Quantum levitation could prevent nano systems from crashing together

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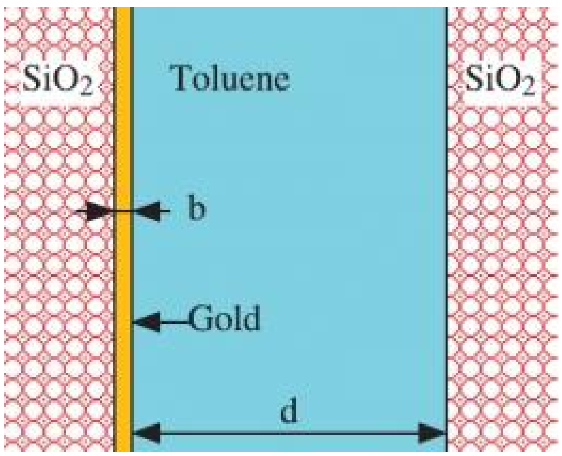

Two pieces of silica - one with a gold nanocoating - will experience a repulsive Casimir-Lifshitz interaction beyond a critical distance. Without the gold nanocoating, the interaction would be attractive at the same distance. Image credit: Boström, et al. ©2012 American Institute of Physics

(Phys.org) -- Since the first demonstration of microelectromechanical systems (MEMS) in the mid-'80s, the technology has not proven as useful as originally anticipated. One of the problems is that the tiny components tend to stick together due to strong surface adhesion forces on the nanoscale, an effect that engineers call "stiction." Now in a new study, scientists suggest that this problem might be solved by inducing quantum levitation between components, which they demonstrate by simply adding a thin metallic coating to one of the interacting surfaces.

The team of researchers, from institutions in Norway, Australia, and Sweden, has published the study on quantum levitation between nanosurfaces in a recent issue of *Applied Physics Letters*.

The odd thing about this levitation is that it stems from the Casimir-Lifshitz force, which has the unusual property of being either attractive or repulsive. As a type of van der Waals force, it arises between nearby particles due to their inherent electrical properties.

In this study, the scientists looked at the Casimir-Lifshitz force that occurs between two silica surfaces in a liquid (either bromobenzene or toluene). Normally, this force is attractive, but it weakens as the silica particles move further apart. This weakening is called retardation, and the researchers found that they could decrease the distance at which retardation occurs by coating an ultrathin layer of gold on one of the silica surfaces.

This small modification shifts the retardation regime from a separation distance of several nanometers down to a few nanometers by modifying the dielectric properties of the coated silica surface. In fact, retardation weakens the attraction so much that the force becomes repulsive when the surfaces are separated by a few nanometers or more, at a critical distance called the levitation distance. Below the levitation distance, the force again becomes attractive, while above this distance it becomes increasingly repulsive up to a maximum point. At still larger distances, the repulsion stabilizes below the maximum value.

The ability to control the Casimir-Lifshitz force is not completely new. Scientists have known about these effects theoretically since the 1970s, but only recent advances in nanotechnology have allowed for experimental investigations.

“The interaction between two silica objects in toluene is attractive,” coauthor Bo Sernelius of Linköping University in Sweden told *Phys.org*. "Previous studies have shown that, if one of the objects is replaced by a solid gold object, the interaction turns repulsive for distances beyond the levitation distance. Thus there is a potential barrier that reduces the chance for the objects to come close and stick to each other. We found, and this is new, that if instead of having a solid gold object we had a silica object with a thin gold coating, the levitation distance shrunk and the barrier became higher. The chance of preventing stiction increased considerably."

By preventing stiction, quantum levitation may offer a way to prevent surfaces used in MEMS and nanoelectromechanical systems (NEMS) from crashing together due to other attractive van der Waals forces that exist between them. Since the thickness of the nanocoating changes the dielectric properties of the interacting surfaces, researchers would have to precisely determine the correct thickness for a desired levitation distance. If the technique works, it may provide a much needed revitalization of the fields of MEMS and NEMS.

In the future, the researchers plan to extend their investigations to other materials, such as zinc oxide and hafnia, which are widely used in microelectrical and microoptical devices. They also have an upcoming paper (arxiv.org/abs/1206.4852v1) in which they investigate the repulsive and attractive forces between excited Cesium atoms that are confined in a nanochannel, which are very different from those in free space.

"Two Cesium atoms that are close together and in an excited state can form unusually large molecules when they are between two gold surfaces," explained coauthor Mathias Bostrom of the Norwegian University of Science and Technology in Trondheim, Norway, and Australian National University in Canberra, Australia. "The effects from retardation for these excited state interactions between atoms are very similar to what we found for the Casimir-Lifshitz force between a gold-coated silica surface and a silica surface in toluene. Hence we found long-range attraction that brings the atoms together and short-range repulsion enabling bound states (preventing the atoms from crashing together, i.e., forming super large molecules)."

Finally, the researchers plan to further investigate how quantum levitation may be used for NEMS systems by looking at anisotropic effects, which are the different properties that arise when parallel or perpendicular to the material interface.

"Our colleagues in Oslo (Professor Clas Persson of the University of Oslo and his team) have calculated the actual optical properties of the materials (the dielectric function) for thin gold sheets which will be used to investigate how anisotropic effects may influence NEMS systems with gold nanocoatings. It is likely that the range with repulsive forces (preventing the system from crashing together) may be influenced in such improved calculations. Our aim is to do such calculations this autumn."

More information: Mathias Boström, et al. "Ultrathin metallic coatings can induce quantum levitation between nanosurfaces." *Applied Physics Letters* 100, 253104 (2012). DOI: 10.1063/1.4729822