Determining the Obstacles and Potential for RFID Printing

A Senior Project

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Abstract

Radio frequency identification (RFID) is currently a thriving technology with many applications and enormous potential. When RFID technology is mixed with printing technology, new opportunities begin to surface. Recently it has become possible to print an entire RFID chip and antenna, but this technology is still impractical for real world application. This study investigates and discovers that size is a major obstacle for printed RFID technology. In addition, this study determines there are several areas of potential applications for printed RFID technology including barcode replacement, advanced inventory management, and smart cards. These applications can become reality when printing technology meets the practicality needs of printed RFID technology.

Introduction of Purpose of Study

Radio frequency identification, or commonly known as RFID, is a method of communicating data between an electronic tag and a reader with radio waves. This technology is generally used for tracking and identification purposes. RFID technology dates back to World War II where it was used to identify aircrafts as “friend or foe” by the United Kingdom. Its next major appearance was in the early 1970’s when a man named Mario Cardullo created several new applications for the RFID technology. The applications in his patent covered several aspects within the fields of transportation, banking, security, and medicine. Some examples of his idea include automatic toll systems, electronic credit cards, automatic gates, and patient history for hospital settings. Mario Cardullo’s ideas sparked the beginning of the technology that is prevalent in the lives of many people today.

Currently some of the major areas for RFID are in public transportation, inventory tracking, logistics, animal identification, and asset management. This technology is so efficient and useful that a few companies have decided to make a requirement for its suppliers to participate in an RFID system. For example, as of January 2005 Wal-Mart, a large retailer, made it a requirement for their 100 top suppliers to comply with the Wal-Mart RFID system. For the suppliers of Wal-Mart this means they must place an electronic tag on pallets and cases of their products. When receiving goods, this electronic tag is then read by Wal-Mart, which strongly aids in the tracking of inventory. It is evident that RFID is a thriving technology with several major applications, but it has

only just begun to fill its potential. A major method for future innovation in RFID technology is the addition of printing.

With the combination of printing and RFID, the new opportunities start to surface. Putting electronic tag directly onto a product gives way to ideas such as smart labels, smart cards, and smart packaging. All of these ideas rely on RFID technology to create a system to replace barcodes, the current and popular identification system. The purpose of this study is to investigate these potential applications for printable RFID and how they can streamline everyday life processes. Presently, the actual printing portion of RFID technology is printing the antenna, which extends the radio waves transmitted and reduces cost by eliminating the previous method of etched antenna. Once the antenna is printed, the chip or electronic tag is attached. Currently the market for RFID printing is small due to the expense of the process and materials. Even with the reduction in cost with a printed antenna, the process currently cost approximately 10 cents (Romano). For it to be cost effective for newer applications, the price of each tag needs to lower to five cents (Romano). The price of the chip itself can cost upwards of eights cents, which makes up a large majority of the cost (Romano). The solution to the cost issue can be found in printing. It is possible that the chip could be printed as well and the antenna, but this poses a great challenge for printing technology.

Once the necessary technology for RFID printing exists, there will be an explosion of opportunities in new markets. This study will answer the following question: To merge Radio Frequency Identification (RFID) and printing technologies, what advancements must be made? Once this technology is established, what are the major markets printable RFID can be applied to?

Literature Review

Overview of RFID Technology

Radio frequency identification (RFID) tags are an identification and logging technology that currently uses a microprocessor to stores information and antenna to transmit information (RFID). The other portion of this technology is the RFID reader, which interrogates, or obtains information form, the tag (RFID). This interrogation from the RFID reader is done by transmitting a radio frequency signal to communicate with the tag (RFID). Using passive backscatter, the reflection of waves back from the direction they came, the tag communicates back to a receiver on the RFID reader (RFID). The information received by the RFID reader is then sent to a computer to translate and log the information (RFID). The process can be confusing because the name "RFID reader" implies the tool can only read, when in reality it also has the ability to write when sending the interrogation signal (RFID). The communication between the tag, reader, and computer is the basic process of RFID technology. This communication is displayed in figure 1.

