'Critical baby step' taken for spying life on a molecular scale

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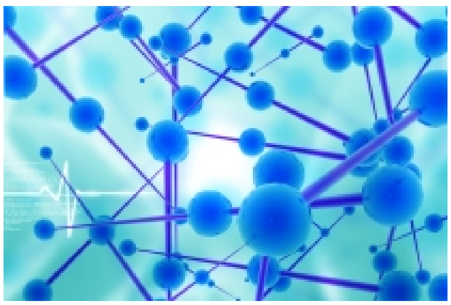

(PhysOrg.com) -- The ability to image single biological molecules in a living cell is something that has long eluded researchers; however, a novel technique, using the structure of diamond, may well be able to do this and potentially provide a tool for diagnosing, and eventually developing a treatment for, hard-to-cure diseases such as cancer.

In a study published today, Thursday, 19 May, in the Institute of Physics and the German Physical Society's New Journal of Physics, researchers have developed a technique, exploiting a specific defect in the lattice structure of diamond, to externally detect the spins of individual molecules.

Magnetic Resonance Imaging (MRI) has already taken advantage of a molecule's spin to give clear snapshots of organs and tissue within the human body, however to get a more detailed insight into the workings of disease, the imaging scale must be brought down to individual biomolecules, and captured whilst the cells are still alive.

Co-lead author Professor Phillip Hemmer, Electrical & Computer Engineering, Texas A&M University, said, "Many conditions, such as cancer and aging, have their roots at the molecular scale. Therefore if we could somehow develop a tool that would allow us to do magnetic resonance imaging of individual biomolecules in a living cell then we would have a powerful new tool for diagnosing and eventually developing cures for such stubborn diseases."

To do this, the researchers, from Professor Joerg Wrachtrup's group at the University of Stuttgart and Texas A&M University, used a constructed defect in the structure of diamond called a nitrogen vacancy (NV)—a position within the lattice structure where one of the carbon atoms is replaced with a nitrogen atom.

Instead of bonding to four other carbon atoms, the nitrogen atom only bonds to three carbon atoms leaving a spare pair of electrons, acting as one of the strongest magnets on an atomic scale.

The most important characteristic of a diamond NV is that it has an optical readout—it emits bright red light when excited by a laser, which is dependent on which way the magnet is pointing.

The researchers found that if an external spin is placed close to the NV it will cause the magnet to point in a different direction, therefore changing the amount of light emitted by it.

This change of light can be used to gauge which way the external molecule is spinning and therefore create a one-dimensional image of the external spin. If combined with additional knowledge of the surface, or a second NV nearby, a more detailed image with additional dimensions could be had.

To test this theory, nitrogen was implanted into a sample of diamond in order to produce the necessary NVs. External molecules were brought to the surface of the diamond, using several chemical interactions, for their spins to be analyzed.

Spins that exist within the diamond structure itself have already been modelled, so to test that the spins were indeed external, the researchers chemically cleaned the diamond surface and performed the analysis again to prove that the spins had been washed away.

Professor Hemmer continued, "Currently, biological interactions are deduced mostly by looking at large ensembles. In this case you are looking only at statistical averages and details of the interaction which are not always clear. Often the data is taken after killing the cell and spreading its contents onto a gene chip, so it is like looking at snapshots in time when you really want to see the whole movie."

"Clearly there is much work to be done before we can, if ever, reach our long-term goal of spying on the inner workings of life on the molecular scale. But we have to learn to walk before we can run, and this breakthrough represents one of the first critical baby steps."

More information: Sensing external spins with nitrogen-vacancy diamond, Bernhard Grotz et al 2011 *New J. Phys.* 13 055004
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Abstract

A single nitrogen-vacancy (NV) center is used to sense individual, as well as small ensembles of, electron spins placed outside the diamond

lattice. Applying double electron–electron resonance techniques, we were able to observe Rabi nutations of these external spins as well as the coupling strength between the external spins and the NV sensor, via modulations and accelerated decay of the NV spin echo. Echo modulation frequencies as large as 600 kHz have been observed, being equivalent to a few nanometers distance between the NV and an unpaired electron spin. Upon surface modification, the coupling disappears, suggesting the spins to be localized at surface defects. The present study is important for understanding the properties of diamond surface spins so that their effects on NV sensors can eventually be mitigated. This would enable potential applications such as the imaging and tracking of single atoms and molecules in living cells or the use of NVs on scanning probe tips to entangle remote spins for scalable room temperature quantum computers.

Provided by Institute of Physics

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