Plastics for RFID technology

A memory for things

All products in the future, from containers on ships to milk cartons, are to be equipped with a "digital memory" in the form of RFID tags. Scanned by radio signal, they contain information on the origin, destination and shelf life of an object. Researchers at Bayer MaterialScience are working on new materials for these modern radio chips.

Sushi bars, with bite-size delicacies passing diners on a conveyor belt, can now be found just about everywhere in the world. Sushi plates with integrated price tags were recently introduced in Japan: a tiny chip and antenna on the bottom of the plate send price information to a reader and continuously update the bill. The smart chips, based on Radio Frequency Identification (RFID), are the next revolution in information technology. Using this method, data can be transmitted via radiowaves without any physical or visual contact. RFID unites the data world with our real world. Take logistics, for example, where packages today are already provided with radio labels to permit automatic tracking, or sushi restaurants where RFID systems help guests to determine how many more delicious bits of eel, tuna fish, salmon, seaweed and rice they can afford.

A complete RFID system includes a chip, known as the transponder, which is affixed to an object, a reader to access the chip's identification code, and a software application with database interfaces. The RFID labels or tags disclose their information via an antenna that picks up passing radiowaves emitted by the reader. In most cases, the chip contains a numerical code representing information stored in a database. By this method, each and every object in the world can be given an unmistakable identity. RFID chips are used on sushi plates as well as tickets to last year's Soccer World Cup. In a few years, they probably will be found on virtually all products. Special active tags even have their own minicomputer or database.

Global market volume: US$ 12 billion

As many as one trillion objects will be equipped with RFID chips by 2012, predicts U.S.-based Sun Microsystems. For the economy, RFID is more than just an IT issue; it's a comprehensive logistics concept, and this fact is evident in industry forecasts. According to the Swiss Federal Institute of Technology in Zurich (ETH Zurich), the global market for RFID systems will increase to some US$ 12 billion by 2010, with US$ 4 billion being attributable to active tags with on-board power supply, US$ 5.5 billion to passive tags, meaning those without an energy source, and a good US$ 2 billion to readers.

The greatest force driving this development is the retail sector. The Metro Group, for example, is testing the use of RFID as part of its Future Store Initiative. A shopping cart with navigation system guides buyers to special offers and supports contactless payment at a register equipped with an RIFD reader. The technology pays off for Metro because it has reduced slow-moving inventory by 14 percent (a retail segment that otherwise generates an average of eight percent in lost sales) and losses due to theft by as much as 18 percent.

RFID system navigates through the supermarket

Currently, however, the market for RFID applications is growing at a slowed

Buying advice via RFID: the changing-room mirror of the future (large photo) could give customers information on available colors and sizes, as well as care instructions. It's all made possible by an RFID tag sewn into the garment. Current models can already do the job, like the one stuck to the laptop of Bayer researcher Dr. Ramesh Pisipati (right), Head of the Global RFID team at Bayer MaterialScience.

Food-shopping made easy: shopping carts at the Metro Future Store are equipped with a Personal Shopping Assistant (PSA). It registers all goods in the cart via RFID and is simply turned in at the register.

pace, because radio labels are still too expensive: passive tags, which draw energy from the electromagnetic field of the reader, cost 30 eurocents, while active tags go for several euros. Costs of this magnitude are negligible when the tags are affixed to reusable containers in a factory, but exorbitant when their purpose is to store the expiry date on a carton of milk. In this scenario, the tag costs nearly as much as the milk. However, a great number of applications have already emerged. For example, some two million books and manuscripts in the Vatican library have radio tags to accelerate inventory and borrowing procedures. In the Airbus A380, about 10,000 RFID transponders simplify routine tasks. Maintenance workers can quickly locate important components; every single part has its own maintenance log. At Legoland in Billund, Denmark, missing children are reunited with their families using RFID armbands and at Baja Beach Club in Barcelona, a one-cm chip injected under the skin serves as a membership card. A brewery in Flensburg, Germany, has even equipped all its beer kegs with RFID transponders, thus enabling the cleaning system to determine which type of beer was in the keg and automatically adjust the intensity of the cleaning cycle.

Innovative silver materials for antennas

Innovation manager Dr. Daniel Rudhardt, responsible for future applications in logistics, is working with an international team of Bayer researchers to make RFID technology cheaper and more durable. At present, the antenna, chip and substrate material for a passive tag each make up about a third of the total cost. The Bayer experts are searching for the best material solutions for all three components in order to further reduce the price over the next few years, and they have already come up with a lot of promising ideas, the most viable at present being substances for the antenna (see box on page 94, "Silver ink from a printer"). They must possess high conductivity like metal, meaning that organic materials currently are not an alternative. "The best option is an ink made of dispersed metal particles," reveals Dr. Stefan Bahnmüller, Nanotechnology Innovation Manager at Bayer MaterialScience.