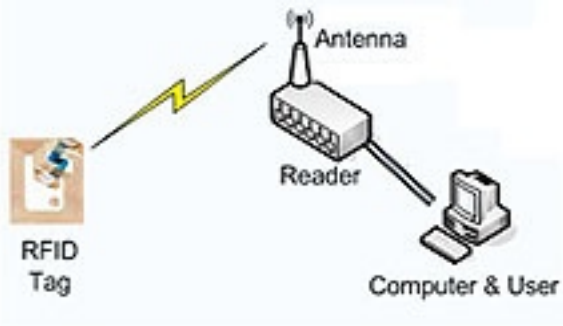

Figure 1

Communication between RFID tag, reader and computer (Shwaitzberg)

There are two basic types of RFID tags separated by the use of a power source; one type has a power source and the other type does not (RFID). The first and most simple is a passive tag, which has no power source (RFID). The only time a passive tag has power is when it is communicating and being supplied power by an RFID reader

(RFID). Because a passive tag has no power source of its own, its effective range between the tag and reader it is limited to a maximum distance of three meters or approximately ten feet (RFID).

The second most basic form of an RFID tag is an active tag that is self-powered. With the addition of their own power source, active tags have the ability to have an effective transmission range of 100 meters (approximately 330 feet) or more (RFID). Because an active tag has its own power source, the tag needs much less of a signal from an RFID reader in order to transmit back causing the significant increase in transmission range (RFID). With its own power, passive tags also do not have to rely on the reader for an initiation of transmission (RFID). Communication can be initiated by the RFID reader or the active tag, where as a passive tag can only communicate when the RFID reader initiates the communication (RFID). Another advantage to an active tag when compared to a passive tag is its ability to self-log data in a greater amount of memory (RFID). When considering mass data collection active tags are superior to passive tags (RFID). In order for a group of passive tags to transmit an accurate reading it is required that all passive tags are read simultaneously. In contrast, a grouping of passive tags have the ability to be read at different times and still get an accurate reading (RFID). This means all the active tags do not need to be in range of the RFID reader at the same time.

Taking cost into consideration, the passive tag has fewer parts and much more affordable and because there is no power source the tag has no lifetime limit (Ruth, RFID). But when there is a demand for sophisticated functionality, the active tags offer

much more to the RFID system (RFID). When comparing the two basic types of RFID tags, they both have advantages (RFID).

How can RFID tags be printed?

The current theory on printing an RFID tag is base on carbon nanotube technology (Williams). Carbon nanotubes are “large molecules of pure carbon that are long and thin and shaped like tubes, about 1-3 nanometers (1 nm = 1 billionth of a meter) in diameter, and hundreds to thousands of nanometers long” (Carbon Nanotubes). These carbon nanotubes are infused with ink and printed on using injet technology (Williams). Inkjet is a printing process where very fine ink droplets are sprayed in a controlled manner on to a substrate or printing surface (Injet Definitions). With the inkjet printing process and carbon nanotube infused ink combined, there is the ability to print thin film transistors, which are a key element in RFID tags (Williams). These printable transistors can be printed on paper or plastic (Williams). This new carbon nanotube ink used to print the transistors was created in the Rice Lab of James Tour in Korea (McGlaun). Now with the joint effort of Rice University and Sunchon National University in Korea, they are printing RFID tags on a roll to roll process (McGlaun). The

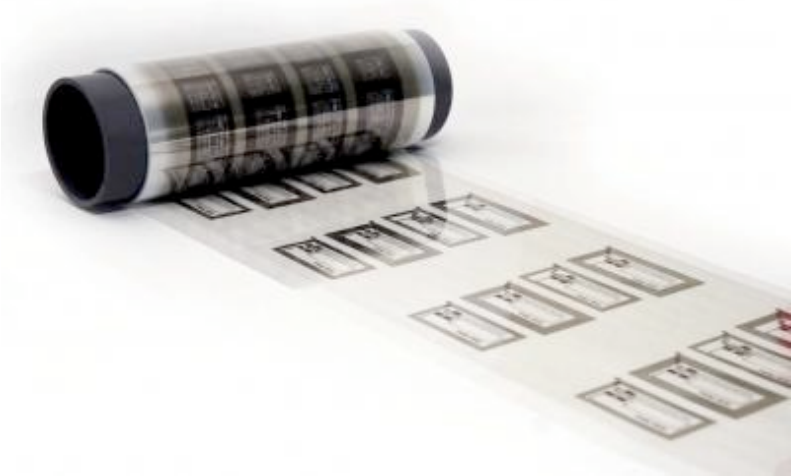

Figure 2

Printed RFID material on a roll (Ruth)

roll-to-roll technique simply means to create the tags on a roll of plastic. The printed RFID roll can be seen in figure 2.

Is printing RFID tags possible?

