A card-swipe for medical tests: Diagnostic device uses same principle as hard disks, MP3 players

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The green circuit board at left, with its sensors shown in expanded view, would serve as the active component of a card-reading device (upper center) able to detect disease-related substances within samples of blood, urine, saliva or other fluids on a credit card-like "wellness card." Another option would be for the medical samples to be placed on a rotating platter and read much like a computer hard drive (bottom center). Whichever approach is used, the results could be transmitted to a PDA (personal digital assistant) read by a doctor or medical technician (lower right). Credit: Michael Granger, University of Utah

University of Utah scientists successfully created a sensitive prototype device that could test for dozens or even hundreds of diseases simultaneously by acting like a credit card-swipe machine to scan a card loaded with microscopic blood, saliva or urine samples.

The prototype works on the same principle – giant magnetoresistance or GMR – that is used to read data on computer hard drives or listen to tunes on portable digital music players.

"Think how fast your PC reads data on a hard drive, and imagine using the same technology to monitor your health," says Marc Porter, a Utah Science, Technology and Research (USTAR) professor of chemistry, chemical engineering and bioengineering.

Porter is the senior author of a pair of studies demonstrating the new method for rapid disease testing. The research will be published in the Saturday, Nov. 1, 2008, issue of the journal *Analytical Chemistry*.

"You can envision this as a wellness check in which a patient sample – blood, urine, saliva – is spotted on a sample stick or card, scanned, and then the readout indicates your state of well-being," says USTAR research scientist Michael Granger, a co-author of the research. "We have a great sensor able to look for many disease markers."

Unlike lab tests today, results could be available in minutes, not hours to weeks.

Porter and Granger conducted the research with John Nordling, Rachel Millen and Heather Bullen at Iowa State University in Ames – where Porter once worked – and Mark Tondra, then at NVE Corp., in Eden Prairie, Minn.

The Utah Science, Technology and Research initiative seeks to create new high-tech jobs by recruiting world-class research teams to develop products and services that can be commercialized to start new businesses and stimulate Utah's economy.

Homeland Security, Environmental Monitoring,

Veterinary Medicine

The prototype card-swipe device consists of a GMR "read head" and sample stick. Right now, the device is about the size of a PC. But Granger says that when it is developed commercially, the GMR sensor device will look like a credit card reader.

Porter expects a more advanced version will start being used to test farm animals for diseases in about two years, and a version for human medical tests might begin clinical evaluation in five years, perhaps sooner if pursued by certified laboratories.

"We also think it has homeland security applications," Porter says.

A card swipe device could be taken into the field, where a sample card or stick "could be dipped in groundwater, dried off and read in our device to look for E. coli, plague, smallpox or other suspects on the homeland security list," he says.

Granger says cards with GMR sensors also could be used for environmental monitoring of various toxins or toxic chemicals in an office building's water or air.

The new research showed the method was very sensitive, detecting as few as 800 microscopic particles that mimicked disease-related substances.

GMR's capability to detect a single particle of a biological substance "is just over the horizon," which could be used to test blood or other samples for viruses that can cause disease in minute concentrations, Porter says.

Card-swipe testing devices would be inexpensive because they use existing, inexpensive hard-drive technology, Granger says. "The price would be such that small diagnostic labs could buy them, and eventually your local pharmacist could have one," Porter envisions.

Porter says a sample card swiped in a GMR sensor device conceivably could hold 1,900 different samples for testing, but that in most medical settings, less than a dozen tests would be needed. Nevertheless, "you eventually might test for hundreds of proteins or other compounds in the body when profiling a person's health," he says.

Turning Nobel-Winning Knowledge into Medical Technology

The new testing method makes use of "giant magnetoresistance," or GMR, a phenomenon discovered independently in 1988 by Albert Fert of France and Peter Grünberg of Germany. They shared the 2007 Nobel Prize in Physics for the discovery.

Magnetoresistance is the change in a material's resistance to electrical current when an external magnetic field is applied to the material. That change usually is not more than 1 percent. But some multilayer materials display a change in resistance of as much as 80 percent. That is giant magnetoresistance.

