Restless neighborhood

Strategy allows evaluation of the magnetic interaction between nanoparticles

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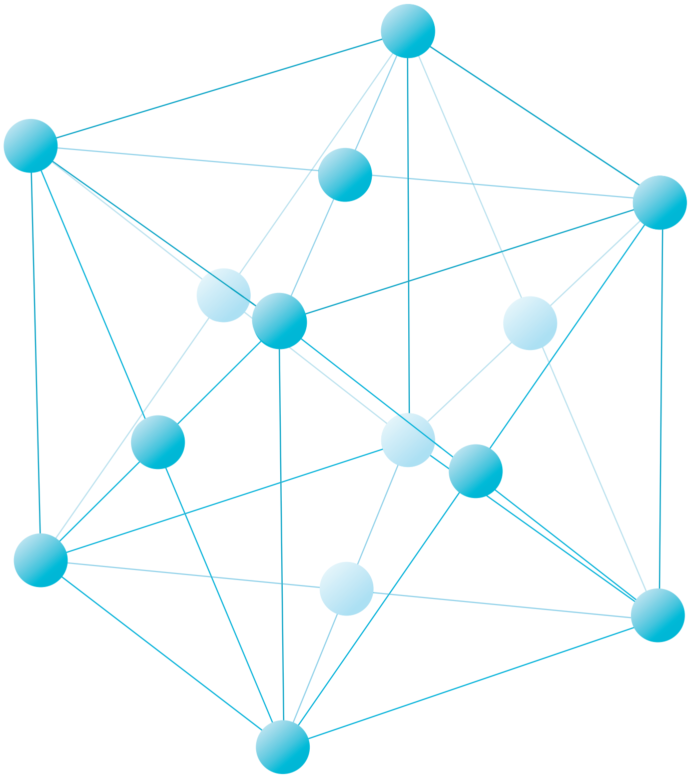
Sueli Hatsumi Masunaga and Renato de Figueiredo Jardim, physicists at the University of São Paulo (USP), have developed a relatively simple strategy for measuring a phenomenon that affects the storage and transmission of information registered on magnetic media, such as computer hard drives (HD). If this method of evaluating the characteristics of the material that comprises computers' magnetic memories proves to be economically feasible, it may become possible to produce, using the same material used currently, hard drives with a storage capacity up to five times higher than the current capacity.

The hard drive of a standard computer, which registers information in films of small magnetic particles of cobalt (Co), chromium (Cr) and platinum (Pt) covered with isolating material, stores 200 gigabytes of data on a surface comparable to that of a matchbox. "If the manufacturing of this component is optimized, the same area would be able to store 1 terabyte," states Jardim, director of USP's Physics Institute (IF).

Expanding the storage power of this material, which features an exact composition and capacity that are not commonly disclosed by the industry, depends on the control of the influence that the nanoparticles exert on one another, a phenomenon of the atomic world known as dipolar interaction because the nanoparticles behave like tiny magnets (magnetic dipoles). "This interaction, the intensity of which increases as the space between the particles decreases, occurs even at distances that are considered as being long in the nanometric world," says Sueli.

When one hits the "enter" key of a computer to save a text file, for example, a small coil (head) that floats tenths of a millionth of a millimeter from the hard disk converts electrical pulses into magnetic ones and guides the nanoparticles' magnetic field in a specific direction or in the opposite direction, which requires turning 180 degrees. The direction of this magnetic field (imagine an arrow pointing upward or downward) functions as a unit of information, the bit, represented by the numbers 0 and 1. Once the save command is activated, a long sequence of zeroes and ones is coded in the magnetic direction of the nanoparticles. This magnetic coding does not change when the computer is turned off.

Increasing the storage capacity of this kind of memory, which was created by IBM in the 1950s, requires accommodating a higher number of particles in the same area. However, this process is complicated by dipolar interactions, among other factors. As the nanoparticles come closer together, the magnetic fields generated by them interact with each other until, depending on the distance, they provoke the inversion of the nanoparticles' direction, or, as physicists refer to the phenomenon, they flip. In this case, a flip is synonymous with instability, which is not desirable when information is stored.



Metallic cube: organization of nickel atoms at room temperature

In January, Jardim and Sueli proposed a way of avoiding this problem, which they explained in the *Applied Physics Letters* journal. They suggest using two sets of characteristics of the material to estimate at which point the dipolar interaction becomes relevant. The first set, of a structural nature, takes into account the size of the particles and the distance between them. The other measure is magnetic susceptibility, that is, the material's response to a magnetic field.

The two researchers devised this strategy by investigating the behavior of a material containing nanoparticles of nickel that had been synthesized by Sueli as part of a thematic research grant supported by FAPESP and coordinated by physicist Reginaldo Muccillo. Nickel (Ni) is a model metal for the study of magnetic properties because it is naturally magnetic at room temperature, as are iron (Fe) and cobalt (Co).

In the lab, Sueli mixed an acid (citric acid), an alcohol (ethylene glycol) and a salt (nickel nitrate), maintaining the liquid at a temperature of 80 degrees Celsius until it had gelled; this gel was subsequently put inside an oven for a period of three hours at a temperature of 300 degrees Celsius. The resulting resin was crushed and heated again in an atmosphere of nitrogen to eliminate impurities. The result was the formation of sphere-shaped nickel nanoparticles immersed in a matrix of carbon and silica. With an average diameter of five nanometers, each nanoparticle is actually a group of nearly 6 thousand atoms organized in the form of cubes that behave as if they are a single dipole.

Interaction – By increasing the concentration of nickel, which ranged from 1.9% to 12.8% of the compound's mass, Sueli observed through the electronic microscope that the distance between the nanoparticles had decreased from 21 to 11 nanometers. Concurrently, the magnetic susceptibility revealed a higher level of interaction among the particles. From a certain distance onward, the magnetic susceptibility was no longer organized as expected for independent particles, an indication that the nanoparticles' magnetic fields had begun to interfere with each other. "The dipolar interaction became important at distances of less than 14 nanometers," says Sueli, who described her findings in an article published in *Physical Review B* journal in 2009 and in another article scheduled for publication in the *Journal of Applied Physics*. A set of HD-containing nanoparticles organized so close to each other would behave in a manner similar to a memory affected by Alzheimer's disease: it could lose the information immediately after acquiring it.

"This characteristic, which renders the material inappropriate for data storage, could be interesting for phenomena that do not require the preservation of the state, such as the transmission of information," says Jardim. According to the physicist, the strategy could be applied to any material, a property that could attract the interest of the industry. "The method", he says, "could be adopted as a protocol to monitor the construction of computer magnetic memories and test their quality." ■

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