Magnetically levitating graphite can be moved with laser

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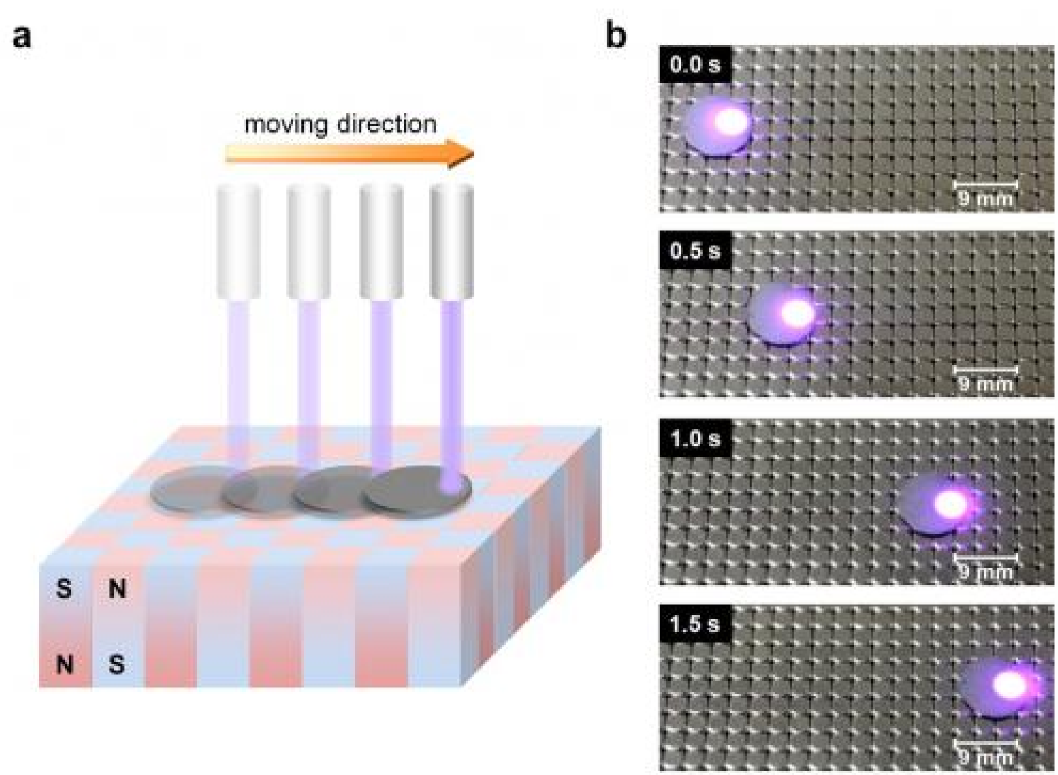
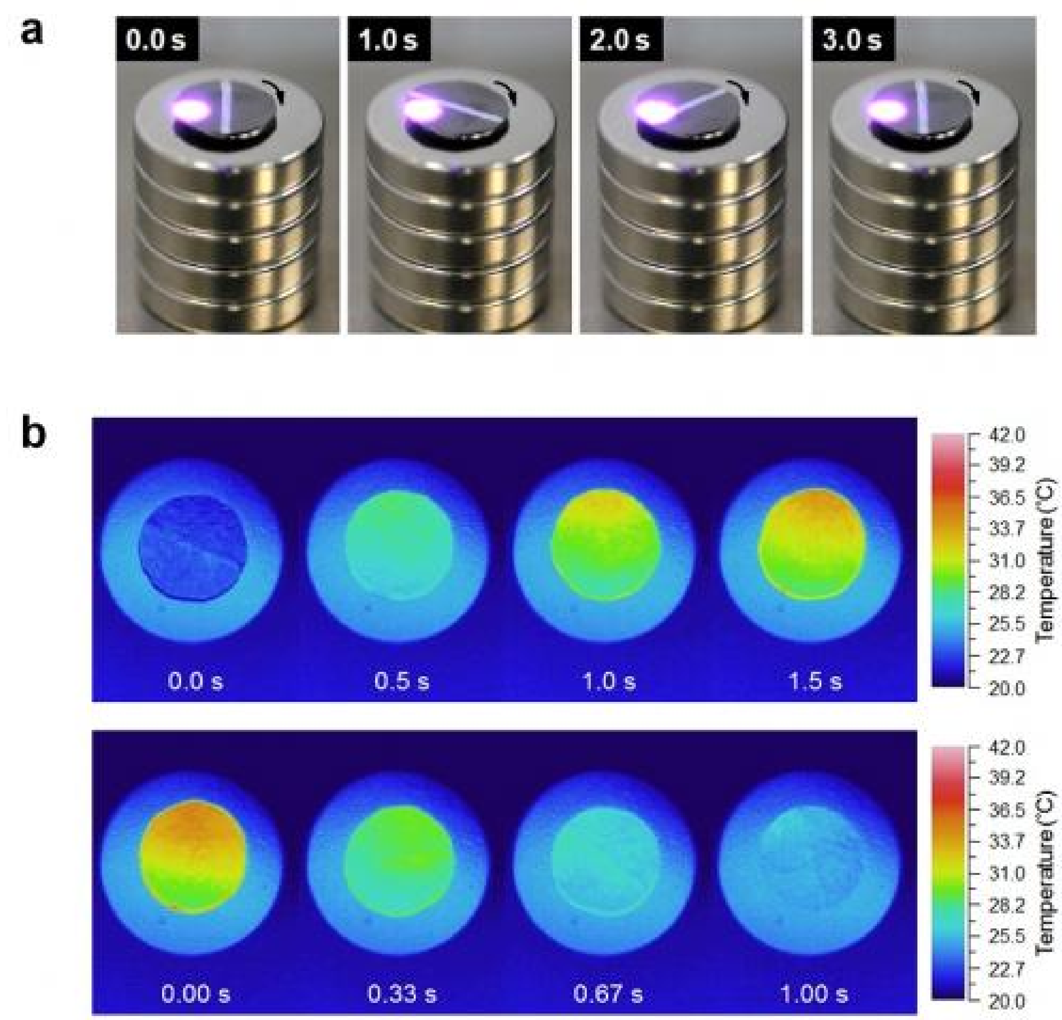