In order for RFID tags to be printed commercially there are still several obstacles to navigate (Ruth). One major setback is the size of the tag. Current print technology does not offer fine enough print of the correct material for RFID tags, so the tag must be printed larger in order to function. To be practical the size of the tag must be one-third its current size, which is about the size of a standard barcode (Ruth). Another major issue is the transmission range is too short (Ruth). The tags that are currently being printed are passive and have to be very close to the reader to work (Ruth). Developers from Suchon National University have a goal to reach a working range of one meter for the printed passive RFID tag (Ruth). The third large obstacle is the amount of data the tag can store (McGlaun). The current tags hold only one bit of information, but Cho of Suchon National University is working on 16-bit tags that would be practical for real world use (McGlaun). 16-bit tags will be able to provide scientifically information to the RFID reader.

Despite these bumps in the path to commercialization, experts agree printable RFID technology will be part of the future. Frank Romano, professor emeritus at RIT, in an article for AmericanPrinter notes, “This market is moving aggressively; we will see the confluence of printing as we know it and RFID, as well as other electronics, by 2015 or perhaps earlier” (Romano). Cho is also confident in printable RFID technology for the

future and states “we are going to a society where RFID is as key player” (Ruth). Cho expects to see printable RFID technology mature in five years (Ruth).

Research Methods

Radio frequency identification has made tremendous progress since it was created. By adding new print technology to the existing RFID technology, there will be many new opportunities for real world applications. To investigate the progress of RFID technology and the real world applications for printable RFID, I performed elite and specialized interviews and referred to case studies to provide accurate information that pertains to these topics. My research for this project was split into two sections, each with its own research method.

In the first portion of research I carried out a series of elite and specialized interviews to find precisely what advancements in print technology need to be made for the commercialization of printable RFID technology. According to Dr. Harvey Levenson, department head of Graphic Communication at California Polytechnic State University (CPSU), when conducting elite and specialized interview it is crucial that the questioning is structured in an opened-ended manner to get informative answers. It is important to avoid questions that may be asked of a general consumer when interviewing an expert. Levenson also explains the interviewer should strive to become part of a discussion and avoid a set list of pre-made questions.

I performed three elite and specialized interviews with experts in RFID technology. I will find these interviewees in various departments on the campus CPSU such as the Graphic Communication and the Engineering departments. The first two interviewees, both from the Graphic Communication department: Malcolm Keif and Brian Lawler. The last interview was Larry Rinzel of Industrial and Manufacturing

Engineering Department. These professors all have valuable knowledge in various areas of printable RFID technology. Once the interviewees had been contacted and an interview time and date was scheduled I performed an effective interview. With the information gathered, I analyzed the content and provided appropriate information for a successful report on advancements that need to be made in print technology to accommodate RFID technology.

For next portion of the research in this project I used the historical and descriptive research method to examine the potential applications for printable RFID. Levenson defines historical research as “an attempt to establish fact and arrive at a conclusion concerning past events” (Levenson). Levenson explains that the historical information gathered by the researcher helps clarify what will happen in the future. Levenson describes descriptive research as studies “designed to determine the nature of a situation as it exists at the time of the study” (Levenson). Levenson lists seven types of studies that fall under descriptive research: case studies, surveys, developmental studies, follow-up studies, documentary analysis, trend analysis, and correlation studies.

To use the historical and descriptive research method I used resources such as the Robert E. Kennedy Library and the Internet. Once I defined the specific research I needed to explore I used appropriate keywords to search various search engines. Articles I used for section of research include “Start the Presses”, “Breakthrough on 1-Cent RFID Tag”, “Barcode pioneer talks about RFID” and “Printed Electronics RFID Tags: From Promise to Reality”. Once I identified historical data and descriptive

research from these articles, I analyzed the content to find viable information that will help me determine the potential applications for printable RFID.

Results

Advancements Needed for Printed RFID

Before any exciting applications for printed RFID technology are determined, it is imperative that the capabilities to actually print the RFID tag exist. As noted in chapter two, RFID tags have successfully been printed but for various reasons they are not practical for use. These various reasons are what stand between printed RFID tags and their real world application. The following section of research reports a series of elite and specialized interviews that will further investigate what exactly these various reasons for impracticality are.

What advancements need to be made for printed RFID technology to reach success? The response to this question by each interviewee is reported in the following research.

Brian P. Lawler

"You would have to purify the inks to where they do not have little oxygen bubbles in them and you would have to come up with a way to put them down with enough precision and with essentially 100 percent effectiveness and print successfully every single time. That is the secret."

"Putting down a trace of printable conductive ink thick enough to conduct electricity flawlessly remains one of the big challenges."

