Graphene, Silicene and Forgotten Lessons of Surface Science

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The nickname of a 'miracle material' has been widely accepted by the graphene community. It normally means the material superior properties. However, all the properties are only the outward manifestation of the graphene wonderful nature. The real miracle of graphene is that it is a union of two entities: the physical and chemical ones, each of which is unique in its own way. The physical superior properties of graphene are widely discussed. Much less has been told about its chemical uniqueness that is generated by carbon atoms packing in a flat honeycomb structure. The structure, based on benzenoid units, offers three neighbors to each carbon atom leaving the atom fourth valence electron on its own. These electrons form the pool of *odd* electrons whose behavior might change from the covalent bonding, characteristic for π electrons, to free electrons of radicals when the interaction between the electrons becomes weaker and weaker. The two electron states belong to different limit cases in terms of the electron correlation: π electrons are not correlated while radical electrons are strongly correlated so that two electrons with different spins occupy different places in the space. π-Electrons of the benzene molecule belong to the first limit case while odd electrons of benzenoid units of graphene (as well as fullerenes and carbon nanotubes) are correlated, which is caused by the difference in the C-C bond lengths while the critical length of 1.395$\mathrm{\AA}$ and below marks the first limit case [1].

The odd electrons correlation and the exceptionally close relationship between the correlation extent and benzenoid bond structure make graphene

material highly sensitive to any kind of external action such as morphological changing, chemical modification, mechanical loading and fixation, application of electric and magnetic field, and so forth thus making it structurally-and-electronically non stable. The “fluid” electronic structure accompanied with the flexible space structure aggravated with equal-energy topological phase transitions are the main reasons for failures of stable technologies for converting graphene from semimetal to semiconductor [2]. The way to improve the situation can be seen in inhibiting the odd electrons correlation by depositing one-layer adsorbate of either carbon (graphene) or silicon (silicene) on a proper substrate.

1. E.F.Sheka. *Fullerenes. Nanochemistry, Nanomagnetism, Nanomedicine, Nanophotonics*. CRC Press, Taylor and Francis Group, Boca Raton (2011).
2. G. Lu et al. *Nanoscale* (2013) 5, 1353-1368.