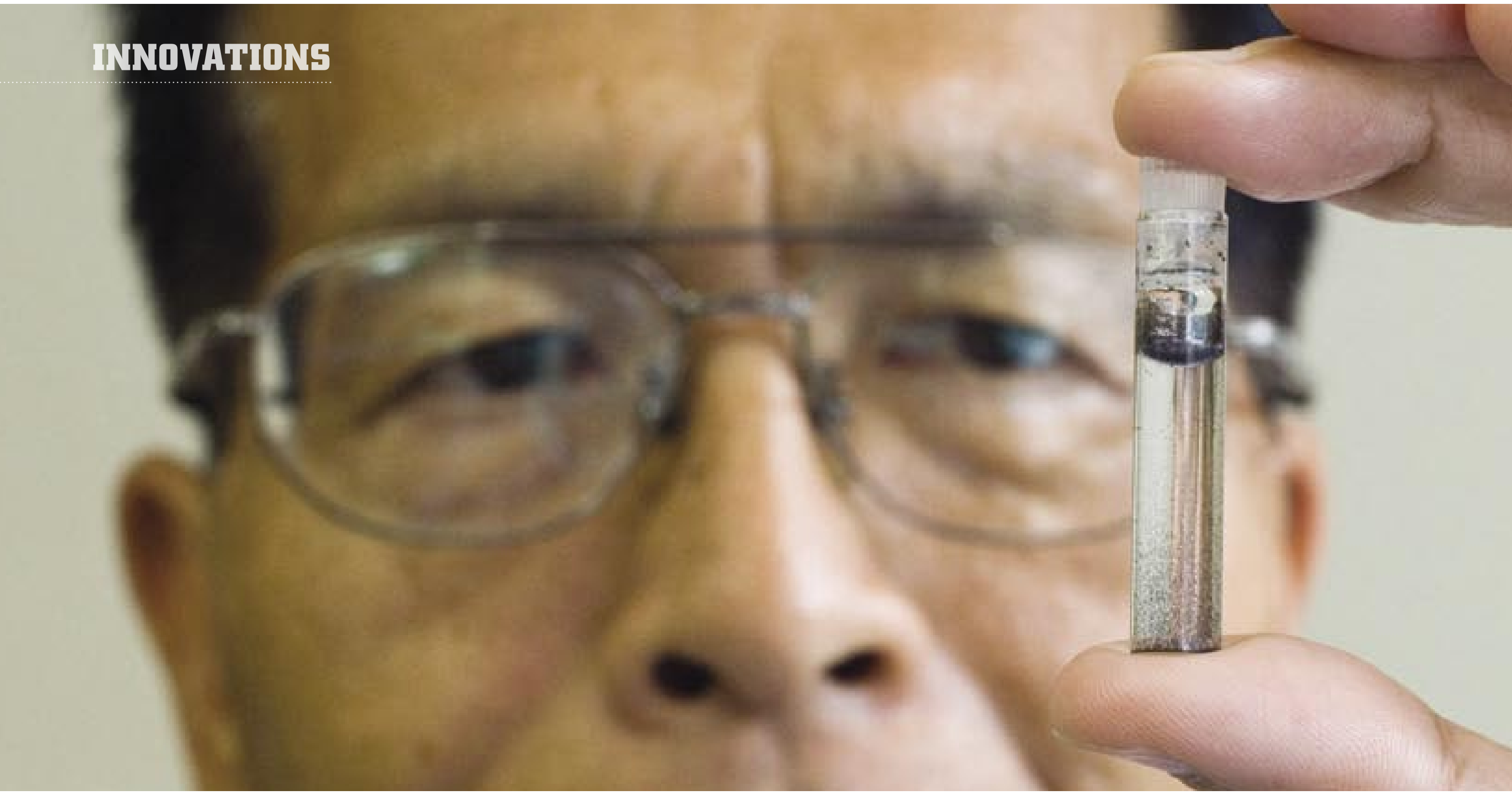


RFID Powder

KEY CONCEPTS

- Radio-frequency identification (RFID) tags, an electronic alternative to bar codes, are becoming increasingly common. They mark shipping pallets and library books, for example, and are key to remote toll-paying systems.
- Hitachi, which already produces a tiny chip for use in such tags, has announced a prototype for an almost invisible chip.
- The company intends for the new chip to be incorporated into high-value vouchers—such as gift certificates, tickets and securities—to thwart counterfeiters.

—The Editors

More than 22 million visitors attended the Expo 2005 World's Fair in Aichi, Japan. Not one got in with a bogus ticket. The passes were practically impossible to forge because each harbored a tiny RFID (radio-frequency identification) chip—just 0.4 millimeter (mm) on a side and 0.06 mm thick—that transmitted a unique identification number via radio waves to a scanner at the gates.

