Researcher's chiral graphene stacks break new ground

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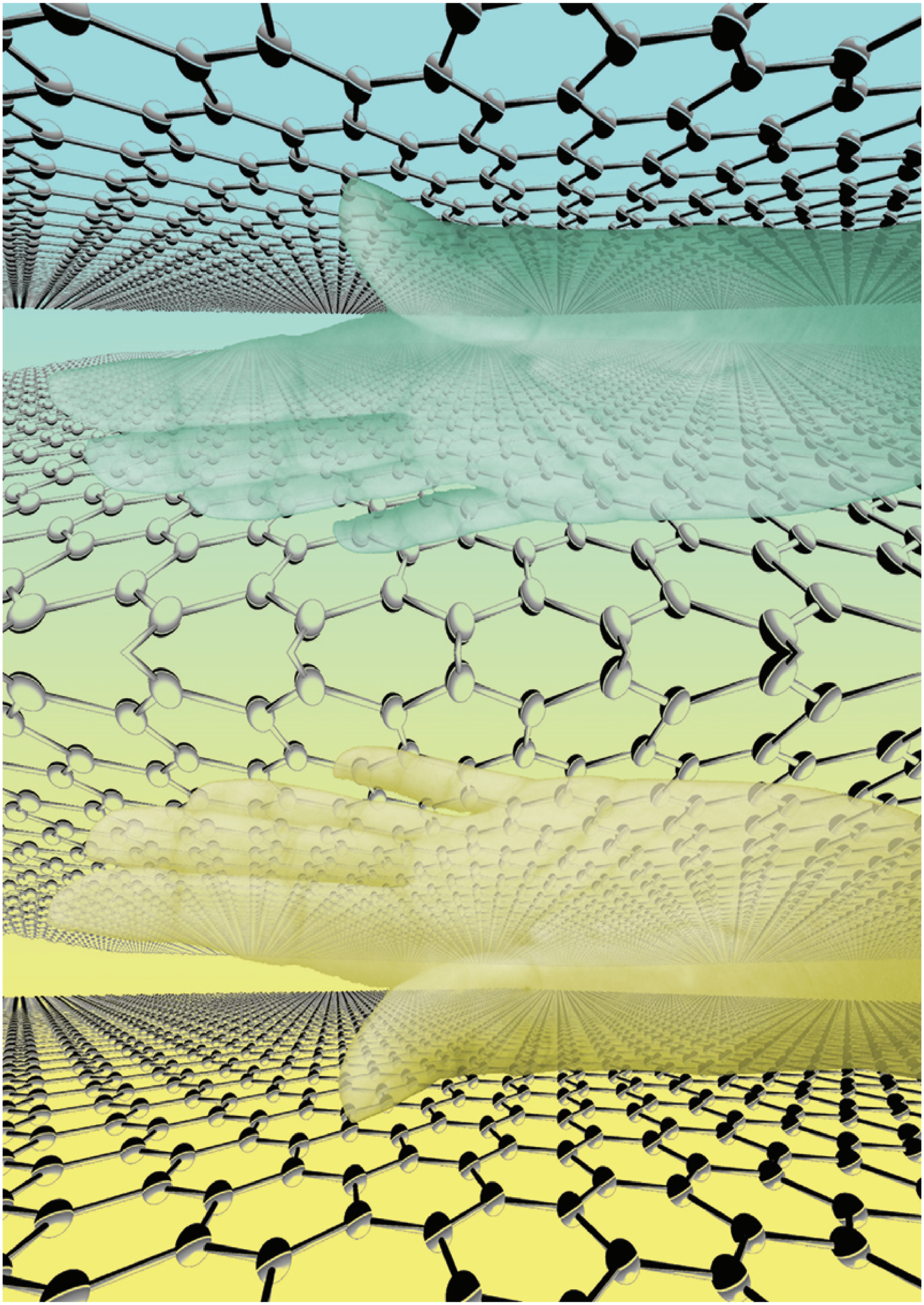

An artist rendering of right- and left-handed stacks of two-atoms-thick graphene, connected by a mirror plane in the middle. Credit: Cheol-Joo Kim, Zack Ziegler

Hands and feet are two examples of chiral objects – non-superimposable mirror images of each other. One image is distinctly "left-handed," while the other is "right-handed." A simple drinking glass and a ball are achiral, meaning the object and its mirror image look exactly the same.

