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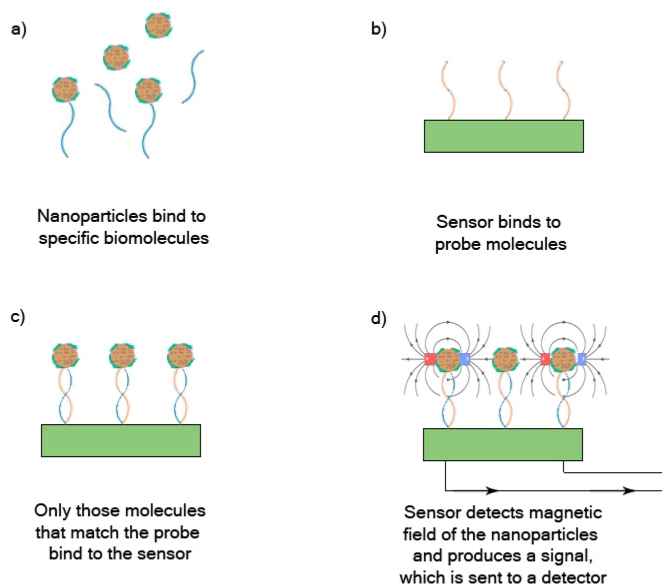
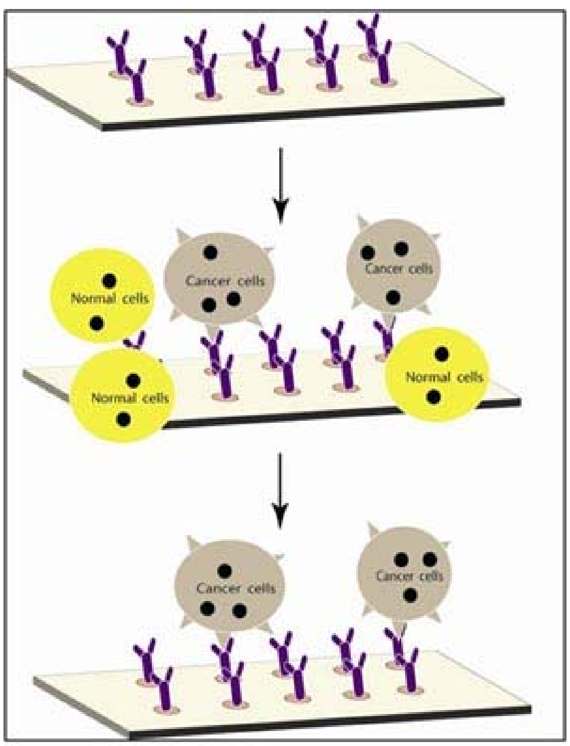
(Magnetic) Spintronic Immunoassay: Using Magnetics for Identification and Characterization of Biomolecules

Nowadays, going to the doctor and getting a check-up is the only way to ensure a clean health bill. The doctor holds the key to a correct diagnosis, and testing your blood and other body fluids in a laboratory for harmful bacteria, viruses, and other particles is currently the easiest way to do so. However, this process can take hours, even days, to complete. But imagine that instead of going to the doctor and waiting a few days to know the status of your health you could test your blood on a hand-held device, verifying your body's health status in an instant. This former subject of science fiction novels could soon be a very tangible reality.



Current research at Micro Magnetics, Inc. (the parent company of DirectVacuum) focuses on developing a magnetic biosensor, a device that can detect the presence of virtually any particle in your body, foreign or natural. By utilizing tiny magnetic nanoparticles to tag the DNA, viruses, bacteria, or cancer cells in question, it is possible to detect the exact concentration of almost any molecule or particle present in the body.



Cancer-cells and normal cells bound to nanoparticles are introduced to a magnetic sensor. Only the cancer cells bind to the sensor, and the normal cells are washed away.

How it works is relatively simple. First, magnetic nanoparticles (NPs) that bind only to specific molecules are fabricated. These NPs are then introduced into the sample to be tested. If the molecules, viruses, DNA, or other cells which the NPs are designed for are present, the NPs will be tightly bound to or inside them. Later, the biological sample will be introduced to an array of magnetic sensors with "probe" molecules (antigens, compliementary DNA) on each sensor. These probe molecules will bind tightly to certain compounds in a sample if they are present, and the compounds that do not bond to the probe molecules will be washed away. The sensor can then detect the presence of these NPs by sensing their magnetic field. The sensor would then

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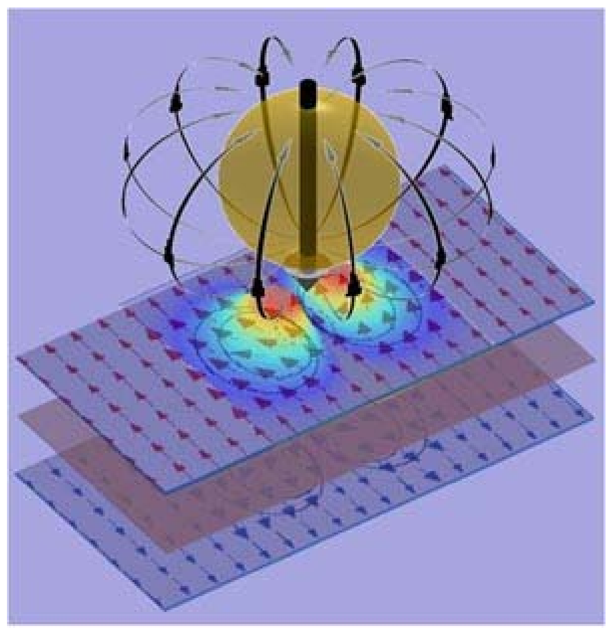
produce a signal confirming their existence. The strength of the signal is proportional to the concentration of such molecules. The biomagnetic sensor is so sensitive that even a single biomolecule can be detected.

