MD Medical Design

Medical Design Online – December 2009

Nano-level DNA research underway in Israel

Dec 14, 2009 3:49 PM, by Jim McMahon, technology writer

Scanning probe microscopy and negative-stiffness vibration isolation are enabling nano-level DNA research at Israel's Weizmann Institute of Science. DNA is able to recognize other molecules, other strands of DNA, and because it binds together with similar DNA strands in a unique way, scientists are considering the possibility of using DNA as an electronic circuit without having to build in any other circuitry. The DNA would bind with other similar DNA strands and use the connecting properties of the DNA to create a self-assembled biological wire for electrical conduction. Recent research on the capacity of single molecules of DNA to transport current along individual strands and conducted by Sidney R. Cohen in collaboration with Ron Naaman and Claude Nogues of the Weizmann Institute of Science, Scanned Probe Microscopy Unit, in Rehovot, Israel, has shed new light on the electrical transport properties of DNA, focusing on the capacity of single molecules of DNA to transport current along individual strands.

DNA (deoxyribonucleic acid) is a nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms and some viruses. The main role of DNA molecules is long-term storage of information. DNA nanotechnology uses the unique molecular-recognition properties of DNA to create self-assembling branched DNA complexes with useful properties.

To measure the electronic properties of DNA, Cohen and his staff connected a volt electrode to the end of a DNA molecule (a few nanometers in length), using an AFM (atomic force microscope). To facilitate this bio-molecular connection, the lab attached a bio-link, a gold electrode, to a single strand of DNA, and then attached a gold ball just 10 to 20 nanometers in size to a complementary DNA strand. Then these two strands were hybridized (linked, aided by genetic similarity between corresponding DNA sequences). When strands are complementary, a double strand is formed. While single strands of DNA do not conduct electricity, double strands conduct for certain configurations. Using an AFM, with the DNA double strand displayed on a flat surface, researchers could locate the gold ball, put the AFM tip on top of the ball, flow a current through the double strand, and view the current voltage characteristics.

"There are two possibilities when we talk about electrons flowing through a DNA molecule," explains Cohen. “One is a 'tunneling process,' when the electron effectively shoots through the molecule without caring too much about the internal structure of the molecule. The other is a 'hopping process,' where the electron actually resides for small periods of time in certain positions along the molecule. In this case the electron will be affected by temperature."

Researchers also found that variations in both the sequence and the composition of a strand's base pairs can affect the progress of electron transport through the strand. Similarly, bases that are electron rich have better electron conductivity than those with fewer available electrons.

The characteristics of electron conductivity in DNA also have implications in molecular electronics, which may lead to devices that, instead of working on the standard silicon circuitry, function through innocuous molecules. Because of DNA's facility to bind with similar types of DNA molecules, it is not necessary to physically place each molecule in a set location. DNA put into solution can be expected to organize itself in the right way and become a predictable medium for electrons.

The Weizmann Institute is one of the few research groups in the world that has actually managed to measure the electrical transport properties of a single molecule of DNA. A critical factor in the Weizmann Institute's ability to consistently measure DNA electron structures at such extreme nano-level resolutions is the lab's use of negative-stiffness vibration isolation systems by Minus K Technology.

Negative-stiffness mechanism (NSM) isolators have the flexibility of custom tailoring resonant frequencies vertically and horizontally. They employ a mechanical concept in low-frequency vibration isolation. Vertical-motion isolation is provided by a stiff spring that supports a weight load, combined with an NSM. The net vertical stiffness is made low without affecting static load-supporting capability of the spring.

Beam-columns connected in series with the vertical-motion isolator provide horizontal-motion isolation. The horizontal stiffness of the beam-columns is reduced by the "beam-column" effect. A beam-column behaves as a spring combined with an NSM. The result is a compact passive isolator capable of low vertical and horizontal natural frequencies and high internal structural frequencies. Transmissibility with negative-stiffness is substantially improved over air systems, which can make vibration isolation problems worse since they have a resonant frequency that can match floor vibrations. Transmissibility is a measure of the vibrations that transmit through the isolator relative to the input vibrations. The NSM isolators, when adjusted to 0.5Hz, achieve 93 percent isolation efficiency at 2Hz; 99 percent at 5Hz; and 99.7 percent at 10Hz. NSM transmissibility is also improved over active systems.

Since they run on electricity, active systems can be negatively influenced by electronic dysfunction and power modulations, which can interrupt scanning. They also have a limited dynamic range, which is easy to exceed – causing the isolator to go into positive feedback and generate noise underneath the equipment. Although active isolation systems have fundamentally no resonance, their transmissibility does not roll off as fast as negative-stiffness isolators.