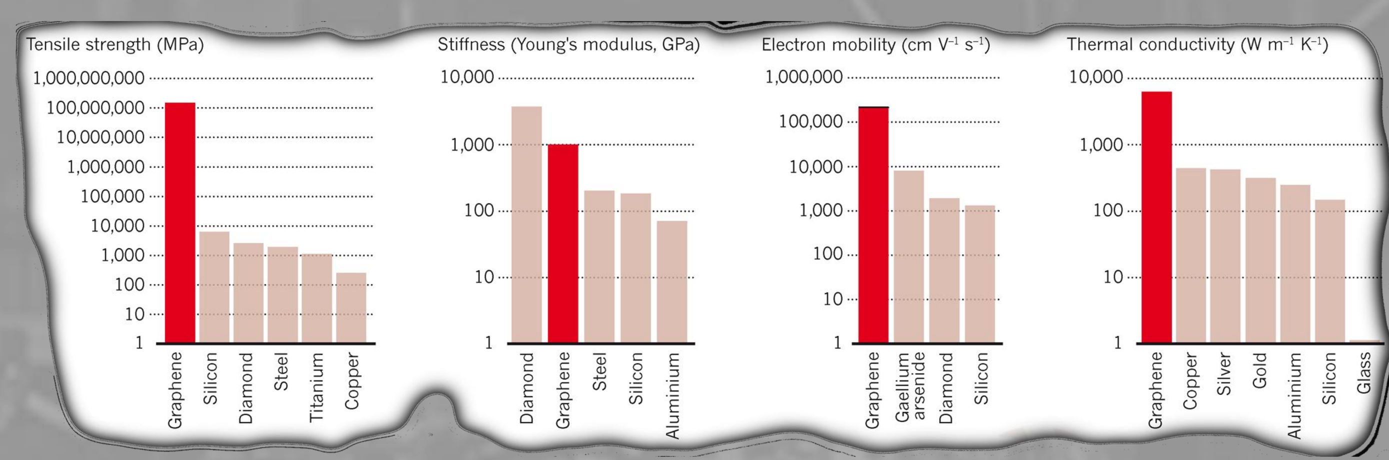
The exciting world of 2D Materials

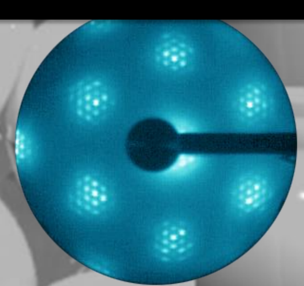
Joint efforts at the Surface Science Laboratory and SuperESCA beamline of Elettra

2D Materials are attracting considerable attention for their superlative physical and chemical properties. They consist of ultra-thin sheets exhibiting covalent in-plane bonds. Following the discovery of graphene, with its unique properties, entirely new synthetic 2D materials provide access to a great range of properties through the choice of the constituents elements and substrates. Since 2008 our teams are strongly involved in the study of a wide range of properties of these amazing materials.