In these statements Professor Lawler is referring to how printed RFID tags may be possible but they are not consistent. Issue such as, oxygen bubbles in the ink, the precision of the printing device, and the thickness of the ink are all variable that contribute to the inconsistency of the RFID tag printing process. He believes once these issues can be resolved with 100 percent effectiveness then printing RFID tags become closer to success.

“The question comes down to, can you make a trace small enough and 100 percent effective every time”?

Professor Lawler’s thoughts here were considering the practical size of the printed RFID tag. It may be possible to print a RFID tag but it will be much to large for any practical use. As the entire printed RFID tag is scaled down in size, issue and complications mentioned earlier become an increasing threat. The challenge is to produce a printed RFID tag at a small enough size for practical application with out jeopardizing its 100 percent effectiveness.

“Current RFID’s are at lease an inch square. If they were that size but maybe twice as big, they worked, they didn’t use rare metal and you could print them, you’ve got it made.”

In this statement, Professor Lawler is first considering the maximum size for a practical printed RFID tag. He compares the practical size of a printed RFID tag to an estimated square inch, the size of a current non-printed RFID tag. He projects the maximum practical size to be two square inches. He then states that the printed RFID

tag must work at this size, or in other words meet the standard he set of 100 percent effectiveness.

Professor Lawler's next point is the issue of rare metal. In another portion of the interview he state how current non-printed RFID tags often use rare and irreplaceable metals for their production. He considers this to be a waste and impractical, and therefore provides another obstacle for printed RFID tags. There are replacement materials available, such carbon nanotubes as mentioned in chapter 2, but these replacements do not function for RFID technology as well as the rare metals.

"If you want to put one (printed RFID tag) on every Snickers bar you're going to have to show me how to print in at the same time you're print the word snickers. Until they can do that, it's too expensive, it's just too costly."

In this statement Professor Lawler makes, he is referring to the practicality of the production process. He uses the packaging process of Snickers bar as an example. With all previously mentioned complications with printing RFID tags aside, Lawler considers the point in the production process that would be practical to put an RFID tag on packaging. He predicts that printed RFID tags on packaging will only be practical if the RFID tag is printed at the same time as the rest of the packaging is printed. This presents a great challenge for the current methods of packaging printing. Any other method or additional production would cause too much cost to the manufacture to be practical.

Malcolm Keif

“With our current imaging technology that we have in printing, we would have to print a chip (RFID tag) that is roughly 8 ½’’ x 11’’ to be able to store enough information to be EPCglobal compliant.”

In this statement, Professor Keif is describing the smallest size of a printed RFID tag in terms of EPCglobal compliance. EPCglobal discribles themselves as “leading the development of industry-driven standards for the Electronic Product Code™ (EPC) to support the use of Radio Frequency Identification (RFID) in today's fast-moving, information rich, trading networks.” The relevant information for Professor Keif’s point is that EPCglobal sets the standard for the capacity of information need in an RFID tag. Because there is a standard set for this capacity, Professor Keif assumes that this is a practical amount of capacity for printed RFID tags. To achieve this practical amount of information capacity, a printed RFID chip must be printed at a very large size, 8 ½’’ x 11’’. The smaller the tag becomes, the amount capacity for information becomes more limited. In order to meet the practical information capacity amount set by EPCglobal, the size of the printed RFID tag must be unpractical.

“The obstacle is how do we get finer imaging quality”.

Professor Keif’s next point plays of his previous statement concerning EPCglobal standards. To meet practical standards of information capacity and a practical size that is much smaller than 8 ½’’ x 11’’, there is a need for finer image quality. With finer image quality, or smaller printed lines, the printed RFID tag can be scaled down to a practical

size for use and still keep the same amount of information capacity. Finer image quality faces printing technology with many complications and produces a challenge for the printing a RFID tag.

Larry Rinzel

"Right now, antennas take up most of the space."

"The complexity of the decision making within the tag (printed RFID tag) is the greatest obstacles"

In these statements, Professor Rinzel explains how large antennas are in relation to the complex chip in a printed RFID tag. The antenna is the simpler portion of the printed RFID tag to be produced in contrast to the complexity of the chip. Unfortunately the chip is very small compared to the antenna, leaving the antenna to account for a large majority of the printed RFID tag. Because the chip has such high complexity it needs to be printed larger, causing the entire RFID tag must be scaled up. The up scaling of the chip creates an up scaling of the antenna and produces a very large printed RFID tag. This printed up scaled RFID tag would become too large for real world application. To correct this issue, there would have to be improvements made in print technology that would allow the chip to be printed at a smaller size.

