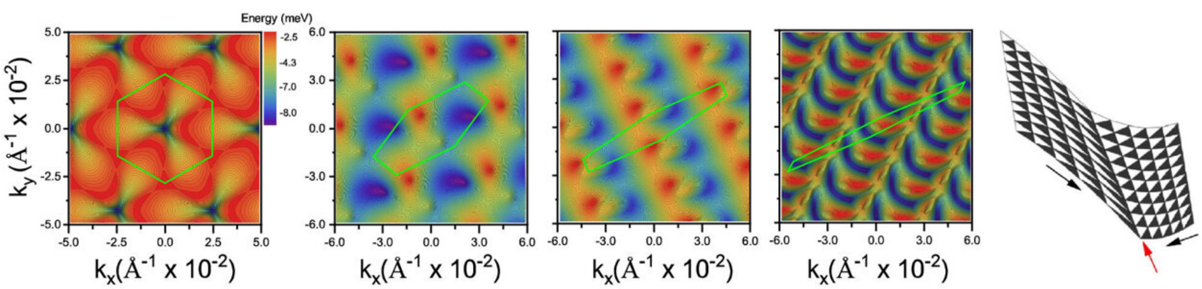
The right twist and strain for graphene to form 1D moirés

October 30 2023, by Elena Alonso-Redondo



Evolution of the energy landscape of twisted bilayer graphene as a function of the applied strain. Credit: *Physical Review Letters* (2023). DOI: 10.1103/PhysRevLett.131.166402

Researchers at IMDEA Nanociencia have developed an analytical method to explain the formation of a quasi-perfect 1D moiré pattern in twisted bilayer graphene. The pattern, naturally occurring in piled 2D materials when a strain force is applied, represents a set of channels for electrons.

Dr. Pierre Pantaleón, researcher at the Group of Theoretical Modeling at IMDEA Nanociencia, was talking with group leader Prof. Paco Guinea about strained bilayer graphene, which is two layers of graphene piled on top of each other and slightly stretched out by a small force. Pierre, a meticulous researcher with a penchant for visual aids, was showing the group his animated visualization of strained graphene when Paco noticed an anomaly that had escaped everyone else's scrutiny.

As it turns out, when bilayer graphene goes under strain, its Brillouin zone (the unit cell in the momentum space) distorts and eventually collapses in one direction. This distortion at the collapsing point caused an error in Pierre's visualization program suggesting the presence of some kind of singularity.

In physics, singularities, like the one the researchers were observing, demand careful consideration. They could indicate something may be amiss or shifting, or simply needs a closer examination. Dr. Andreas Sinner, a theoretical physicist currently working on Opole University on Poland, joined Paco's research group and started looking together with Pierre on the origin of this singularity.

It was the concurrent transformation in real space that truly captivated their attention: strained graphene gave rise to the emergence of almost perfect one-dimensional moiré patterns—one-dimensional channels—within the 2-dimensional material.

Previously, scientists had glimpsed such phenomena through a microscope and had regarded them as design errors such as dislocations or adhered materials. See for example the work of McEuen (Cornell University), Mendoza (Rio de Janeiro University) or Zhu (Columbia University).

But behind what appeared to be artifacts were masked effects. The research team at IMDEA Nanociencia confirms that this is a natural occurrence within hexagonal honeycomb lattices—like those of graphene—specifically taking place when two layers are stacked at a slight twist angle and strain is applied.

The most significant contribution of the researchers lies in their discovery of analytical solutions for the critical strain required to generate these one-dimensional channels. Surprisingly, this solution is beautifully simple, relying on just two variables: the twist angle and the Poisson ratio—a material-specific constant. These findings lead them to create a single mathematical formula to describe the phenomenon, and this formula gives us information its physical origin.

The physics described in their work, now published in *Physical Review Letters*, is not new, but the explanation of the phenomenon in such simple terms—a single analytical expression—is elegant and unique.

The findings open the door to engineering novel materials on surfaces capable of featuring these one-dimensional channels. Within these channels, electrons find themselves confined, in contrast to the free movement they exhibit in the standard 2D graphene landscape. Electrons within these channels also exhibit a preferential direction of movement.

The implications of this discovery are vast, with potential applications extending to other materials, such as dichalcogenides, that can be extended to other geometric configurations as well.

More information: Andreas Sinner et al, Strain-Induced Quasi-1D Channels in Twisted Moiré Lattices, *Physical Review Letters* (2023).
DOI: 10.1103/PhysRevLett.131.166402

Provided by IMDEA Nanociencia