Now Hitachi, the maker of that chip, is aiming even smaller. Last year it announced a working version of a chip only 0.05 mm on a side and 0.005 mm thick. Almost invisible, this prototype has one sixty-fourth the area yet incorporates the same functions as the one in the Expo tickets. Its minuteness, which will allow it to be embedded in ordinary sheets of paper, heralds an era in which almost anything can be discreetly tagged and read by a scanner that it need not touch.

In Tokyo the chip's designer, Mitsuo Usami of Hitachi's Central Research Laboratory, holds up a small vial of liquid, points to a swirl of particles inside it and smiles. They glitter like stardust in the afternoon sunlight. "This is the smallest chip of its kind in the world," he enthuses.

The Allure of the Small

Even before this size breakthrough, RFID tags (combining chips with antennas) were being touted as a revolutionary force in the supply chain. Despite costing more than bar codes, they are seen as a more efficient alternative to those familiar line patterns; a good RFID tag does not have to be scanned manually or oriented in a certain way to be readable. Major retailers such as Wal-Mart have introduced them in recent years with an eye to saving billions on inventory and labor costs. Other growing applications include electronic toll collection, public transit passes and passports; some people have even implanted the devices in their hands to allow easy access to home and computer.

But Hitachi's main goal for the new chip is use in anticounterfeiting technology. It could be embedded in high-value vouchers such as securities, concert tickets, gift certificates and cash. Usami and his colleagues believe that the smaller the chip, the more easily it can be seamlessly buried. "As sophisticated high-tech gear becomes cheaper and cheaper, it's easier to forge things made out of paper," Usami says. "Even

TIM HORNYAK

MITSUO USAMI of Hitachi shows off a vial containing thousands of the minuscule chips (*black specks*) he invented for use in radio-frequency identification (RFID) tags.

Radio-frequency identification tags label all kinds of inventoried goods and speed commuters through toll plazas. Now tiny RFID components are being developed with a rather different aim: thwarting counterfeiters **By Tim Hornyak**

though e-money is getting popular, bank notes are still very convenient."

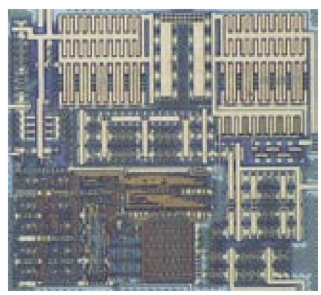
Like other "passive" RFID chips, the one that was used at the Aichi Expo—known as the μ-Chip (pronounced "mew chip")—operates simply and requires no batteries or power supply. When it is embedded in an item along with an attached antenna (usually a filamentlike strip), it will respond to 2.45-gigahertz microwaves from a scanner by reflecting back a unique 128-bit ID number stored in its read-only memory (ROM). The scanner then checks the number against a database—which can be anywhere in the world—to immediately authenticate the item containing the chip.

Hitachi says the μ-Chip can be used to identify "trillions of trillions" of objects, because the 128-bit architecture affords an almost infinite number of digit combinations: 10^{38}. Each unique ID number is meaningless in itself, but when matched to a database entry it will call up whatever information the user has assigned to the chip. The smaller chip under development, officially called the Powder LSI chip, also stores a 128-bit identifier. ("LSI" stands for "large-scale integrated.")

Both the μ-Chip and the powder version grew out of a vision Usami, a veteran circuit engineer, sketched out after seeing an ad for the "i-mode" cell phones that Japanese telecom giant NTT introduced in 1999. These pioneering devices allowed users to access the Internet through a handset. Usami imagined a network of tiny RFID chips and servers: RFID chips would be attached to small devices and would essentially be empty except for a unique identity number that would be conveyed to a server. Having received a valid number, the server would provide the various functions a person might want to use. The notion is similar to "cloud computing" of today, in which applications that would otherwise be stored on an individual's computer reside elsewhere and are accessed through the Internet.

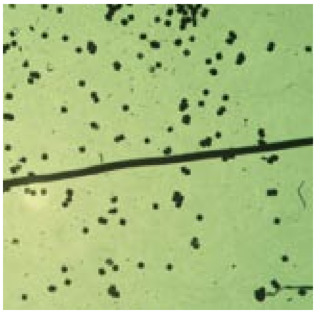
Usami therefore turned his attention to creating an RFID chip that would be small enough to incorporate in anything. To be marketable, it also had to be inexpensive, simple and secure. He already knew something about developing diminutive chips. Earlier in the 1990s he had designed an ultrathin telephone card that was embedded with a microchip instead of having a magnetic strip, because the chip could provide security through encryption. The embedded chip was 4 mm on a side and 0.25 mm thick.

But Usami wanted to go smaller. First he had to figure out the minimum functions a chip would need to perform. He turned to colleague Kazuo Takagi, a computer security specialist at Hitachi's Systems Development Laboratory, for help. After the two discussed the problem at length, Usami decided that using just a 128-bit ID number would enable him to keep the design very simple yet still provide a very high number



POWDER CHIP surface is shown at roughly 800 times its true size.

