3M Technology Paves the Way for Low-Cost Radio Frequency Identification

Dr. Paul Baude and his development team in 3M's Electronics and Inorganics Technology Center are moving contrary to conventional wisdom in the electronics industry, which defines state of the art as ever-faster and smaller silicon chips.

The 3M team has chosen to pursue a course where advantages accrue by replacing silicon with organic semiconductors to produce transistor circuits that may be larger and slower, but may ultimately provide dramatic cost reduction and the ability to use glass or flexible substrates in certain applications. While still in a preliminary development stage, they're making good progress.

"We're pursuing a number of application ideas sparked by the availability of inexpensive integrated circuits and the ability to fabricate these circuits on nontraditional substrates," Baude said. Several technical breakthroughs and advances have put them on track to produce a low-cost, radio-frequency identification (RFID) chip, such as those used in workplace passes that employees swipe across an electronic reader to record their arrival or departure.

In a paper published today in Applied Physics Letters, the group presents the details of an organic-semiconductor-based radio frequency (RF) transponder tag operating at carrier frequencies of 125kHz and well over 1 MHz. A RFID reader remotely powers the thin film circuitry, which, in turn, generates a clock signal. That clock signal is then detected by the reader circuitry. This breakthrough is, in essence, a 1-bit tag and the group already is well on its way to completing transponders that provide higher information content.

3M's project would make these RFID chips cost effectively, so that they could be attached to individual items, such as clothing, commuter transportation tickets or baggage. "Bar codes used today for inventory tracking require line-of-sight communication, but RFID systems don't," Baude added. "So, the tag could be underneath, behind or located inside a package, for example."

"Bigger, slower and less capital intensive doesn't sound like a paradigm shift, but that's precisely what organic circuitry is for the electronics industry," said Dr. Jerry McAllister, executive director, 3M Research and Development, Corporate Technology, and Safety, Security and Protection Services Business. "It tantalizes the product innovator with the potential for new products and new markets."

Other potential uses include vapor or fluid sensors to warn against safety hazards and even a blinking, talking greeting card. "In some cases, these integrated circuit products could be disposable," Baude maintains.

Baude also talks about 3M's capabilities to provide dispersed electronics integrated on a substrate: "You need to put a single transistor here, a little circuitry over there and another circuit elsewhere." An example of this is a display where you have an array of pixels and a transistor at each pixel. That's a task now handled by amorphous silicon. "We could manufacture a low-cost, active-matrix backplane for a variety of display formats and platforms," he notes.

Like other scientists pursuing plastic-based circuitry, the 3M team is working with pentacene, which Baude describes as "a small molecule ... a linear arrangement of five fused benzene rings, which happens to be one of the best organic semiconductors." Other companies working in this emerging segment include Philips, Xerox, Seimens and Infineon.

With silicon, there's a motivating factor to go to smaller sizes. Transistors become faster and you can pack more circuitry into a given area, resulting in an overall performance improvement. However, while silicon technology is very powerful, it is expensive, requires a large investment in capital equipment and necessitates high temperatures during fabrication. That's one of the reasons why it's difficult to integrate silicon onto glass or flexible substrates. 3M's team has demonstrated organic semiconductor-based circuitry on glass, plastic and even paper substrates.

That opens up a market at the other end of the cost-performance continuum where, Baude says, "Our vision is an identification circuit sold competitively and in huge volumes."

Scientists measure transistors by gate length, which is the distance from one side of the transistor to the other. Advanced silicon chips operate with transistors having approximately 0.1-micron gate lengths, while 3M's organic-transistor gate lengths approach 20 microns. Their transistors are significantly larger, but the fabrication cost is substantially less.

3M's approach is based on proprietary technologies in the areas of shadow-mask patterning, circuit architecture, and surface chemistry that give the company a leadership position in organic-semiconductor research and development. The three-year-old program has produced numerous patent applications in these areas.

Perhaps their major advance is "doing what nobody else has done ... eliminating the need for a diode stage to convert alternating current to direct," according to Baude. That's important, he adds, because "Diodes are relatively straightforward to create in silicon chips, but difficult to incorporate into organic-semiconductor-based circuitry, and they limit operation in higher-frequency ranges." This 'ac powering' scheme allows the circuits to work with higher radio frequencies.

In the project's first two years, 3M created circuits powered at 125 kHz, a common RFID frequency, but without the capability to communicate with remote reader circuitry. Then, within the past nine months, the 3M team demonstrated circuitry capable of modulating the 125 kHz RF carrier enough to be detected by the remote reader. Using its alternate-current-powering scheme, the group was able to show adequate modulation with carrier frequencies as high as 8 MHz.

"That's a significant advancement over state of the art," Baude says, and it put his team on track to create an organic chip operating at 13.56MHz -- another standard frequency for RFID.

A shadow-mask-patterning process that's new to the world is another key to 3M's program. It's a polyamide film, instead of metal. The 3M process uses a laser to punch or ablate microscopic holes (20 microns) through the polyamide material. The arrangement of holes replicates an artwork image created on glass and, in turn, provides a stencil-like patterning tool to define the various layers that are deposited sequentially to form the integrated transistors. This is potentially important for pentacene, because "Pentacene-based devices tend to degrade, or even fail, when exposed to common wet-chemical-based patterning processes. The shadow mask patterning scheme is 'dry' and eliminates that disadvantage," Baude says.

The shadow-mask process also offers an environmental benefit, because the process eliminates a solvent wash to remove excess material, a common step in other patterning approaches.

The laser technique comes from 3M's microreplication technology, which also produces microscopic surface changes to materials used in products ranging from brighter reflective materials for safety to microabrasives for polishing surgical steel.

The 3M shadow-mask-patterning process also eliminates production difficulties with other patterning approaches. 3M's surface chemistry contributes to the process by speeding up the movement of electricity through the organic chips. The surface treatment results in a noteworthy fivefold increase in mobility, from about 1 cm2/V-sec to around 5 cm2/V-sec. While the mobility is much lower than silicon mobilities, it is more than sufficient for display backplane and low-end RFID circuitry, Baude maintains.

3M's research team continues to make significant advances in process and application development for commercializing organic-semiconductor-based integrated circuitry. The story will continue to unfold over the next several years as organic electronics evolves and 3M defines its role in this exciting technology area.

About 3M

3M is a $16 billion diversified technology company with leading positions in consumer and office; display and graphics; electronics and telecommunications; health care; industrial; safety, security and protection services; transportation and other businesses. Headquartered in St. Paul, Minnesota, the company has operations in more than 60 countries and serves customers in nearly 200 countries. 3M is one of the 30 stocks that make up the Dow Jones Industrial Average and also is a component of the Standard & Poor's 500 Index. For more information about 3M, go to www.3M.com/profile/pressbox/index.jhtml.

Note to Editors: The 2 in cm2/V-sec should be superscript.

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