Dress them with molecules! Elevating 2D materials to a new dimension

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The already exceptional properties of 2D materials can be further tuned, enriched and enhanced by interfacing them with ad hoc molecules, by exploiting principles of supramolecular chemistry. Harnessing the vast arsenal of molecules that can be designed and synthesized with predetermined functionalities, one can engineer 2D materials exhibiting dynamic physical and chemical properties, by conferring them unprecedented functions, with the ultimate goal of generating multifunctional hybrid systems for applications in electronics beyond CMOS through the functional diversification following a "more than Moore" strategy. [1]
In my lecture I will present our recent findings on the covalent and non-covalent functionalization of 2D materials to engineer hybrid systems. This has been accomplished via the controlled interfacing of their two surfaces either in a symmetric or asymmetric fashion with molecular switches, thereby imparting additional properties to MoS_2, back phosphorous or WSe_2, rendering 2D material-based transistors capable to respond to as many as four different independent stimuli.[2] Such a strategy enabled to execute complex function thereby emulating neuromorphic-based cognitive processes.[3] Physical sensors for medical diagnosis and health monitoring were also realized, upon engineering active materials with sensitivities in the low-pressure or medium-pressure range. Example of flexible piezoresistive pressure sensors compatible with wearable technologies for digital healthcare, human-machine interfaces and robotics will be provided. [4]
On the other hand, the covalent connection of 2D nanosheets is employed to generate 3D networks displaying improved electronic connectivity which is demonstrated through the fabrication of field-effect transistors and chemical sensors with enhanced performances.[5]
Our modular strategies relying on the combination of 2D materials with molecules offer a simple route to generate multifunctional coatings, foams and nanocomposites with programmed properties to address key global challenges, to ultimately improve the quality of life on our planet.

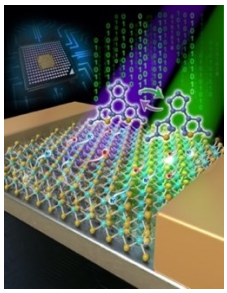

Figure 1: Optically switchable multilevel high-mobility FETs based on few-layer ambipolar WSe_2.

Figure 2: Printed networks of 2D materials obtained covalently bridging semiconducting MoS_2 nanosheets with ad hoc molecules.

References

[1] For reviews: (a) *Chem. Soc. Rev.* **2018** *47*, 6845-6888. (b) *Adv. Mater.* **2018**, *30*, 1706103. (c) *Chem. Rev.*, **2022**, *122*, 50–131.
[2] (a) *Chem. Sci.* **2022**, *13*, 315. (b) *Adv. Funct. Mater.* **2021** *31*, 2102721. (c) *ACS Nano* **2021**, *15*, 10668. (d) *Adv. Mater.* **2020**, 32, 1907903
[3] *Adv. Mater.* **2024**, *36*, 2307359
[4] *(a) Adv. Mater.* **2019**, *31*, 1804600. *(b) Adv. Mater.* **2025,** *37*, 2503867
[5] (a) *Nat. Nanotech.* **2021**, *16*, 592. (b) *Adv. Mater.* **2023**, *35*, 2211157.