

The New Age of Printed Electronics

Introduction

From smart identification labels to flexible display monitors and moving images integrated into books and magazines, the rapidly evolving world of printed electronics promises to provide additional functionality to existing products and introduce a host of next-generation applications, revolutionizing almost every major industry. In the past 40 years the electronics industry has grown from a respectable \$29 billion to an impressive \$1,150 billion. With the arrival of printed electronics, projections indicate it will become the single largest industry.¹

Background

The electronics industry has always strived to invent better, more robust products. Once components could be made of a single material, silicon, they could be interconnected to form a complete circuit, marking the invention in 1958 of the integrated circuit ("IC").²

Today, the industry is utilizing the same concept to take electronics to the next level – and the smaller the better. Still on the cusp of growth, printed electronics is widely understood as thin film silicon or inorganic or organic semiconductors that can be used to form Thin Film Transistor Circuits (TFTCs) with the purpose of replacing the traditional silicon chip. The ultimate objective is to make many different components, such as batteries, displays, sensors, etc., at the same time and out of the same material and techniques, hence saving cost and improving reliability.³

The Industry

Today, over 50 companies, large and small, are using a combination of conductive materials to create printed circuitry and electronic components that will be printed in one continuous process.

The principle elements driving market demand for next-generation printed applications include new laws and mandates demanding increased product security and traceability, and the growing importance of environment-friendly, disposable products and packaging, not to mention the desire to decrease prices for end-consumers.

Another significant contribution to the push towards printed electronics is the persisting problems with silicon. Although the volume and performance of silicon-based components is on the increase, development costs remain high. Establishing a new silicon fabrication plant costs between \$2-\$3 billion; the price of the cheapest silicon chip has been \$0.05-\$0.10 for the past 20 years, and despite developments in computers-on-chips, external power, resistors, and capacitors are still required, so costs

remain high due to the interconnects and multiple production processes.⁴

By the time the printed electronics industry is mature, the costs of manufacturing will be substantially lower and the final product will only be a fraction of today's semiconductors. The most popular alternative today is flexible organic semiconductors, based on small molecule conductive plastics. They can be used to create both a functional transistor and more functional and complex circuits. They can be printed in a number of printing processes including inkjet, lithography, gravure, and other components such as batteries, sensors, and displays can be produced using similar printing materials and techniques, such as roll-to-roll continuous printing. In addition to the benefits of low material and manufacturing costs, printed electronics also enable circuits to be placed on a variety of substrates, such as paper, plastic, film, and foils.

The printed electronics revolution is still in the early stages. Organic semi-conductors cannot yet perform nearly as well as silicon.

They do, however, offer the possibility of using electronics in applications where the use of silicon would previously have not been possible, due to its size and rigidity. For example, the entire smart labels industry demands electronic capability within a very small area, i.e., electronic sensor labels for perishable consumer goods such as food and drugs. Likewise, organic semiconductors are appropriate in cases where flexible circuits are needed on certain computer displays, signage, and novelty items, where flexibility is key.

Printed RFID Antennas

In the last decade, a number of industries have adopted both passive (un-powered) and active (powered) radio frequency identification (RFID) technologies, which enable non-line-of-sight identification and multiple reading capabilities. RFID labels and tags can fulfill a number of functions, such as asset and product tracking (crate, pallet, container, equipment, item), works-in-progress tracking, product handshaking, logistics management, access control, payments, and movement and theft alarms. Though RFID technologies are not new, events in 2003 propelled them into the limelight, as large organizations such as Wal-Mart (US), Tesco (UK), Target (US), Metro Group (Ger.) and the US Department of Defense (DoD) have mandated that their top 100 suppliers begin implementing RFID labels on pallets and crates during 2005.



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Today, the antennas that go into RFID tags are twisted or etched into a pattern using strands of copper, aluminum, or another conductive metal. But some companies are experimenting with printing the pattern for the antennas with ink made with conductive metals, especially silver.

Printed RFID antennas that are put on packaging and other materials using conductive inks are beginning to emerge, promising high volume, lower-cost antennas, and signaling a convergence of printing and electronics in the RFID space.

A number of companies are working in the area, including Graphic Solutions, International and Precisia. Printing the antenna directly onto the packaging or a product enables a flexible and economic manufacturing process, as well as the potential to customize an antenna to an individual product.

Conclusion

Although there is much hype surrounding printed electronics, the revolution is clearly under way. With first generation applications already being utilized in a variety of products on the market, it will not be long before TFTCs and Organic LEDs on packaging is a reality. In addition to Power Paper's batteries and battery-assisted RFID label, other printed electronics products include printed conductors (ASK France), Dow Printed Display

Solutions, moving color displays, and KSW's electrochromic displays.

Currently in the labs are such futuristic applications as Aardex's plastic pill bottles that can report if you have just taken one tablet or two; OrganicID claims that it is developing a complete organic process that includes all circuit components at performances necessary to build a fully standardized, fully printable RFID tag. A number of companies are developing non-emissive displays, such as E-Ink, Gyroicon and SiPix, some of which are printable.

Although organic ICs may not be available for several years, the wide array of complementary printable electronic products and technologies have already sprung a host of new applications. According to ABI Research analyst Josh Laurito, "At the end of the decade, the electronics industry is going to look quite different. With the radically lower cost of printed IC fabs, it's a chance for a lot of companies that haven't been involved in semiconductors to make the jump."

^{1, 2} Texas Instruments on-line archive

³ "Printed Electronics Opportunities," ABI Research, Nov. 2004

⁴ "Printed Electronics White Paper," IDTechEx, Dec. 2004

Can Machines Understand Us?

