In static friction, chemistry is key to stronger bonds

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(Phys.org)—Inspired by phenomena common to both earthquakes and atomic force microscopy, University of Wisconsin–Madison materials engineers have learned that chemical reactions between two silicon dioxide surfaces cause the bonds at that interface to "age," or strengthen gradually over time.

In researchers' understanding of static friction, it's an advance with staying power. "What happens is that when you form one bond across the interface, it actually affects the local environment and makes it harder for other bonds to form," says Izabela Szlufarska, a UW–Madison associate professor of materials science and engineering. "As a result, the process slows down in a very specific way—logarithmically—and that happens in materials such as silica that have strong directional bonding."

Szlufarska and Ph.D. student Yun Liu (now a postdoctoral researcher at the Massachusetts Institute of Technology) published results of their research in the Nov. 2, 2012 online issue of the journal Physical Review Letters.

Silicon dioxide, or silica, is abundant in the Earth's crust and is of great importance for the semiconductor industry. Relevant in several fields in which humidity is a factor, the advance could, for example, enable manufacturers to fine-tune semiconductor wafer bonding processes or help geologists better understand the conditions under which tectonic plates slide and earthquakes occur. "The mechanism we discovered is possible because there are chemical reactions at the interface enabled by water," says Szlufarska.

Friction is the force that resists motion, or sliding, between surfaces that touch. However, Szlufarska and Liu addressed the mechanisms underlying static friction, or "stiction," in which two solid surfaces resist that sliding motion—and in fact, bond more tightly together over time. Known as ageing, that process is continuous, yet gradually slows down.

For many years, researchers believed that one reason two materials bond more tightly over time is that one material "sinks" into the other and deforms it—somewhat like the way in which a heavy book would sink into a soft pillow. The result is an indentation that enlarges the interface between the materials and, thus, increases friction.

While that explanation holds true on larger scales, sinking and deforming isn't evident in experiments where researchers are studying contacts as small as tens of nanometers and consisting of just a few hundreds of atoms. "There, the forces are just too small to see any of this plastic deformation," says Szlufarska. "So, something else was going on."

Under certain circumstances—as with silica surfaces in conditions that include water—that "something else" is chemistry.

To study materials on a super-small scale, researchers work in a field called quantum mechanics, in which a different set of physics laws applies to interactions among particles smaller than atoms. Enabled by recent advances in computing power and state-of-the-art methods, Szlufarska and Liu based their simulations, which each took weeks to run, on those established laws of quantum mechanics. "Doing these well-defined studies allowed us to isolate specific chemical effects at the interface and then bring understanding to much more complex phenomena that take place at the micro and macro scale," says

Szlufarska.

Their advance contributes new knowledge in surface chemistry of how reactions occur at interfaces. It also increases researchers' fundamental understanding of friction, especially as ageing between surfaces occurs over time. And while they studied silica, Szlufarska and Liu believe the advance could be applicable to a broader range of materials, such as other oxides, that have directional and stiff bonding.

Provided by University of Wisconsin-Madison

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