Researchers look to patterns to envision new engineering field

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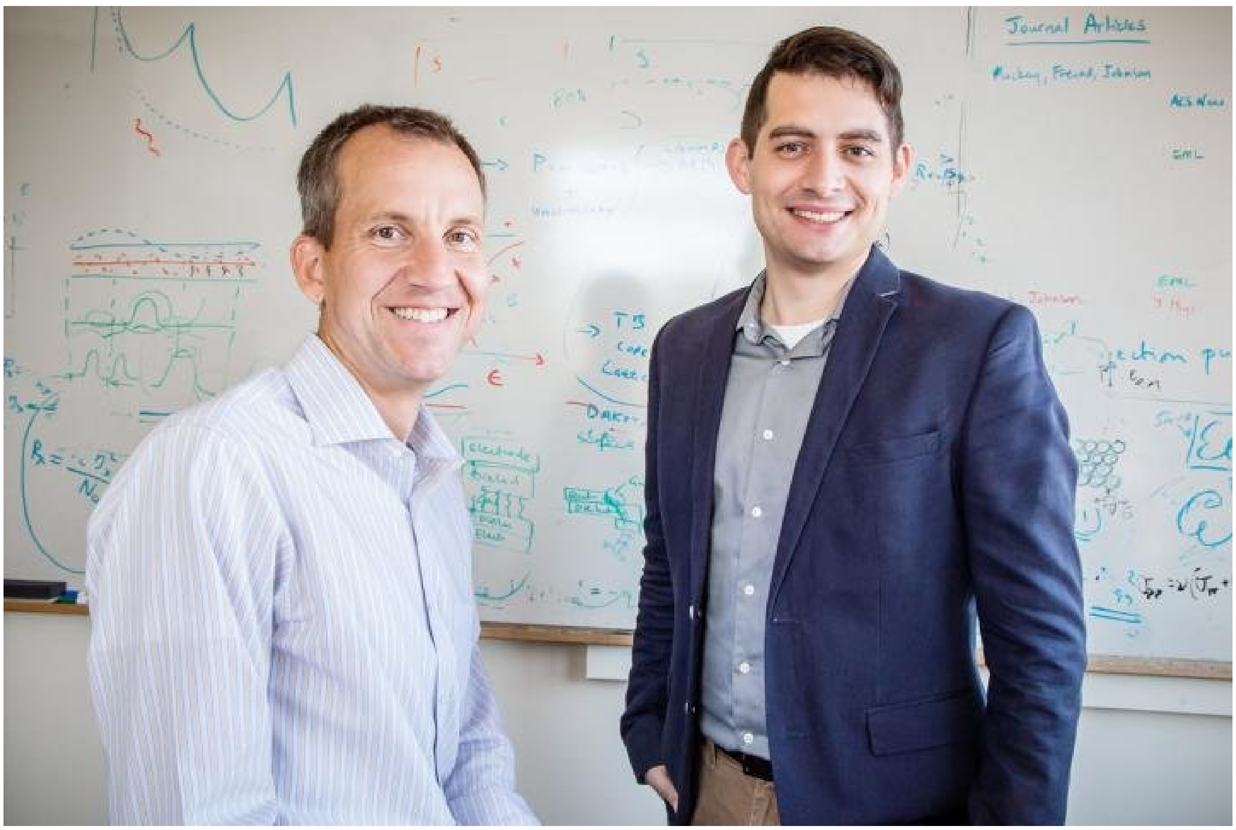

Mechanical science and engineering professor Harley Johnson, left, and graduate student Brian McGuigan look to a common optical phenomenon for inspiration in electronics design. Credit:L. Brian Stauffer

The phenomenon that forms interference patterns on television displays when a camera focuses on a pattern like a person wearing stripes has inspired a new way to conceptualize electronic devices. Researchers at the University of Illinois are showing how the atomic-scale version of this phenomenon may hold the secrets to help advance electronics design to the limits of size and speed.

In their new study, mechanical science and engineering professor Harley Johnson his co-authors recast a detail previously seen as a defect in nanomaterial design to a concept that could reshape the way engineers design electronics. The team, which also includes mechanical science and engineering graduate student Brian McGuigan and French collaborators Pascal Pochet and Johann Coraux, published its findings in the journal *Applied Materials Today*.

On display screens, moire patterns occur when the pixelation is at almost the same scale as a photographed pattern, Johnson said, or when two thin layers of a material with a periodic structure, like sheer fabrics and window screens, are placed on top of each other slightly askew.

At the macro scale, moires are optical phenomena that do not form tangible objects. However, when these patterns occur at the atomic level, arrangements of electrons are locked into place by atomic forces to form nanoscale wires capable of transmitting electricity, the researchers said.

"Two-dimensional materials - thin films engineered to be of single-atom thickness - create moire patterns when stacked on top of each other and are skewed, stretched, compressed or twisted," Johnson said. "The moire emerges as atoms form linear areas of high electron density. The resulting lines create what is essentially an extremely thin wire."

For decades, physicists observed microscope images of atomic arrangements of 2-D thin films and recognized them as periodic arrays of small defects known as dislocations, but Johnson's group is the first to note that these are also common moire patterns.

"A moire pattern is simply an array of dislocations, and an array of dislocations is a moire pattern - it goes both ways," Johnson said. This realization opened the door to what Johnson's group refers to as moire engineering - what could lead to a new way to manufacture the smallest, lightest and fastest electronics.

By manipulating the orientation of stacked layers of 2-D thin films like graphene, wires of single-atom thickness can be assembled, building the foundation to write nanocircuitry. A wire of single-atom thickness is the limit of thinness. The thinner the wire, the faster electrons can travel, meaning this technology has the potential to produce the quickest transmitting wires and circuits possible, the researchers said.

"There is always the question of how to connect to a circuit that small," Johnson said. "There is still a lot of work to be done in finding ways to stitch together 2-D materials in a way that could produce a device."

In the meantime, Johnson's group is focusing on types of devices that can be made using moire engineering.

"Being able to engineer the moire pattern itself is a path to new lightweight and less-intrusive devices that could have applications in the biomedical and space industries," he said. "The possibilities are limited only by the imagination of engineers."

More information: Pascal Pochet et al, Toward Moiré engineering in 2D materials via dislocation theory, *Applied Materials Today* (2017). DOI: 10.1016/j.apmt.2017.07.007

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