COURTESY OF HITACHI LTD. CENTRAL RESEARCH LABORATORY



MINUTENESS of powder chips is evident in a micrograph showing a single hair from a Japanese woman surrounded by silicon bits the size of those chips.

of digit combinations. At the same time, the approach would ensure security because the information stored in the read-only memory would be unchangeable. He also stripped out all inessentials, leaving behind, aside from the ROM, a simplified radio-frequency circuit (to interact with the antenna), a rectifying circuit (to manage current flow) and a clock circuit (to synchronize the chip's activities and coordinate them with a scanner).

Ironically, Usami's biggest challenge in realizing a shrunken microchip was nontechnical. Then, as now, conventional chip development favored ever increasing memory and functionality, so Usami was swimming against the current with his stripped-down design. Hitachi's business division was deeply opposed, wanting the chip to incorporate rewritable encryption features. Without the division's financial support, his idea would never get off the drawing board.

But an unexpected white knight intervened. Shojiro Asai, then general manager of Hitachi's R&D Group, recognized the project's potential. He said he would fund prototype production of what became the μ-Chip (named for the Greek letter in the micron symbol, μm) on the condition that Usami recover all costs. Offering the chip for counterfeit protection did the trick. Its success at the Aichi Expo in 2005 convinced Hitachi to allow Usami to keep shrinking his creation.

Making Powder

Powder chips have essentially the same components as the μ-Chip, but these are snuggled into a smaller space. One key to the extra miniaturization was employing what is called 90-nanometer silicon-on-insulator (SOI) technology, a method of advanced chipmaking pioneered by IBM and now being used by others. SOI makes processors that perform better and consume less power than those produced by conventional methods because it isolates transistors with an insulator. The insulator both reduces the absorption of electrical energy into the surrounding medium—boosting signal strength—and keeps the transistors separate. Separation in this way prevents interference between transistors and allows them to be packed more closely together, which makes it possible for chip size to shrink.

Electron beam lithography helped as well. This technology wields a focused beam of electrons to produce a unique wiring pattern that represents a chip's individual ID number in a compact area. Electron beam lithography lays down circuit patterns more slowly than photolithography does, because it generates patterns serially instead of in parallel. Hitachi, though, developed a method that produces powder chips 60 times faster than the μ-Chip is made.

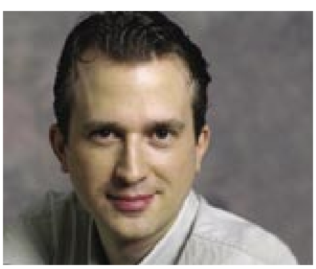
RFID tags typically consist of chips and external antennas, and the same is true of the μ-Chip. For certain applications, though, μ-Chips and the powder form will need an internal antenna, one embedded right on the chip. But those reduce how far away a scanner can be. The maximum scanning distance for Hitachi's commercial μ-Chips with external antennas is currently 30 cm (about a foot), and the range of the powder prototype is the same—short but acceptable for most applications involving money or securities. The company is doing research aimed at extending the range of both external and internal antennas. The application will determine the range required: money or securities would require only a few millimeters or a centimeter, whereas package sorting would require a range of about one meter. The firm is also working on "anticollision" technology that would allow the simultaneous reading of multiple chips, such as when goods sit together on a store shelf or are jumbled in a shopping basket.

[SCENARIO]

A Likely Use for Powder Chips

Hitachi's bare-bones, powder RFID chip could be embedded in money, securities, tickets and such to thwart counterfeiters. Imagine a clerk

[THE AUTHOR]



