Applications of Switchable Interfacial Dopants

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Doping of bulk semiconductors and low-dimensional structures (carbon nanotubes, graphene, etc.) in order to modulate their electronic properties is a well-established concept.[1] However, it is usually permanent. Even in cases where doping of thin films by analytes (e.g. carbon nanotubes by ammonia) is applied in sensors, it is only reversed by physical removal of the dopant molecules, e.g. through heating. On the other hand, molecular switches are also an old concept by now, but practical examples of facile detection of their state with a thin film sensor are less common. We demonstrate the facile doping and de-doping of iron oxide films as well as carbon nanotube networks in contact with different oligoaniline oxidation states as an example of interfacial doping with a switchable dopant, i.e. a molecular switch. The idea that a small local change in carrier concentration (in this case due to a modification of the doping state) results in a large change in resistivity is somewhat reminiscent of (but not identical to) a chemical field effect transistor (in which case the electric field is modulated due to creation of electric charges), in that it also constitutes an active sensor. While for most conventional sensing applications, the removal of the dopants from the film present one challenge and the selectivity to a particular dopant another, even bigger, challenge, our devices keep the dopants in place. The sensing performance is achieved by switching the dopants between active and inactive states. A redox sensor for measuring chlorine concentrations in drinking water [2] is the first member of this new class of sensors, although the concept certainly can be applied to many other systems. Not only are these systems relevant for sensors, but charge transfer in closely coupled redox systems (e.g. oligonanilines and iron oxide) also find applications in corrosion inhibition [3] and smart coatings, another application that we are exploring in our group.

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