

At the nanoscale, graphite can turn friction upside down

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(Phys.org)—If you ease up on a pencil, does it slide more easily? Sure. But maybe not if the tip is sharpened down to nanoscale dimensions. A team of researchers at the National Institute of Standards and Technology (NIST) has discovered that if graphite (the material in pencil "lead") is sticky enough, as measured by a nanoscale probe, it actually becomes harder to slide a tip across the material's surface as you decrease pressure—the exact opposite of our everyday experience.

Technically, this leads to an effectively "negative [coefficient of friction](#)," something that has not been previously seen, according to team leader Rachel Cannara. [Graphite](#), Cannara explains, is one of a special class of solids called "lamellar" materials, which are formed from stacks of two-dimensional sheets of atoms. The sheets are graphene, a single-atom-thick plane of [carbon atoms](#) that are arranged in a [hexagonal pattern](#). Graphene has a number of exotic electrical and material properties that make it attractive for micro- and nanoelectromechanical systems with applications ranging from [gas sensors](#) and [accelerometers](#) to resonators and optical switches.

Zhao Deng, a University of Maryland postdoctoral researcher at NIST's Center for Nanoscale Science and Technology, noted some odd data while experimenting on graphite with an [atomic force microscope](#) (AFM). Deng was measuring the friction forces on the nanoscale tip of an AFM tracking across the graphite as he modified the "stickiness" of the surface by allowing tiny amounts of oxygen to adsorb to the topmost graphene layer.

Theoretical Simulations of Friction Between Graphite and AFM Probe:

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Deng found that when the adhesive force between the graphene and the stylus became greater than the graphene layer's attraction to the graphite below, reducing the pressure on the stylus made it harder to drag the tip across the surface—a negative differential friction.

Backed by theoretical simulations performed by collaborators from NIST and Tsinghua University in Beijing, Cannara's team found that, after the AFM tip has been pressed into the graphite surface, if the attractive force is high enough, the tip can pull a small localized region of the surface layer of graphene away from the bulk material, like raising a nanoscale bubble from the surface. Pushing that deformation around takes more work than sliding over a flat surface. Therefore, whenever the researchers pressed the AFM tip against the sticky graphite [surface](#) and then tried to pull the two apart, they measured an increase in friction force with a sensitivity in the tens of piconewtons.

"Once we have a complete model describing how these graphene sheets deform under repeated loading and sliding at the nanoscale—which we're working on now—friction force microscopy may be the most direct way to measure the energy that binds these layered materials together. And, since it's nondestructive, the measurement can be performed on working devices," Cannara says. Understanding how the

sheets interact with each other and with other parts of a device would help quantify the energy required to produce individual sheets from bulk material, assess device operation, and assist in formulating new structures based on layered materials, she says.

More information: Z. Deng, A. Smolyanitsky, Q. Li, X.-Q. Feng and R. J. Cannara. Adhesion-dependent negative friction coefficient on chemically modified graphite at the nanoscale. *Nature Materials*. Published online: 14 October 2012 | [doi:10.1038/nmat3452](https://doi.org/10.1038/nmat3452)

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