The Bayer researchers also have their eyes on the substrate material: "It requires real expertise in electronics. In addition, the demands imposed on the material itself are very high and entirely different from one application to another," explains Dr. Martin Hoppe, an electrical/electronic applications

Interview

More than the sum of its parts

Friedemann Mattern, a professor at the Swiss Federal Institute of Technology in Zurich (ETH Zurich), is head of the Distributed Systems faculty. The computer scientist develops visions of the future, in which all things are connected in a network.

In your book "The Internet of Things", you describe a world in which virtually all objects are "intelligent" and networked with other objects. What do we have to expect in this new world?
Smart objects, as they are called, will be able to perceive their environment, process data and pass on the information to other objects. The "informationizization" of our world will increase rapidly. For example, RFID tags with built-in sensors will be ejected from airplanes to observe the environment. Other sensors will measure soil moisture levels and automatically switch on the sprinkler in your yard - of course only if there's no rain in the Internet weather forecast.

What technical issues do you still have to solve along the way?
When it comes to solving the energy problem, meaning lower power consumption and longer battery service life, we are not making as much progress as I would like. We can't keep changing the batteries on autonomous sensors used to monitor the environment. Similarly, we still don't know what the infrastructure will be like, for instance which radio signaling standards are suitable for networking sensors with one another and the Internet.

Just because something is technically feasible doesn't mean we need it, right?
Correct! Until now, we haven't really missed intelligent, networked objects. On the other hand, we also didn't have a pressing need for mobile telephones ten years ago, but are still happy they exist today. Our pursuit of security, status, comfort and entertainment will ensure that many applications of this kind are accepted.

Will we accept intelligent objects that act without our knowledge?
On the Object Internet, the difference between online and offline will not be as clear. Acceptance is most critical in situations where objects - and frequently also their owners - can be localized and followed. That's great if you've lost your keys, but not so good if it allows governments to keep an eye on their citizens.

What happens when intelligent objects fail or break down?
When objects become more and more intelligent and autonomous, they don't always behave the way we would expect them to. Some people therefore say we must have the ability to switch the intelligence of networked objects on and off. But it is this intelligence that offers decisive added value, just like a human being is more than just the sum of his or her body cells. We must design the systems such that even exceptional situations are controllable. Our environment must continue to function without the help of intelligent objects.

Is there money to be made on the Object Internet?
We are working with the University of St. Gallen and several major corporations like Bayer to develop business models. One trend is "Pay Per Use", a system by which fees are collected for using an object, similar to how we pay for telephone service. Cars could report how many miles and how fast they have traveled, and where they are parked at night, as a basis for calculating liability and collision insurance. I myself am very curious to see which business models with smart objects will prove to be most successful.

specialist in the Bayer MaterialScience New Business department. He helps to identify new RFID applications, because in the future, the label on a bag of chips must be just as elastic as the package itself, and the radio tags on frozen pizzas must display good thermal stability. These goals cannot be achieved with standard tags made of paper with an adhesive backing, which today make up 75 to 80 percent of the market and are sold by numerous manufacturers. For this reason, the Bayer material experts are concentrating on RFID tags exposed to extreme conditions, for example tags that must withstand high pressures and temperatures or aggressive chemicals during manufacture or use, tags requiring high flexibility, and those designed for antiforgery applications, such as identification documents or patient data cards in hospitals. One application on which the Bayer researchers currently are working is intelligent labels for clothing. They must withstand hot wash cycles and reliably store information, such as manufacturer, material and care instructions. This information would help hospitals and industrial facilities, for example, to wash large quantities of clothing and return the items to the correct owners. Home washing machines are also being tested to select the right wash cycle using the data on the label. Some 20 to 30 percent of the market for passive tags will be attributable to durable labels, and this is where Bayer MaterialScience wants to offer customers its material- and process-based system services. "An application becomes a possibility when it pays off for a customer," says Dr. Ramesh Pisi-

