Enabling Active Packaging

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ABSTRACT

Product commoditization has put a lot of pressure on companies to come up with new ideas to increase their margins. One area is providing functionality to the packaging, making it active, interactive and/or smart. Printable inks can help break the commodity cycle by adding another dimension from aesthetics to functionality. Some existing and future opportunities for printable inks in areas including lamination displacement, active packaging and intelligent packaging are presented. Technical and engineering challenges ahead are also discussed.

INTRODUCTION

At a time when the chemical industry is facing skyrocketing raw materials prices, companies rely more than ever on their capabilities to innovate and bring new products to market. The need to offer differentiated products to capture higher margins is a trend that can be seen across many industries including packaging. From boxes with eye-catching features to radio frequency identification (RFID) enabled containers, there is a range of products and technologies that are revitalizing the packaging industry. Although multiple paths are available to create such valued added, coatings and printable inks have the advantage of being a common ground between older products and more recent offerings. However, traditional inks and coatings are typically not sufficient to create new value propositions for the customers. Therefore, there is a need for special materials to help bring ideas to life.

DISCUSSION

Inks and coatings are known to be part of the value chain at converters. They usually offer flexibility, simplicity of use with existing process equipment, and a lower cost. They can be applied locally, i.e. only where needed, and reduce the need for multiple substrates. In many cases printable solutions simplify packaging operations compared to other processes that would involve lamination, transfer, vacuum deposition or other off-line manufacturing steps. An example of the superiority of printable solutions can be found in the field of lamination displacement. Via use of coatings or printable inks, it is possible to provide high gloss, scratch resistance, transparency, and flexibility while imparting barrier properties for oxygen, moisture or carbon dioxide through the package. Applications of such technology include retort pouches, plastic containers such as those containing soda, beer or dressing, as well as more advanced fields like organic light emitting diodes. The basic principle behind the use of inks and coatings in this case is to reduce the number of layers in laminate structures. Simple coatings such as crosslinked polyvinylalcohol (PVA) with a dry film weight of about 0.5 grams per square meter have proven to significantly reduce oxygen transmission through a polyethylene terephtalate (PET). However, crosslinked PVA's barrier properties undergo significant changes when the level of relative humidity increases. In fact, at about 80% relative humidity and 23°C, the oxygen transmission rate through the coated film shows no advantage over an uncoated film. More recent developments involving proprietary chemistry have closed this gap and provide an even barrier performance across the broadest range of humidity and temperatures.
Another area of intense activity is the field of antimicrobial coatings. Leveraging the fear of *e*-coli and other bacteria, consumer electronics and telecom product manufacturers have realized that they could exploit the marketing angle of such technologies. For instance, the advertisement for a new cell phone revolves around the benefits of the new silver based antimicrobial coating as key differentiated feature to set the device apart from the competition. With the avian flu becoming a growing concern, the next logical step on the technical roadmap is antiviral coatings for which a significant amount of research and development is already taking place often with the support of government funding. Active materials have also been instrumental in the development of applications related to food packaging and more specifically with the idea of extending the life of perishable goods and/or indicating freshness. Oxygen scavengers, ethylene absorbers, oxygen, thermochromic and carbon dioxide indicators are essential materials supporting these new applications.

One of latest developments in intelligent (or smart) packaging is the use of RFID. Although the basic principles on which RFID technology relies on are relatively old [1], the implementation of RFID in the supply chain has seen an exponential growth over the past few years. This growth is expected to continue as the technology moves down to item level tagging. In 2006, market analysts foresee the sale of 1.3 billion tags for a total RFID market value including systems and services of $2.77 billion [2]. By 2010 the market value is even expected to exceed $12 billion. One of the inherent advantages of the new technology versus the historical bar code is the fact that the reader does not require direct line-of-sight to the tag. Figure 1 presents a schematic view of an RFID system and its components. The main frequencies at which the RFID chip operates for supply chain applications include "high frequency" (HF) at 13.56MHz and the "ultra high frequency" (UHF) ranging from 868 to 930MHz.