This new immunoassay method has some very important implications. Virtually any biomolecule can potentially be detected using this "lab-on-a-chip" technology. All tests and experiments could potentially be conducted on this single device using microfluidic circuitry, such as valves, tubes, mixers, pumps, and channels on a very small scale. These components, constructed of polymers, can be constructed in a similar way to microelectronic circuitry. This would revolutionize medical diagnoses as a non-invasive, quick, portable, and relatively inexpensive way to thoroughly detect health problems.

For example, imagine that a healthy-looking individual actually has a premature, underdeveloped cancerous tumor which would normally go undetected in a first checkup. In many cases, this tumor would be left to grow to dangerous levels since it would not be noticed in its early stages. However, with this new immunoassay technology, NPs introduced into the cancerous cells in blood samples would be absorbed by these cancer cells as well as healthy, normal cells. Then, these cancer cells would bind to molecules attached to a magnetic sensor, while normal cells would not bind to the sensor since it is coated with a cancer-cell specific antibody. Normal cells would then be washed off, leaving only the cancer cells. The sensor would detect the NPs inside the cancer cell, and a positive diagnosis of cancer would result, saving time, energy, money, and most importantly, the life of the patient. In a real application, the sensor would be coated with multiple types of antibodies, allowing for the detection and diagnosis of many types of diseases with the same chip.



A magnetic sensor detects the magnetic field produced by a nanoparticle.

The physical phenomenon behind this process is a property that certain magnetic materials have called magnetoresistance (MR). MR is the property that the resistivity, or charge carrying capacity, of a material changes with the strength of an external magnetic field. MR materials transmit more or less current depending on the strength of the magnetic field, and by measuring this current, the strength of the field can be calculated. MR technology is currently used in modern hard drive heads for reading stored data, as well as in extremely sensitive magnetic field sensors.

The specific type of magnetic field sensor used in this biosensing application is known as a magnetic tunneling junction (MTJ). They way an MTJ works, and the way that the NPs interact with the MTJs, arises purely due to quantum mechanical interactions between electrons and magnets. Essentially, the electrons have a spin degree of freedom which can either point up or down, as does a magnetic atom. If an electron approaches a magnetic atom of opposite spin polarization (direction), then the electron will not be able to pass through. However, electrons and atoms with parallel spin configurations can tunnel (travel) through without a problem. We exploit this property by having two magnetic layers separated by an insulating barrier, one with a permanent magnetic orientation, and the other with a controllable

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orientation. The amount of current tunneling through the insulating layer is a function of the relative orientation of the two layers to each other, controlled by an external magnetic field. Thus, the presence of a magnetic field changes the amount of current allowed to tunnel through the layers, and measuring the current flow through the plates will give information about the strength, or existence at all, of the magnetic field.

Guidelines in Choosing SpinTJ Products for Biomagnetic Applications

In general, biological sensing applications which use magnetic micro- or nanoparticles as markers require four components: (1) a magnetic sensor, (2) a package on which the sensor is mounted, (3) sensor electronics for powering the sensor and monitoring its response, and (4) a microfluidics circuit that allows the biological solution to flow across the sensing area.

The standard STJ-001 SpinTJ sensor (bare die) can be used for single micron-size magnetic marker detection.

For determining the concentration of smaller magnetic markers (nano to micron sizes), the low-noise magnetic field sensor STJ-201 (bare die) can be used. We can also custom-design and fabricate SpinTJ bridges, with sensing elements covering areas ranging from 1 μm^2 to 100,000 μm^2.

For single sub-micron or nano-scale markers, we design and fabricate custom-made sub-micron (down to 100 nm) SpinTJ sensors. Call us to discuss your application and we will provide a quote for the service.

A single SpinTJ sensor can be mounted (at an additional cost) by our technicians on a package provided by the customer. We typically recommend the use of DIP or SOIC-to-DIP IC packages.

We strongly recommend the use of the D-801 (sensor preamplification electronics board). SpinTJ sensors can be directly plugged into the D-801, which also provides better ESD/EOS protection for the sensor. The D-801 amplifies and filters the voltage across the sensor and outputs an analog voltage proportional to the magnetic field. The proprietary design of the D-801 allows power supply noise and other common-mode noise across the sensor to be attenuated by over 100 dB.

We can also design and fabricate microfluidic circuits which can be coupled to the SpinTJ sensor(s) according to customer specifications.

Contact Micro Magnetics for more information on the biological applications of our SpinTJ magnetic sensor products.