Porter says GMR "is an ultrasensitive method to detect magnetic footprints," and is used to read data from computer hard disks and from MP3 music players.

According to the Nobel Foundation: "A hard disk stores information, such as music, in the form of microscopically small areas magnetized in different directions. The information is retrieved by a read-out head that scans the disk and registers the magnetic changes. … A read-out head based on the GMR effect can convert very small magnetic changes into differences in electrical resistance and therefore into changes in the current emitted by the read-out head. The current is the signal from the read-out head and its different strengths represent ones and zeros."

In the first new study, Porter, Granger and colleagues set the stage for using GMR devices to test medical, environmental or other biological samples.

The prototype reader had four GMR devices: two sensors to detect changes to the magnetic fields of the sample spots, and two "reference elements" to distinguish how magnetic measurements were affected by temperature changes as opposed to the presence of disease indicators in medical samples.

The prototype does not yet look like a credit card reader or card-swipe device. Instead, it is used to "read" a Pyrex glass sample stick about three-quarters-inch long and one-eighth-inch wide. Biological samples can be placed on the sample stick, which then is "scanned much like a credit card reader," Porter says.

In the first study, instead of holding blood or other medical samples, the sample stick had 15 raised spots of iron-nickel "permalloy," a magnetic material that produces a magnetic signature read by GMR sensors.

"We are simulating a signal to test the card-swipe device," Granger says. "It's not a real sample."

The study determined how measurements by the GMR sensors – the heart of a future card-swipe device – can be calibrated to account for variations in the size of the permalloy spots, the amount of separation between the sensors and the sample stick, and the angle of the sample stick as it is scanned by the sensors.

Those factors determine how consistently and accurately a card-swipe device would detect minute amounts of substances associated with diseases.

Simulating a Disease Test

In the second study, the sample stick's alloy spots were replaced by the material that would be used on real medical test cards: microscopic spots or "addresses" of gold that were no longer than the smallest known bacterium. The widths were varied to test which size of addresses could be "read" most accurately.

A substance named biotin or vitamin B-7 was bound chemically to the gold spots on the sample stick. Tiny drops of magnetic particles coated with streptavidin – a protein found in eggs – were placed on the gold spots.

"The gold address has no magnetic signature," Granger says. "Once the particles are bound to it, GMR picks up that magnetic signature. It's a proof of principle."

The experiment was repeated hundreds of times with different concentrations of magnetic particles bound to the biological substance.

"We could detect as few as 800 magnetic particles on an address," Porter says. "We believe that with further development, we can get down to single-particle detection."

The Utah scientists cite examples of how a GMR card reader might be used medically for humans and animals:

-- Current tests for prostate specific antigen (PSA) – an indicator for possible prostate cancer – only look for "free" PSA but not for other forms. A card-like sample stick with multiple "addresses," each with an antibody that binds to a different kind of PSA, would be able to test a blood sample for multiple forms of PSA and for their relative abundances, and thus be more reliable in predicting prostate cancer, Porter says.

-- "The same approach can be used to screen patients for other cancers or heart disease," Granger says.

-- A rapid, card-reader test for genital or oral herpes could help reduce the number of Caesarean sections. If obstetricians suspect maternal herpes, they sometimes do C-sections to avoid transmission to the newborn, Porter says. A conclusive, rapid test for herpes can tell doctors if a C-section is really necessary.

-- Porter envisions GMR sensors as tools for personalized medicine, in which "you want to establish everybody's baseline with various health markers" – tests for various diseases and disease susceptibilities. Then, people would monitor health changes by periodic re-testing in a doctor's office, pharmacy or perhaps at home.

-- GMR sensors could provide rapid detection of porcine parvovirus, a respiratory infection that kills pigs; feline calicivirus, which does the same to cats; and bacteria that cause Johne's (pronounced yo-knees) disease, a fatal wasting disorder in dairy cows that costs $1.5 billion annually in the United States.

Source: University of Utah

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