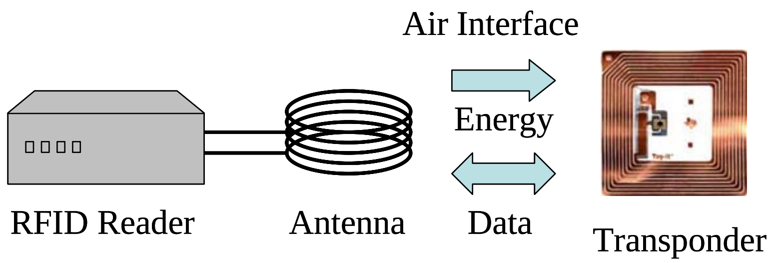

Figure 1. Essential components of an RFID system

Historically, HF tags have been considered more robust due to their better performance in proximity or contact with metals and liquids. For this reason, HF has been able to penetrate the pharmaceutical packaging market more quickly. This trend however may reverse in the coming years as new technologies for UHF tags have emerged such as near-field coupling to solve the primary shortcomings of the technology [3]. Because of their lower cost and smaller form factor, UHF tags are expected to be the leading technology for item level tagging. Over the years, inks developed for RFID have helped reduce the cost of production of tags primarily by offering more affordable ways of producing antennas. Whether it is etch resists, silver conductors, or seed layers for metal plating, inks for RFID have helped manufacturers lower the cost of antennas from above 5 cents for a UHF antenna produced via the original photolithographic etching process down to sub-one cent. One example of such developments providing a new value proposition is the use of high speed printing processes such as flexography in combination with water based silver conductive inks. Such ink is particularly suitable for paper and corrugated substrates and provides fast drying characteristics with a high level of conductivity. Still, there are many challenges to overcome in order to reach Wal-Mart's sub-one cent cost target for item level tagging. Further in the horizon, the emerging field of printable electronics and displays represents a great opportunity to leverage the RFID material developments to capture a share of a market estimated at $300 billion by 2025. High resolution conductive, dielectric and semiconductor inks as well as specific printing methods will be critical to deliver the right level of performance and manufacturability.

CONCLUSION

Innovation in inks and coatings is a key enabler to the development of active and intelligent packaging. Whether it involves the use of nanotechnology, different chemistries to provide barrier properties or differentiated appearance, or conductive inks for RFID, printable solutions are key tools to grow.

ACKNOWLEDGMENTS

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References

1. Landt, J. , "Shrouds of Time, the history of RFID", AIM Inc. publication (2001), Pittsburgh, Pensylvania.
2. Das, R., and Harrop, P., "RFID forecasts, players & opportunities 2006 – 2016", IDTechEx, Cambridge, UK.
3. Desmons, D., "UHF Gen. 2 for item level tagging", proceedings from the 2006 RFID World Meeting, Dallas, Texas.

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Enabling Active Packaging

A materials approach

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OUTLINE

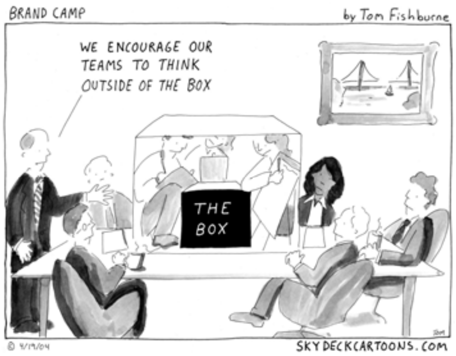
- Introduction
- Inks beyond color
- Examples of functional inks
- Smart Packages / RFID
- Challenges ahead
- Conclusion

… and Questions!

Introduction

- Breaking the commodity cycle
- More than just color
- Potential opportunities:
  - ☑ Lamination Displacement
  - ☑ Active Packaging
  - ☑ Smart Packaging

Need special materials to bring ideas to life



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Why Coatings or Printable Solutions?