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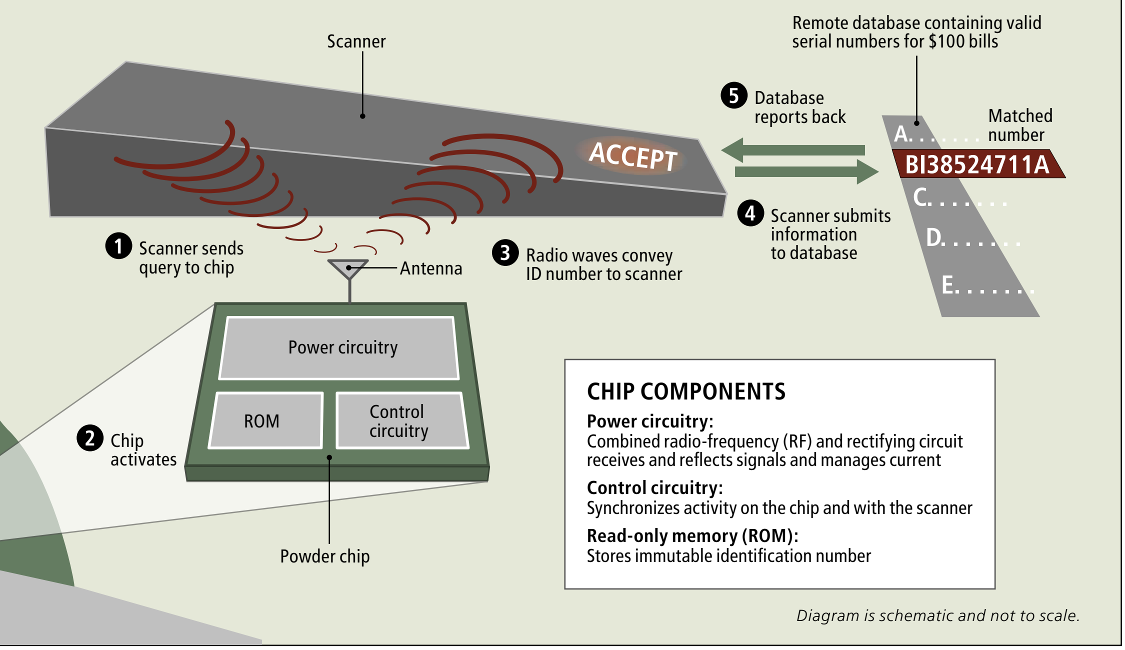
GREG McCARTNEY *Prime Light Photo* (*Hornyak*); COURTESY OF HITACHI LTD. CENTRAL RESEARCH LABORATORY (*powder chips*) wanting to verify that a $100 bill is real. The clerk would pass the bill near a scanner. The scanner would detect the unique ID number stored in the chip (*1–3*) and send it to a database of bill numbers (*4*), which would indicate whether the money was legitimate (*5*).



RELATIVE SIZES

A standard chip in a "passive" RFID tag (one that has no battery) affixed to a library book might measure one to two millimeters on a side (like the cross section of lead in an unsharpened number 2 pencil). Hitachi's *μ*-Chip is less than a quarter that size in area, and the powder chip is some 64 times as tiny as the *μ*-Chip.

Magnification

Chip in library tag
Actual size:
1 mm × 1 mm × 0.18 mm

***μ*-Chip**
Actual size:
0.4 mm × 0.4 mm × 0.06 mm

Powder chip
Actual size:
0.05 mm × 0.05 mm × 0.005 mm

For visibility, the representations above are about 10 times actual size.

Little Brother?

Although putting chips into money is a logical application for minute RFID chips, chipped cash could exacerbate privacy concerns surrounding the use of RFID technology. It raises the specter, for instance, of an unscrupulous person scanning the contents of another's wallet from far away. Choosing tags requiring a short-range scanner, such as the readers in ATM machines, would limit such intrusion, however. And the criminal would also need access to the right server and database for the information to have any meaning.

The infinitesimal size of the Powder LSI chips under development also helps to conjure sci-fi scenarios. Could police, say, spray the powder on a crowd of rioters and then trace them afterward through security scanners distributed along roads or in public transit? Hitachi asserts that it is infeasible to deploy the chips by sprinkling them—they must be attached to antennas to function. And, Usami says, "many civic groups have developed guidelines to protect privacy with RFID. A fundamental guideline for this technology is that it not be used surreptitiously."

The *Guardian* newspaper in London, though, has already documented a case in which the supermarket chain Tesco tested selling Gillette razor blades packaged with RFID tags able to trigger a hidden camera if theft were attempted. Although privacy advocates may recognize the shipping and supply benefits of RFID, they want to be able to remove or turn off the tags once an item has been purchased.

Usami thinks the potential benefits of RFID outweigh the risks. "For example, embedding sidewalk tiles or crosswalks with RFID tags could help autonavigation systems in wheelchairs. This is important especially in Japan, which has an aging society." Even as paper use diminishes, tiny RFID chips will come in handy in situations where size, access and complexity are constraining factors. As an example, Hitachi envisions using the powder chips to reduce the time it takes to install and verify complex electrical wiring systems at companies, factories and other facilities. Cables and terminals would be equipped with chips so workers could quickly check them against a database and the related schematics instead of relying on lengthy visual inspections.

But if privacy advocates have concerns about chips becoming harder and harder to find, that particular fear is real: Usami says the miniaturizing trend will continue. ■

MELISSA THOMAS

MORE TO EXPLORE

RFID: A Key to Automating Everything. Roy Want in *Scientific American,* Vol. 290, No. 1, pages 56–65; January 2004.

Hitachi Achieves 0.05-mm Square Super Micro RFID Tag, "Further Size Reductions in Mind." Available at **http://techon.nikkeibp.co.jp/english/NEWS_EN/20070220/127959/**

RFID Journal: **www.rfidjournal.com**