mott variable-range hopping (2D-VRH). Based on analysis of the reduced activation energy W(T) [6], we systematically observed a clear transition between two different regimes: Efros−Shklovskii variable-range hopping (ES-VRH) below a critical temperature T* and power law behavior above.

First, we demonstrate that the two regimes are strongly correlated with each other, both depending on the charge localization length ξ, calculated by the ES-VRH model, which corresponds to the characteristic size of overlapping sp^2 domains belonging to different nanosheets. Thus, we propose a microscopic model describing the probability that charges circumvent the hopping barriers increases with film thickness, with a corresponding increase in the effective delocalization of the electronic states up to the micron scale [7].

Acknowledgement: Graphene Flagship, GA-881603

References

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Figures

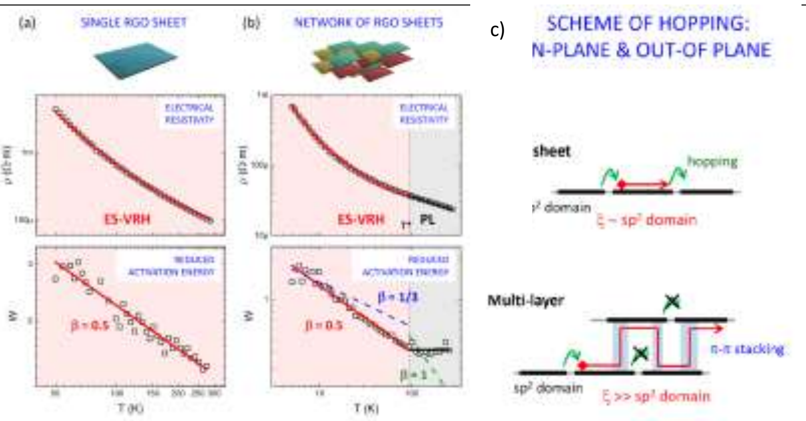

Figure 1: Resistivity vs Temperature of single sheet rGO (a) and thin film (b). Charge transport scheme(c).