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Spinach and Nanodiamonds?
Researchers from Ulm University develop nanodiamond biosensor for detection of ironlevel in blood

Popeye, the comic book hero, swears by it as do generations of parents who delight their children with spinach. Of course, today it is known that the vegetable is not quite as rich in iron as originally thought, but that iron is nevertheless essential for our physical well-being is undisputed. Lack of iron—caused by malnutrition—can lead to anemia while an increased level of iron may signal the presence of an acute inflammatory response. Therefore, the blood iron level is an important medical diagnostic agent. Researchers at Ulm University, led by experimental physicist Fedor Jelezko, theoretical physicist Martin Plenio and chemist Tanja Weil, have developed a novel biosensor for determination of iron content that is based on nanodiamonds. This project was realized under Synergy Grant BioQ endowed with 10.3 million Euro which the scientists were awarded last December by the European Research Council.

"Standard blood tests do not capture—as one might expect — free iron ions in the blood, because free iron is toxic and is therefore hardly detectable in blood," explains Professor Tanja Weil, director of the Institute for Organic Chemistry III, University of Ulm. These methods are based on certain proteins instead that are responsible for the storage and transport of iron. One of these proteins is Ferritin that can contain up to 4,500 magnetic iron ions. Most standard tests are based on immunological techniques and estimate the iron concentration indirectly based on different markers. Results from different tests may however lead to inconsistent results in some clinical situations.

The Ulm scientists have developed a completely new approach to detect Ferritin. This required a combination of several new ideas. First, each ferritin-bound iron atom generates a magnetic fields but as there are only 4,500 of them, the total magnetic field they generate is very small indeed and therefore hard to measure. This indeed, posed the second challenge for the team: to develop a method that is sufficiently sensitive to detect such weak magnetic fields. This they achieved by making use of a completely new, innovative technology based on tiny artificial diamonds of nanometer size. Crucially these diamonds are not perfect —colorless and transparent — but contain lattice defects which are optically active and thus provide color of diamonds.

"These color centers allow us to measure the orientation of electron spins in external fields and thus measure their strength" explains Professor Fedor Jelezko, director of the Ulm Institute of Quantum Optics. Thirdly, the team had to find a way to adsorb ferritin on the surface of the diamond. "This we achieved with the help of electrostatic interactions between the tiny diamond particles and ferritin proteins," adds Weil. Finally, "Theoretical modeling was essential to ensure that the signal measured is in fact consistent with the presence of ferritin and thus to validate the method," states Martin Plenio, director of the Institute for Theoretical Physics. Future plans of the Ulm team include the precise determination of the number of ferritin proteins and the average iron load of individual proteins.

The demonstration of this innovative method, reported in the current issue of the journal published in *Nano Letters*, represents a first step towards the goals of their recently awarded BioQ Synergy Grant. The focus of this project is the exploration of quantum properties in biology and the creation of self-organized diamond structures.

"Diamond sensors can thus be applied in biology and medicine," say the Ulm scientists. But their new invention has its limits ". Whether the children have actually eaten their spinach cannot be detected with the diamond sensor, that’s still the prerogative of parents ", confesses quantum physicist Plenio.

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Pictures: Nanodiamant.jpg (Photo: Fedor Jelezko): Microscope picture of small diamonds, 100 microns in diameter. Specific lattice defects do not only impart colour on the diamonds but also provide the basis for the magnetic field sensor. In their experiments the team at Ulm ground down these diamonds to a size of 20 nanometers (as a comparison, a human hair has a diameter of 70 microns and is therefore 3000 times thicker than the nanodiamonds).
Ferritin.jpg (Graphics: Tanja Weil): Model of the Ferritin with stored iron.
plenio_jelezko_weil.jpg (Photo: Elvira Eberhardt): The research team at Ulm composed of physicists Martin Plenio and Fedor Jelezko together with chemist Tanja Weil have developed diamond sensors that can determine the level of blood iron.

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