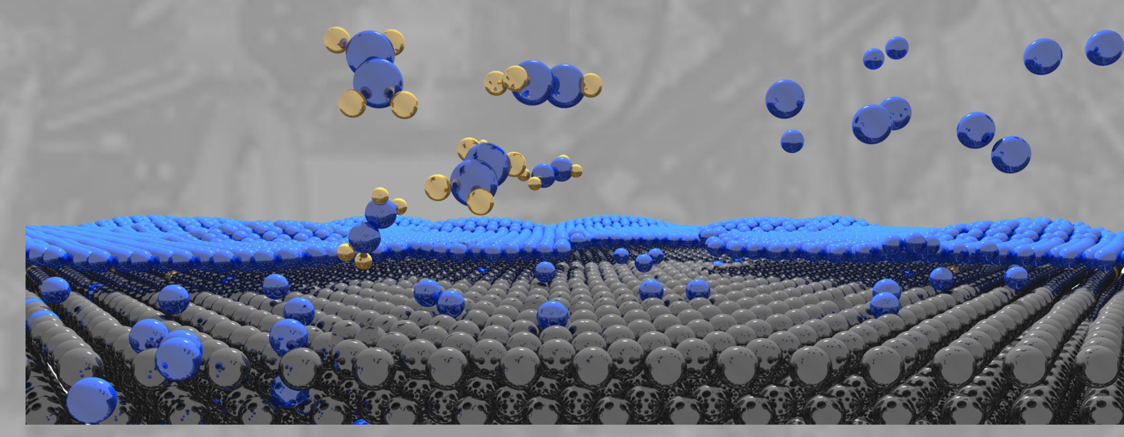
Graphene main characteristics

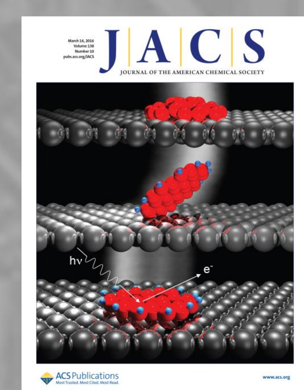


Growth mechanism



Improving the crystalline quality of epitaxially grown 2D materials is one of the main targets to preserve the unique transport properties they present as free standing materials. This can be achieved by studying the mechanisms of growth at atomic level.

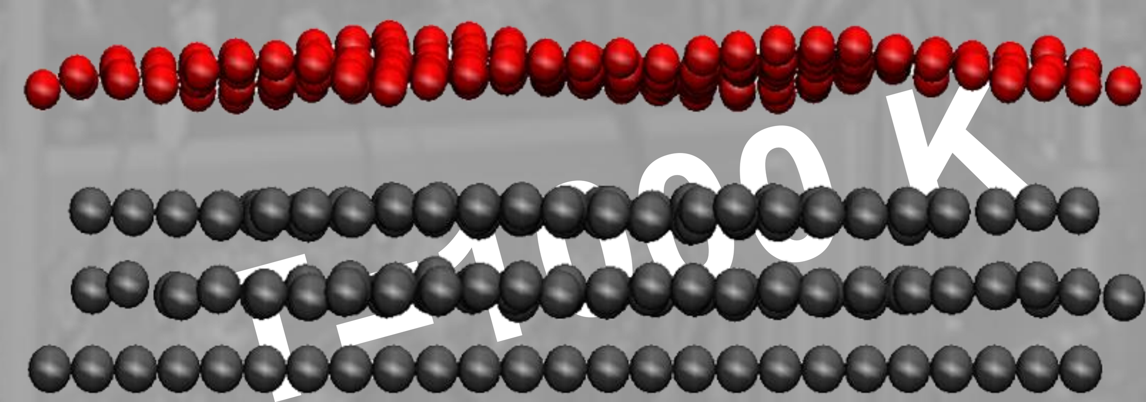




Physical Review Letters 103, 166101 (2009); **Journal of the American Chemical Society** 138, 3395 (2016)

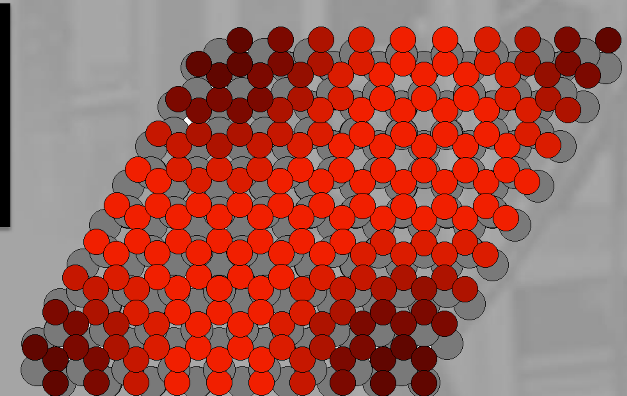
Thermal properties

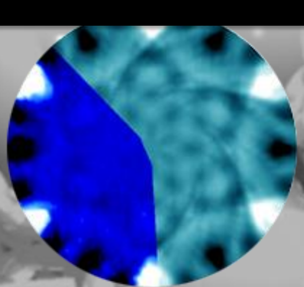
Thermal expansion and stability largely influence the properties of 2D materials which could find applications in nanoscale heat dissipation devices. Graphene is among the few materials presenting a negative thermal expansion coefficient, that can however change when it is supported on different substrates.