"Paper, even though it looks smooth, its not, it has a bunch of hills and valleys".

What Professor Rinzel is referring to in this statement is the substrate, or the material printed on. In the likely case that RFID tags will need to be printed on paper in order to serve a practical use, there will be some complications. As Professor Rinzel describes, when paper is analyzed closely it has a rather uneven surface. The uneven surface would distort the printed lines and render them ineffective. Paper as a substrate provides a great challenge for the printing of RFID tags.

Summary of Interviews

Although the interviewees had different outlooks on the advancement needs for the success of printed RFID, there are some commonalties in their opinions. One common key issue preventing the practical use of printed RFID tags is the size. In all the interviews, issues of size or issues relating to size were discussed. Among the interviewees there is a general understanding that the greatest obstacle for practical real world use is that the current technology is unable to produce a printed RFID tag at a practical size. Once the technology meets the demand of the practical size of a printed RFID tag, real world application will become much closer to reality.

Potential applications for printed RFID

When looking to the future, how can this fanatic printable RFID technology be put to use? In the following paragraphs, several articles containing this topic have been analyzed and compared in an effort to uncover real applications for printed RFID.

The first article, “Breakthrough On 1-Cent RFID Tag” comes from RFID Journal. This article discusses the possibility of “ordinary bags of potato chips and boxes of

cereal will have RFID microchips and antennas printed on them". With this application of printed RFID, there are endless advantages and opportunities. To place focus on this particular application, consider the perspective of a grocery store. If RFID tags are able to be placed on bags and boxes of items sold in the store, the entire grocery store experience and process could be changed. For example, instead of having an employee of the grocery store scan items for purchase, an RFID reader could be put in that employee's place. So as a customer is leaving the grocery store with a shopping cart full of items the he or she wishes to purchase, the cart could be place in the RFID reader for a simulations scan. This scan would produce a list of the items in the shopping cart and their prices and make that list available for purchase to the customer. This would eliminate the cost of the employee to the store and accelerate the grocery store checkout process for the customer with a simultaneous scan.

This article also mentions the RFID tag would be placed on the products "during the commercial printing process." During the commercial print process is the most convenient and efficient time in the production process to produce the RFID tag. This eliminates the need for any costly outsourcing for the placement of RFID tags on the product through it's manufacturing. The printed RFID tag will be conveniently on the packaging when it comes from the commercial printing process.

The article then states the similarity of printing RFID tags to printing traditional barcodes during the commercial print process. Barcodes and printed RFID tags in this application essential serve the same purpose. Although it is a radical idea, when considering their similarities RFID tags could potentially replace barcodes. This idea suggest that every product that currently is printed with a barcode on its packaging

could be printed with a RFID tag. This application would go beyond the grocery store and into any routine, process or procedure that involved barcode and be improved by a RFID tag. A different article from DailyTech titled “Cheap Printed RFID Tags May Replace Barcodes” describes a similar concept. The article explains, “all we might need to do is walk out the door with our carts and our total would be computed automatically.” In other words when purchasing items at a store a customer could leave with what he or she wants to purchase and the total would automatically be charge to that customer. This idea is rather excessive when considering our current technology but offers a deep look into the possibilities. The idea of a barcode replacement is an extreme idea but generates everlasting opportunities.

Other areas of application for printed RFID technology with barcode replacement are discussed in an article called “Digitally Printed RFID tags Revolutionize Consumer Markets” from MyPrintResource.com. This article discusses some additional advantages RFID tags have over barcodes, “RFIDs can store much more information, such as product origination and delivery points, expiration dates for perishables, and more.” With this information recorded digitally on the product’s RFID tag, there could be much more information about the product and it would eliminate the need for unattractive text on the packaging of the product. All the necessary information for the product could be stored in the RFID tag.

This article from MyPrintResourse.com also brings up several other major applications, such as inventory management. Inventory management and traditional RFID have parented together in the past. As discussed in chapter one, Wal-mart is an example of a company that has utilized RFID for their inventory management. With Wal-

marts applications of traditional RFID it is only practical and affordable to attach an RFID tag to each pallet of products. Inexpensive printed RFID can make a difference by being printed on each of the individual products instead of just one for the entire pallet of products. The article for MyPrintResource.com explains this process, “In large shipping operations and warehouse facilities, these readers can be mounted on a frame, and when a pallet or truck of RFID-tagged items passes through, the readers can identify multiple tags simultaneously and store the information in an inventory database.” Because each item has its own printed RFID tag, the process would be significantly more cost effective and the inventory could be more accurate.

