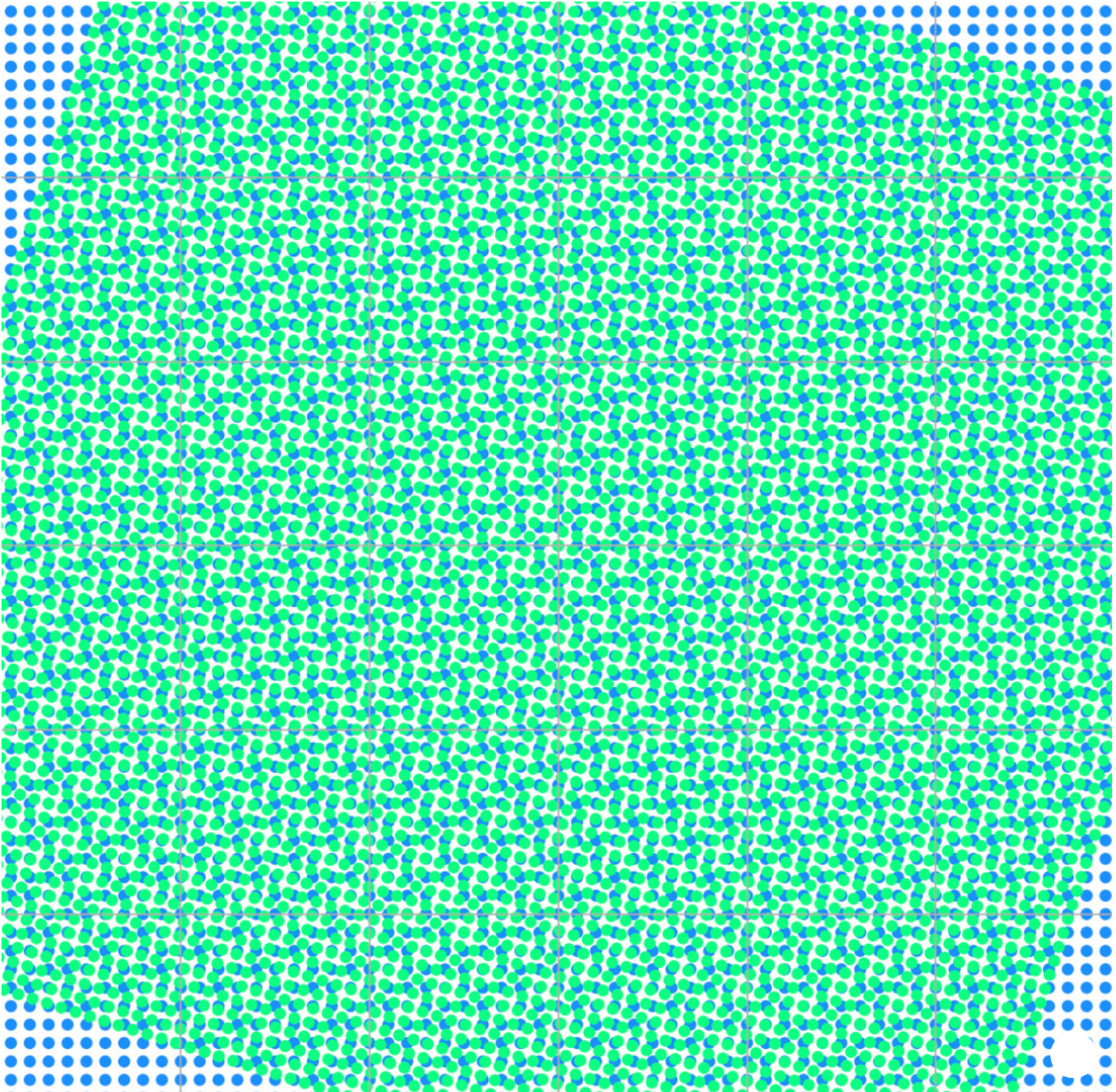


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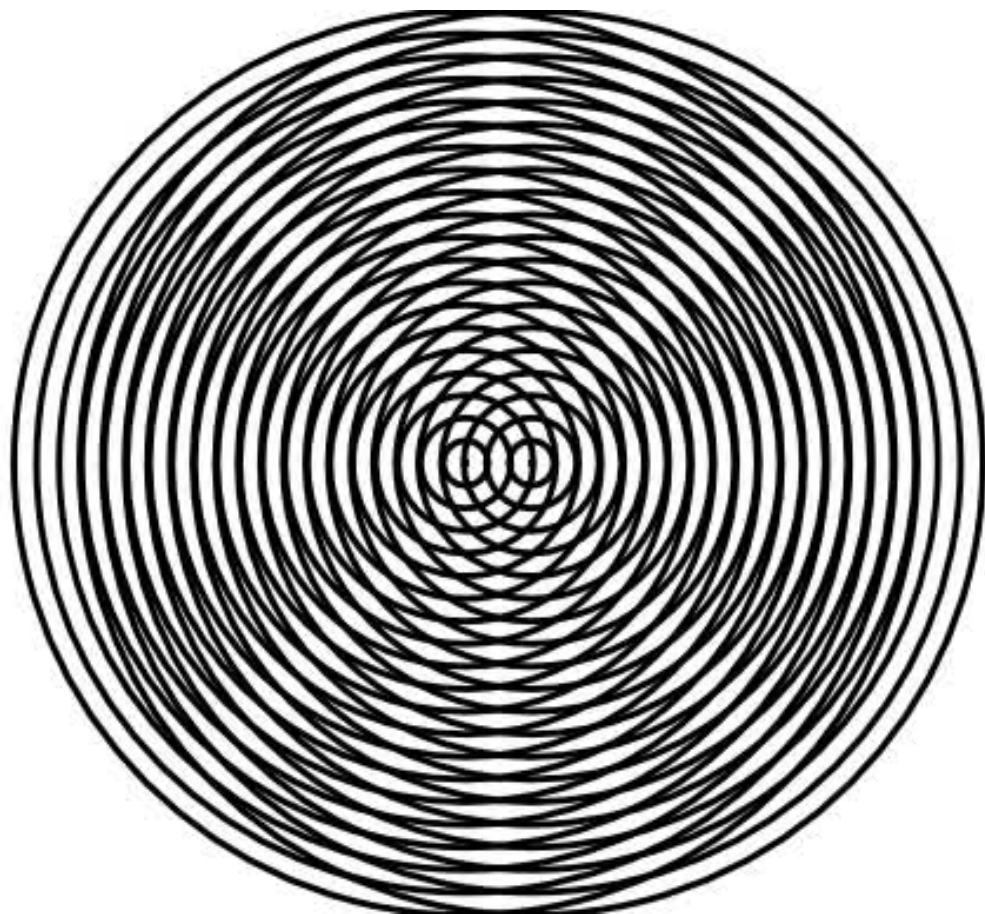
How Atomic-Scale Geometry Might Shape the Future of Electronics

Twistronics could illuminate a path to superconductivity, revolutionize electronic devices, or perhaps hasten the arrival of quantum computing.

BY [ADRIENNE BERNHARD](#) PUBLISHED: JUN 15, 2023



The concept of aperiodic geometry has existed for at least 1,000 years from Islamic mosaics and tessellations to ancient marquetry designs and silk weavings. Since antiquity, artists and geometers have pondered ways to tile a plane with shapes that never overlap or repeat. In order for this *moiré* (from the French for “rippled”) not-quite-periodic geometry to appear, two identical periodic patterns are placed one on top of the other, but with one pattern slightly displaced, rotated, or stretched. As optical illusions, aperiodic *moiré* patterns create neat simulations of movement; as engineered tools, they are frequently used in visual fields such as optics, photography, and color printing, as well as in seemingly far-flung realms such as marine biology or the detection of forged banknotes. And at the atomic scale, *moiré* patterns can generate some unusual electrical properties.



Example of a moiré effect (*University of Utah*)

Mathematicians at the University of Utah have discovered that, by twisting one square lattice over another, composite materials based on the resulting bilayer

moiré pattern display electrical and physical properties that can change quite abruptly. Their findings echo *twistronics*, the science of twisting atomic lattices, and on some rather complex geometric principles. The discovery could have implications for a wide variety of industries, as engineers might be able to precisely calibrate the electrical, optical, thermal, or even acoustic properties of these materials. Specifically, twistronics and aperiodic geometry might soon illuminate a path to higher-temperature superconductivity, revolutionize electronic devices, or perhaps even hasten the arrival of quantum computers.