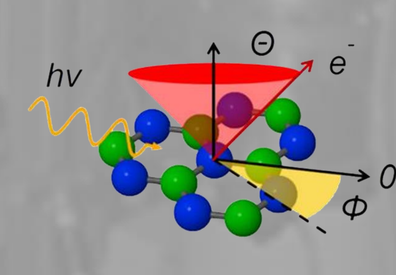
Physical Review Letters 106, 135501 (2011); **Physical Review Letters** 106, 216101 (2011)

Geometric structure





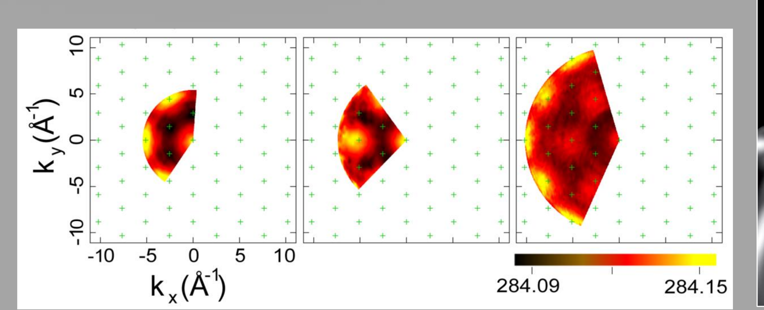
When supported on most metal and oxide surfaces, 2D materials show a modified atomic structure. Instead of being flat they are corrugated. This results in the modification of their electronic structure and of their adsorption properties. The knowledge of the exact position of each atoms of the large units cell in the 3D space is a fundamental requisite for a deep understanding of all properties.

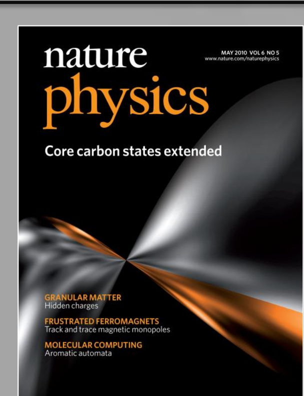


ACS Nano 3, 9551 (2012); **ACS Nano** 8, 12063 (2014)

Electronic structure

In several 2D materials, charge carriers behave like Dirac fermions, i.e. as relativistic massless particles with a ballistic charge transport, turning them into ideal materials for nanoelectronics circuit fabrication. The uniqueness of the electronic structure is reflected not only in the valence electrons, but also in core electrons. Band formation with sizable band dispersion has been observed for the C 1s electrons of epitaxial graphene.

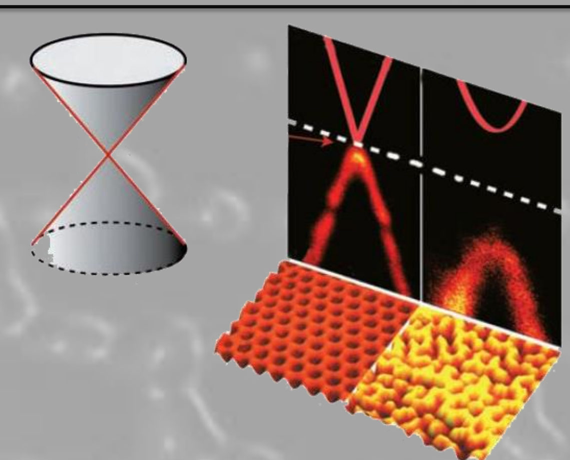




Nature Physics 6, 345 (2010)