Different applications for printed RFID tags are described in another article form RFID Journal called “Start the Presses”. This article suggests the idea of cards with printed RFID tags on them. The article explains the ideas, “(printed RFID) cards would speed lines by eliminating swiping that’s required for magnetic-stripe cards, and do away with constant cleaning and maintenance required on hardware.” In other words, printed RFID would eliminate the need for traditional magnetic strips on these cards and improve the efficiency of their use. The article provides a list of potential areas of applications for these printed RFID cards including airports, libraries, and hospitals. MyPrintedResource.com mentions some other similar and more specific applications. These applications include smart cards, library book labels, passports and laundry tags. The efficiency of the process surrounding these applications would greatly benefit from printed RFID.

Summary of Articles

Of the article reviewed and discussed in this historical and descriptive research, all have a general agreement that printed RFID will be part of the future. These articles all provide a look into what to possibilities are for the real world application of this technology. These articles all provide evidence for magnitude of potential for the application of printed RFID tags.

Conclusion

From the research provided in the chapter 4, the future has become clearer for printed RFID tags. Although the future cannot be certain, with expert opinions and historical and descriptive research, the future can have a well-formulated prediction. Due the thrilling potential of printed RFID tags this research hunted to uncover the advancements printed RFID tags were need and applications where printed RFID tags capabilities would fit.

Through the elite and specialized interview method, this study found that there are several obstacles blocking the success of printed RFID tags. The greatest issue, common among all elite opinions, was the current technology prints RFID tags too large for a practical real world application.

Using the historical and descriptive research method, this research proved there are numerous applications for printed RFID. The ideas discussed only reached shallow into the real world applications for printed RFID tags. The potential for this technology is deep, vast, and waiting to be discovered.

Now the issue has become one of time. When will the technological demand for RFID tags align with the demand of its practical real world applications? Until this time, printed RFID tags will be left rumbling with potential energy.

Works Cited

"Bar Code Pioneer Talks About RFID." *RFID Journal*. 22 July 2002. Web. 09 Mar. 2011. <http://www.rfidjournal.com/article/purchase/173>.

"Break Through on 1-Cent RFID Tag." *RFID Journal*. 2 Dec. 2002. Web. 09 Mar. 2011. <http://www.rfidjournal.com/article/purchase/172>.

"Carbon Nanotubes." *A to Z Nanotechnology*. Web. 04 Feb. 2011. <http://www.azonano.com/Details.asp?ArticleID=1381>.

Clinkunbroomer, Jeanette. "Digitally Printed RFID Tags Revolutionize Consumer Markets." *MyPrintResource.com*. 31 Mar. 2009. Web. 02 June 2011. <http://www.myprintresource.com/article/10265568>.

"EPCglobal." *GS1*. Web. 03 June 2011. <http://www.gs1.org/epcglobal>.

"Inkjet Definition." *The Tech Terms Computer Dictionary*. Web. 04 Feb. 2011. <http://www.techterms.com/definition/inkjet>.

Levenson, Harvey. *Some Idea about Doing Research in Graphic Communication*. Print.

McGlaun, Shane. "Cheap Printed RFID Tags May Replace Barcodes." *DailyTech*. 19 Mar. 2010. Web. 25 Feb. 2011. <http://www.dailytech.com/Cheap Printed RFID Tags May Replace Barcodes/article17930.htm>.

Romano, Frank. "The Truth about RFID Printing." *American Printer Magazine*. 1 June 2007. Web. 04 Feb. 2011. <http://americanprinter.com/binding-finishing/printing_truth_rfid_printing/>.

"RFID" *Lavalink*. June 2004. Web. 4 Feb. 2011. <http://www.lavalink.com/fileadmin/

newsletters/link_06.04.pdf>.

Ruth, David. "Nano-based RFID Tags Could Replace Bar Codes." *EurekAlert*. 18 Mar. 2010. Web. 04 Feb. 2011. <http://www.eurekalert.org/pub_releases/2010-03/ru-nrt031810.php>.

"Start the Presses." *RFID Journal*. Web. 09 Mar. 2011. <http://www.rfidjournal.com/article/purchase/1051>.

Williams, Mike. "Nano-based RFID Tag, You're It." *Rice University*. 18 Mar. 2010. Web. 25 Feb. 2011. <http://www.media.rice.edu/media/NewsBot.asp?MODE=VIEW&ID=13899>.