Speech is the simplest and most natural way of communication. It is used, of course, for communication among people, but can also become the basis for human-machine interaction. Speech-based communication with machines will be easy, natural and intuitive for all users and will enable a wider and easier adoption of machine/computer applications.

Technological progress should enable the development of machines that understand human language, and not require people to learn awkward "machine language". This type of tedious man-machine interaction mainly includes pressing buttons, navigating through complicated menus, and reading laborious user manuals.

When technology enables machines to understand human language, a real revolution will occur in the way we interact with our environment. People will be able to talk to their PC and other home appliances. They will be able to operate their mobile and fixed phones and perform basic car operations by using only a speech interface.

Service centers will be replaced by automatic systems that will recognize speech and respond accordingly, and voice mail systems that currently require the user to push buttons will be truly "hands free" – operated by voice with higher functionality

than is known today.

Our home will become a "smart home", controlled by a computer or a robot to which we communicate using natural, day to day, speech. The technology will become so common-place that we will use it throughout the day whenever the need to communicate with a machine arises.

We could ask our VCR to "Please record the news on channel 100 at nine o'clock" or we could talk to our mobile phone and say "Please call Mr. Smith at his office". We could interact with our voicemail systems and ask "Did I get any new messages from home this morning?"

In the afternoon, we will be able to phone up an automatic ticket ordering system and say: "I would like three tickets to the Harry Potter movie for the nine o'clock show". In the office, we will be able to dictate letters to our PC with no need for a keyboard or mouse, and on our way back from work we could call our "smart home" system and ask "Please turn on the hot water, record the football match, and turn on the news and the house lights in 30 minutes".



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CEO

“Human understanding” machines could also enable the improvement of man-to-man communication. For example, the technology could enable communication between people that speak a different language. The system would recognize what a person said in his/her own language, translate it to the other person’s language, and vice versa. In the early stages, this would be possible via complex systems, but in time it could evolve to standard “carry on” gadgets that enable us to communicate with anyone in the world, using our own language.

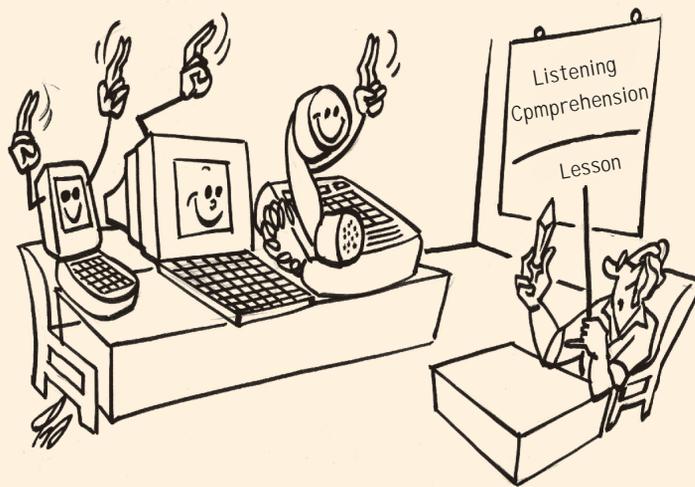
For the last couple of decades there has been substantial research and development of speech recognition and understanding in universities, research labs and industry. The results have lead to an initial penetration of speech recognition technology into our lives. However, there is still a big gap between the current capabilities of this technology, and the real human capability of fully natural speech communication. Science does not yet have a full understanding of the processes in the human brain that are performed during the speech operation – a common action which is done by each one of us many times a day. This lack of knowledge, along with the huge complexity of the issue, explains the current difficulties in developing a system that will actually function as a human being, and our inability to imitate human mechanisms that are used daily and frequently.

For this reason, speech recognition today focuses on more defined and specific areas where the complexity of the issue is diminished in comparison to the open field of natural human-to-human unconstrained communication. In the past, there have been attempts to deploy systems that used speech recognition in a very unconstrained manner, using open-ended dialogues such as “How can I help you?” which implies that the system is able to understand everything the user says, on every subject. However, the technology wasn’t mature enough for such a generic and open implementation, making the use of such systems unreliable and therefore unsuccessful. Today’s systems focus around operating a specific machine or understanding speech in a more closed and pre-defined context. This way, a specific domain can be defined and more fully covered. A useable solution can thus be obtained by using finite vocabulary combined with pre-selected combinations of possible sentences, thereby considerably constraining the linguistic choices.

In order to be able to develop a fully automatic system that can understand human speech that is general and not domain-specific, a major technological breakthrough is required, which will allow a leap in the usage of this technology. This “leap” will

have a crucial effect on our daily lives, which will be reflected not only by convenience, simplicity and automation.

If we broaden our discussion beyond speech recognition into other areas such as digitized character and object recognition, robotics, speaker identification, machine-produced speech, etc., we can see that we can expand the use of these technologies into artificial intelligence (AI) systems, whose level will only improve with time. For example, we can look at robotics, which is now used for relatively simple tasks in industry. As technology progresses, robots will be able to do more complex actions and play an ever more important role in more areas of our lives.



This technological progress will bring mankind to some very important dilemmas such as:

1. If robots do more of our jobs, will the work-week be substantially decreased?
2. If we do much less work, this will greatly affect our free time habits. Will, in fact, most of our time be “non-work” time, and what are the implications of this?
3. If and when technology progress enables building human parts, will we be able to replace defective human parts with artificial ones?
4. If such progress is attained, will the average life-time of mankind dramatically increase? How can we handle the implications of this?

In conclusion, enabling machines with natural human capabilities is a very complex issue, which is very far from being resolved. However, throughout the world much effort is being invested in all of the component areas of artificial intelligence. As research and development progresses, mankind will have to face new, non technical problems that relate to the effect these developments have on our lives.