Metamaterials could reduce friction in nanomachines

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(PhysOrg.com) -- Nanoscale machines expected to have wide application in industry, energy, medicine and other fields may someday operate far more efficiently thanks to important theoretical discoveries concerning the manipulation of famous Casimir forces that took place at the U.S. Department of Energy's Ames Laboratory.

The groundbreaking research, conducted through mathematical simulations, revealed the possibility of a new class of materials able to exert a repulsive force when they are placed in extremely close proximity to each other. The repulsive force, which harnesses a quantum phenomenon known as the Casimir effect, may someday allow nanoscale machines to overcome mechanical friction.

Though the frictional forces in nanoscale environments are small, they significantly inhibit the function of the tiny devices designed to operate in that realm, explained Costas Soukoulis, a senior physicist at the Ames Lab and Distinguished Professor of physics at Iowa State University, who led the research effort.

Soukoulis and his teammates, including Ames Laboratory assistant scientist Thomas Koschny, were the first to study the use of exotic materials known as chiral metamaterials as a way to harness the Casimir effect. Their efforts have demonstrated that it is indeed possible to manipulate the Casimir force. The findings were published in the Sept. 4, 2009 issue of *Physical Review Letters*, in an article entitled, "Repulsive Casimir Force in Chiral Metamaterials."

Understanding the importance of their discovery requires a basic understanding of both the Casimir effect and the unique nature of chiral metamaterials.

The Casimir effect was named after Dutch physicist Hendrik Casimir, who postulated its existence in 1948. Using quantum theory, Casimir predicted that energy should exist even in a vacuum, which can give rise to forces acting on the bodies brought into close proximity of each other. For the simple case of two parallel plates, he postulated that the energy density inside the gap should decrease as the size of the gap decreases, also meaning work must be done to pull the plates apart. Alternatively, an attractive force that pushes the plates closer together can be said to exist.

Casimir forces observed experimentally in nature have almost always been attractive and have rendered nanoscale and microscale machines inoperable by causing their moving parts to permanently stick together. This has been a long-standing problem that scientists working on such devices have struggled to overcome.

Remarkably, this new discovery demonstrates that a repulsive Casimir effect is possible using chiral metamaterials. Chiral materials share an interesting characteristic: their molecular structure prevents them from being superimposed over a reverse copy of themselves, in the same way a human hand cannot fit perfectly atop a reverse image of itself. Chiral materials are fairly common in nature. The sugar molecule (sucrose) is one example. However, natural chiral materials are incapable of producing a repulsive Casimir effect that is strong enough to be of practical use.

For that reason, the group turned its attention to chiral metamaterials, so named because they do not exist in nature and must instead be made in the lab. The fact that they are artificial gives them a unique advantage, commented Koschny. "With natural materials you have to take what nature gives you; with metamaterials, you can create a material to exactly meet your requirements," he said.

The chiral metamaterials the researchers focused on have a unique geometric structure that enabled them to change the nature of energy waves, such as those located in the gap between the two closely positioned plates, causing those waves to exert a repulsive Casimir force.

The present study was carried out using mathematical simulations because of the difficulties involved in fabricating these materials with semiconductor lithographic techniques. While more work needs to be done to determine if chiral materials can induce a repulsive Casimir force strong enough to overcome friction in nanoscale devices, practical applications of the Casimir effect are already under close study at other DOE facilities, including Los Alamos and Sandia national laboratories. Both have expressed considerable interest in using the chiral metamaterials designed at Ames Laboratory to fabricate new structures and reduce the attractive Casimir force, and possibly to obtain a repulsive Casimir force.

Source: Ames Laboratory (news : web)

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