(A) Experimental set-up of a 3-mm-diameter graphite disk levitating on NdFeB magnets arranged to face in alternate directions. (B) A laser moves the disk in the direction of the light beam (photographic frames from the video below). Reprinted with permission from Kobayashi, et al. ©2012 American Chemical Society

(Phys.org)—Magnetic levitation has been demonstrated for a variety of objects, from trains to frogs, but so far no one has developed a practical maglev-based actuator that converts some external source of energy into motion. Now in a new study, researchers for the first time have used a laser to control the motion of a magnetically levitating graphite disk. By changing the disk's temperature, the laser can change the disk's levitation height and move it in a controlled direction, which has the potential to be scaled up and used as a light-driven human transportation system. Laser light or sunlight can also cause the levitating disk to rotate at over 200 rpm, which could lead to a new type of light energy conversion system.

The researchers, Dr. Masayuki Kobayashi and Professor Jiro Abe of Aoyama Gakuin University in Kanagawa, Japan (Abe is also at CREST, Japan Science and Technology Agency in Tokyo), have published their study on optically controlling the motion of maglev graphite in a recent issue of the Journal of the American Chemical Society.

"The most important point in this work is the achievement for a real-time motion control technique which can move a magnetically levitating diamagnetic material without contact for the first time in the world," Abe told *Phys.org*. "Because this technique is very simple and fundamental, it is expected to apply to various daily living techniques, such as transportation systems and amusement, as well as photo-actuators and light energy conversion systems."



(A) A laser causes a magnetically levitating graphite disk to rotate (photographic frames from video). (B) The laser causes temperature changes in the graphite, as measured by infrared images of the disk when under laser irradiation (top) and after the termination of irradiation (bottom). Reprinted with permission from Kobayashi, et al. ©2012 American Chemical Society

As the researchers explain, magnetic levitation occurs due to an object's diamagnetism, which repels magnetic fields. Although all materials have some diamagnetism, it is usually too weak to allow them to magnetically levitate. Magnetic levitation only occurs when a material's diamagnetic properties are stronger than its ferromagnetic and paramagnetic properties (which attract magnetic fields). One of the strongest diamagnetic materials is graphite.

In order to magnetically levitate, an object's total magnetic force must not only be repulsive, but the repulsion must also be stronger than the force of gravity. The height at which a diamagnetic material levitates can be controlled by two factors: the applied magnetic field and the material's own diamagnetic properties. The levitation position of diamagnetic materials has previously been controlled by changing the applied magnetic field, but so far no one has successfully controlled maglev motion in the second way, by changing the material's diamagnetic properties with an external stimulus such as temperature, light, or sound.

Here, the researchers did just that by using a laser to reversibly control the temperature of a graphite disk levitating over a block of permanent magnets. They demonstrated that, as the graphite's temperature increases, its levitation height decreases, and vice versa. The researchers explain that the change in temperature causes a change in the graphite's magnetic susceptibility, or the degree to which its magnetization reacts to an applied magnetic field. On an atomic level, the laser increases the number of thermally excited electrons in the graphite due to the photothermal effect. The more of these electrons, the weaker the graphite's diamagnetic properties and the lower its levitation height.

In addition to controlling the height of maglev graphite, the researchers found that they could also make the graphite move in any direction and rotate it by changing the site of irradiation. Whereas the laser was aimed right in the center of the graphite disk when controlling its height, aiming it at the edge of the disk changes the temperature distribution, and thus magnetic susceptibility distribution, in such a way that the repulsion force becomes unbalanced and the graphite moves in the same direction as the light beam.

To rotate the levitating graphite disk, the researchers replaced the rectangular prism-shaped magnets beneath the disk with a stack of cylindrical-shaped magnets, and again aimed the laser at the disk's edge. The distorted temperature distribution causes the levitating graphite disk to rotate, with the direction and rotational speed depending on the irradiation site. Rotation also occurs when the set-up is exposed to sunlight. By converting solar energy into rotational energy, the disk can reach a rotational speed of more than 200 rpm, which could make it useful for applications such as optically driven turbines.

The researchers predict that the ability to control maglev-based motion with a laser could lead to the development of maglev-based actuators and photothermal solar energy conversion systems. Applications could include a low-cost, environmentally friendly power generation system and a new type of light-driven transportation system.

"At this moment, we are planning to develop a maglev turbine blade suitable for this system," Abe said. "In this case, it is predicted that friction disrupts the rotation of the maglev turbine. Therefore, we would like to develop a light energy conversion system with a high energy conversion efficiency with reference to the so-called MEMS (Microelectromechanical Systems) technique.

"As for the actuator, the maglev graphite can convey anything that has almost the same weight as the levitating graphite disk. So, if the scale expansion of the photo-actuator system is achieved, it is not a dream that a human on the maglev graphite can drive himself."

More information: Masayuki Kobayashi and Jiro Abe. "Optical Motion Control of Maglev Graphite." *Journal of the American Chemical Society*. DOI: 10.1021/ja310365k