In science, chirality is a fundamental concept in a number of disciplines, including medicine. In the 1950s and early '60s, pregnant women were prescribed the sedative thalidomide, but the drug produced horrific birth defects in thousands of children around the world. The reason: The thalidomide molecule is chiral, and while the left-hand molecule was indeed a sedative, the right-hand one was found later to produce fetal abnormalities.

Until very recently, similar "handedness" in large area films with atomic scale precision hadn't been investigated. The research team of Cornell's Jiwoong Park has broken new ground in this area, developing a chiral atomically thin film only 2-atoms-thick, through circular stacking of graphene.

This material is of interest in the fields of polarization optics, stereochemistry, optoelectronics and spin transport electronics, or spintronics.

"I would say that we've been curious about this for a long time, whether we can make this material," said Park, associate professor of chemistry and chemical biology and an executive member of the Kavli Institute at

Cornell for Nanoscale Science.

The Park group's paper, "Chiral Atomically Thin Films," was published Feb. 22 in *Nature Nanotechnology*. Park and Cheol-Joo Kim, a postdoctoral researcher in chemistry and chemical biology, designed and conducted the experiments and co-wrote the paper.

Contributors include Zack Ziegler '16, an engineering physics major; former Cornell postdoc Yui Ogawa; and Cecilia Noguez of the Instituto de Fisica, Universidad Nacional Autonoma de Mexico. Noguez is one of the world's leading computational physicists, and she helped calculate the Park group's results.

"This discovery and its confirmation may have a lot of implications in both pure and applied science," Noguez said. "This may be applied for sensing biomolecules, and to induce and control asymmetric catalysis, among others. I am sure this discovery opens new research directions for other 2-D materials."

For the experiment, Kim and Ogawa grew graphene sheets on copper, then cut them into multiple sheets. Those sheets were then stacked, with each sheet rotated slightly before being placed on the one below it. The rotation went clockwise on one stack and counter-clockwise on the other to form right-handed and left-handed stacks.

Circularly polarized light – alternating left-handed and right-handed beams – were shone onto the stacks, and circular dichroism (or CD, the differential absorption of left- and right-handed light), was measured. It's the circular dichroism of 3-D glasses that allows you to see a movie in three dimensions.

The special graphene film's CD was stronger than the group anticipated. After months of hard work and some setbacks, that discovery came around Thanksgiving 2014, and "that was when the whole process accelerated," Kim said.

But after achieving this atomic-scale breakthrough, the group had to quantify its results, so it turned to Noguez.

"It's one of those rare cases where we knew exactly what we wanted, so we knew what quantity had to be calculated," Park said. "It's not an easy calculation, and we did a lot of research and realized that Cecilia is the best person to do this."

Noguez admitted her group was initially surprised by Park's findings, but in analyzing them further realized the research made sense.

"We predicted a long time ago a similar behavior for single-wall carbon nanotubes and more recently in ligand-protected metal nanoparticles," she said. "So in the end, those results made sense to me."

More information: Francisco Hidalgo et al. Optical Activity of Achiral Ligand SCH Adsorbed on Achiral Ag Clusters: Relationship between Adsorption Site and Circular Dichroism , *ACS Nano* (2013). DOI: 10.1021/nn3046083

Optical circular dichroism of single-wall carbon nanotubes. *Phys. Rev. B* 73, 045401 – Published 4 January 2006. DOI: 10.1103/PhysRevB.73.045401

Cheol-Joo Kim et al. Chiral atomically thin films, *Nature Nanotechnology* (2016). DOI: 10.1038/nnano.2016.3

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