“We rotated and dilated two regular lattices relative to one another, creating a veritable zoo of microgeometries—and some incredible patterns emerged” says Ken Golden, distinguished professor of Mathematics at the University of Utah and senior author of [the study](#). “The resulting moiré provides a template for the geometrical arrangement of two component materials, that, together make up a new twisted bilayer composite,” he tells *Popular Mechanics*. Imagine chicken wire lattices layered on top of each other; these can be twisted one relative to another and form entirely new moiré scales of periodicity or non-periodicity.

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Periodic geometries have clear patterns that repeat at regular intervals—say, an infinite grid of squares on a chessboard, hexagons in a honeycomb, or the molecular structure of table salt. Quasiperiodic behavior, by contrast, is a pattern of recurrence that can display a seeming regularity or component of unpredictability or randomness. Climate oscillations—for example, El Niño—are quasiperiodic, in that they may occur regularly when acted upon by external forces (so called “frequency-locked regimes”), but the time intervals between those events are rough estimates. These functions can simulate regularity or randomness, mathematical chameleons adept at changing form.

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While periodic geometry is ordered and deterministic from a very specific recipe, and quasiperiodic patterns will sometimes mimic regularity, aperiodic geometry is a veritable transition to chaos. A Penrose tiling (named after mathematician and physicist Roger Penrose who investigated them in the 1970s) is the classic example. A Penrose tiling is a plane covered with non-overlapping polygons; these patterns are aperiodic because, if the Penrose tile is shifted by any finite distance, without rotation, the same tiling can never be replicated. Typically, such tilings are predictable, but lack translational symmetry (meaning a shifted copy will never

match exactly with its original). Glass and certain types of crystal also contain aperiodic atomic structures: examples of naturally occurring aperiodic geometry. Quasicrystalline alloys, in particular, first discovered in the early 1980s (quasicrystal alloys have been used as a low-friction coating for non-stick frying pans, or to strengthen the properties of surgical instruments), have predictable yet aperiodic atomic structure, which lack translational symmetry.

It turns out that periodic shapes can be manipulated into non-repeating patterns—precisely what Golden and his team set out to do, led by Physics Ph.D. student David Morison and assistant professor of mathematics Ben Murphy. Tiny changes of less than half a degree in the lattice twist (rotation and dilation) can have significant effects on these patterns. “Sometimes a certain twist angle results in a periodic moiré pattern,” says Golden. “Other times, this results in quasi-periodic patterns.” In either case, the result is a material with exotic, unexpected mathematical and physical properties that scientists can tune at will.



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Graphene is one such example. Graphene is a two-dimensional material composed of a single layer of carbon atoms arranged in a hexagonal lattice, originally obtained using good old Scotch tape to lift a single layer of atoms from a block of graphite. Graphene is 200 times stronger than steel, yet can be up to six times

lighter. By stacking one layer of graphene on top of another, then twisting one layer, a moiré pattern at the atomic scale emerges. Twisted bilayer graphene can exhibit superconductivity at a “magic” twist angle of around one degree.

“This tunable geometry is incredibly general,” explains Golden. According to professor of mathematics Elena Cherkaev, co-author of the study, it could allow for tuning of other material properties, including optical frequencies, thermal conductivity, magnetic imaging, even acoustic or mechanical programming. From nanoscale particles to meter-sized conductors, using so-called “tunable geometry” to create twisted bilayer composites has significant promise. While these findings are in their infancy, down the road materials could be fabricated to achieve desired field characteristics suitable for a broad range of engineering applications.



ADRIENNE BERNHARD

Adrienne Bernhard is a Los Angeles-born, New York-based freelance writer and former assistant to the deputy editor at *The New Yorker*. She has written for the *Financial Times*, *The Wall Street Journal*, the BBC, *Smithsonian*, *The Atlantic*, the *Boston Review*, and *New Criterion*, among others.

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