The molecular approach to multifunctional 2D electronics: from high-performance pressure sensors to brain-inspired cognitive systems

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Abstract

The remarkable characteristics of 2D materials can be further refined, expanded, and improved by integrating them with specifically designed molecules, utilizing principles of supramolecular chemistry. By leveraging the extensive range of molecules that can be tailored and synthesized with specific functionalities, it becomes possible to engineer 2D materials with adaptable physical and chemical characteristics. This approach enables the creation of novel functionalities, aiming to develop multifunctional hybrid systems suited for electronic applications beyond CMOS technology, in line with the "more than Moore" strategy of functional diversification.

In my lecture I will present our recent findings on the use of chemical approaches to develop flexible pressure sensors with enhanced characteristics and complex multi-responsive opto-electronic devices capable to emulate brain-like logic operations.

On the one hand, by tuning of the employed materials, structural design, and functionality, we have realized graphene-based pressure sensors displaying high sensitivity (742.3 kPa^{-1}) with a linear response extended over a widest window exceeding 800 kPa. Such pressure sensors are endowed with a voltage-controlled highly precise inherent correction of thermal drifts to ultimately enable reliable sensing applications across varying environmental conditions.

On the other hand, we demonstrate that the asymmetric interfacing of 2D semiconductors with stimuli responsive molecules and (bio)polymers enabling dipole modulation at the interface with the semiconductor or acting as reservoir of ion that are controllably released offers a precise tool to achieve high control over the dynamic doping. When such organic-inorganic hybrid van der Waals heterostructures are integrated in field-effect transistors, synaptic plasticity including sensory, short-term, and long-term memory operation can be emulated, paving the way for environmental-friendly neuromorphic computing and energy-efficient 2D optoelectronics.

By combining the best of two worlds, the interfacing of 2D materials with the infinite arsenal of functional molecules available on our planet represents a versatile strategy to harness multifunctionality and boost performance in 2D material-based hybrid devices, towards disruptive technologies addressing global challenges in electronics, sensing, and energy-related applications.

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