Functionalization

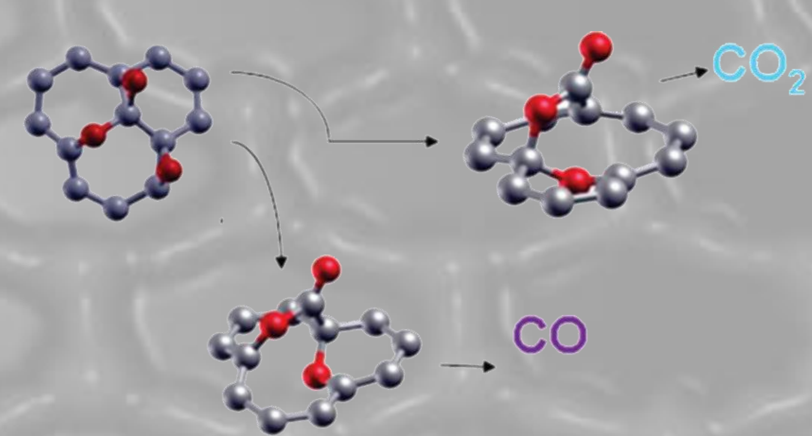
In some cases 2D materials lack, however, an energetic band gap around the Fermi level which is essential for controlling the conductivity by electronic means, as in semiconductor material. A band-gap opening can be induced on graphene by the patterned adsorption of atomic species, through a process of chemical functionalization. The functionalization, for different purposes, can be achieved also via atomic clusters deposition.

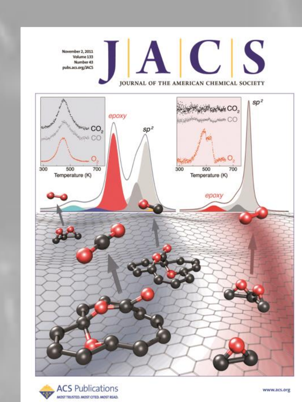


Nature Materials 9, 315 (2010); **ACS Nano** 6, 3034 (2012); **ACS Nano** 7, 3823 (2013)

Chemical reactivity

Defect formation in the two dimensional network during chemical processes compromises the charge carrier mobility in the material. Understanding the mechanisms of the thermal reactions is essential for defining alternative routes to limit the density of defects.





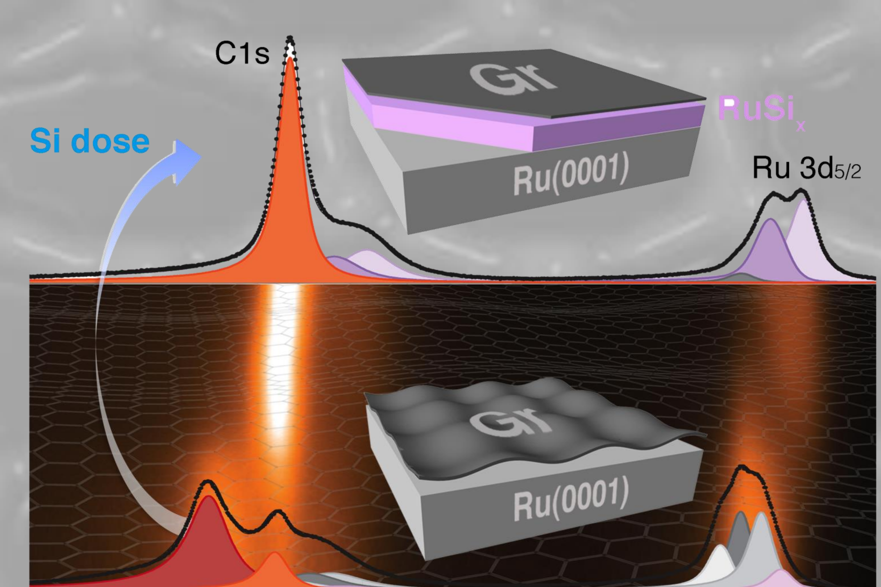
Journal of the American Chemical Society 133, 17315 (2011)

Take a flight on graphene

YouTube

Novel interfaces

New architectures formed by 2D materials interfaces (2D-metals, 2D semiconductors, 2D-oxides, 2D-2D heterostructures) can be adopted in a large range of technological applications from nanoelectronics to energy storage.



Nano Letters 12, 4503 (2012); **ACS Nano** 6, 9511 (2012); **Nature Communications** 5, 5062 (2014)

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