Silver ink from a printer

Inkjet printers can already be found in millions of home offices and even kids' rooms. Soon they may also become a standard piece of equipment in the manufacture of RFID tags, helping to lower the cost. Researchers at Bayer MaterialScience and Bayer Technology Services have now developed a conductive ink that can be applied by tiny nozzles to a plastic film made of polycarbonate, for example, to produce conductor tracks in virtually any configuration and with unsurpassed adhesion. The secret formulation contains silver particles just 20 to 70 nanometers in size which, when printed, form dense packets: the larger particles build a framework into which the smaller particles fall. As a result, the conductivity of the structures is about twelve percent that of pure silver and the ink need only contain four percent by weight silver to reach this level. "Conductivity of this magnitude is enough for most applications," explains Dr. Stefan Bahnmüller, project leader and Nanotechnology Innovation Manager at Bayer MaterialScience. "The low silver content of the formulation gives us an additional competitive advantage when it comes to price."
Dr. Stefanie Eiden of Bayer Technology Services points out another advantage of the Bayer ink: "After printing, the ink is cured on the film in an oven at just 130 degrees Celsius, a temperature that really goes easy on the material." What's more, the film/conductor structure can be molded and compressed into various shapes. Together with Microdrop, an industrial inkjet manufacturer based in Norderstedt, Germany, Bayer has advanced the printing process to market-readiness. Conductor tracks for applications in the entertainment electronics industry are already printed by this method.
Because silver is high-priced and still too expensive for mass-produced RFID tags despite these good results, the Bayer researchers have devised yet another alternative: a conductive layer comprised of carbon nanotubes. "Even they are too expensive for mass production right now, but the price will drop considerably in the future," Bahnmüller predicts. His colleagues at Bayer MaterialScience are already producing and improving the carbon nanotubes, marketed under the name BayTubes®.

pati, Head of the Global RFID team at Bayer MaterialScience.

RFID tags in car tires expose product counterfeiters

Tags in car tires, which store manufacturing information and production data in order to protect against cheap imitations, have to be even tougher. The chips are vulcanized into the sidewall of a tire at over 400 bar and 180 degrees Celsius in a cocktail of aggressive oxidizing agents. And not only that: the sidewall is the place where a rubber tire is subject to the greatest deformation. When a vehicle is in motion, the substrate material of the RFID chip is stretched by up to ten percent of its original length. In freezing weather, it must not become brittle because it would otherwise puncture the tire. Together with tire manufacturers, Bayer experts are working to improve the tags. The material of choice is thermoplastic polyurethane (TPU), various films of which are available with different strength levels and melting points. Soft, low-melting grades serve to bond other plastics, such as polycarbonate, which is used to embed the RFID chips. "The polycarbonate is often too rigid and requires elastic inlays made of TPU to absorb forces that would otherwise crack the polycarbonate," explains Dr. Dirk Schultze, Head of Applications Technology, Development and Quality at Bayer's subsidiary Epurex, which entered the market for RFID substrate films three years ago with a particularly "elastic" technology. Epurex developed a thin sandwich, suitable for passports, comprising three layers of TPU, where the middle layer is punched out to perfectly accommodate the chip and the antenna is embedded between the middle and top layers. This configuration puts the least possible strain on the connection between the chip and the antenna. The company today

RFID experts: the international team of Bayer researchers, (left to right) Dr. Martin Hoppe, Dr. Daniel Rudhardt, Dr. Stefanie Eiden and Dr. Stefan Bahnmüller, is developing new materials for next-generation RFID chips.

expects to generate sales of over €1.3 million with its films in 2007. A major contributor to the success of Epurex is the demand from government agencies for more secure identification papers. For example, U.S. customs requires identification documents with an RFID chip containing biometric data, such as fingerprints.

Special film for forgery-proof IDs

With the help of TPU films from Epurex, the chip, antenna, paper and polycarbonate, PVC or PET films can be bonded in a multi-step process to form a thin sandwich (0.3 to 0.4 mm). Using heat and pressure, this inlay can be bonded between the paper and cardboard of a passport, simultaneously serving to reinforce the spine. Theoretically the process would also work with other plastics, but the TPU film has a decisive advantage: "It gets destroyed if you try to open it," Schultze explains. This, however, is not the end of the road for the innovative RFID specialists. They are continuously testing new applications for their films. Their latest coup: the developers succeeded for the first time in exposing individual points on the plastic, like photographic film, using a special diode laser. With this method, high-resolution grayscale photos can be imaged onto the film to enhance protection against passport forgery compared to a conventional paper photo. Although Dirk Schultze doesn't believe that banknotes will be made of TPU film any time soon, he does think they're feasible. But when asked to predict when women's handbags will send an SOS as soon as a lipstick needs replacing, he politely declines.

www.future-store.org
Click on RFID@Metro for further information on the topic of RFID chips.

Radio tags off the roll: the structure of an RFID tag is based on plastic films that are produced on an extruder, passed over several chill rolls (photo right) and then cut to size. Dr. Dirk Schultze (center) helped to engineer the highly flexible materials for RFID tags.