- Value added at the converter
- More flexibility
- Lower cost
- Locally applied (only where needed)
- Reduce the need for multiple substrates
- Simplify packaging operations

Need special materials to bring ideas to life

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Lamination Displacement

- High Gloss
- Scratch Resistance
- Transparent barrier layers
  - ☑ Oxygen
  - ☑ CO_2
  - ☑ Moisture
- Flexibility

OLEDs

Plastic bottles

Retort pouches

Reducing the numbers of layers in laminates

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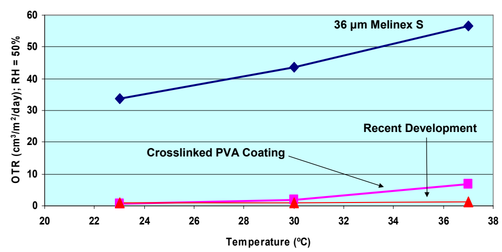
Oxygen Transmission v. Temperature
Coatings on Melinex S (ca. 0.5 gsm)



(Coatings Applied at about 0.5 gsm Dry Film Weight)

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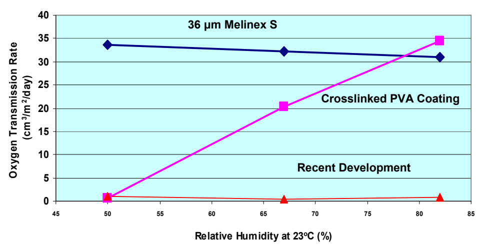
Oxygen Transmission v. Relative Humidiity
Coatings on Melinex S (ca. 0.5 gsm)



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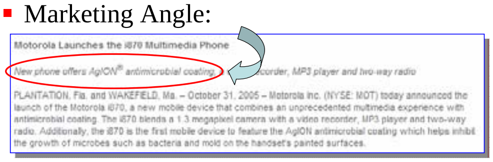
Antimicrobial Coatings

- Growing fear of *e*-coli and other bacteria
- Marketing Angle:


Motorola Launches the i870 Multimedia Phone

New phone offers AgION® antimicrobial coating, [illegible]corder, MP3 player and two-way radio

PLANTATION, Fla. and WAKEFIELD, Ma. – October 31, 2005 – Motorola Inc. (NYSE: MOT) today announced the launch of the Motorola i870, a new mobile device that combines an unprecedented multimedia experience with antimicrobial coating. The i870 blends a 1.3 megapixel camera with a video recorder, MP3 player and two-way radio. Additionally, the i870 is the first mobile device to feature the AgION antimicrobial coating which helps inhibit the growth of microbes such as bacteria and mold on the handset's painted surfaces.

- Technology: Silver (nano)particles & composites

Next step – Antiviral coatings

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Other Active Packaging Examples

- Oxygen Scavengers
  - ☑ Most common mechanisms include:
    - Oxidation of iron (triggered by moisture)
    - UV initiated autoxidation of C=C
    - Common anti oxidants (Vitamins C& E)
- Ethylene Absorbers
  - ☑ Slowing the ripening of fruits & vegetables
- Oxygen & CO_2 Indicators

Active materials are

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CO_2 Indicator Coatings

- **Technology**
  - ☑ pH dependent color change of indicator dyes
  - ☑ Ammonium salt key part of the mechanism

$$[Dye^{-}\ R_4N^{+}.\ nH2O]$$

$$+CO_2 \downarrow \uparrow -CO_2$$

$$[Dye\text{-}H.\ (n\text{-}1\ H_2O)\ R_4N^{+}\ HCO_3^{-}]$$

Mills et al., Anal. Chem. **1992**, *64*, 1383-1389

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Thermochromic Indicators

- Effect adds value
- Active & Smart Packaging
  - ☑ Temperature Indicator only
  - ☑ Time-Temperature Indicators
- Applications
- Technology
  - ☑ Encapsulated leuco dye

Interactive Thermochromic snowflakes

From brand differentiation to safety features

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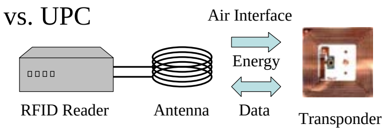
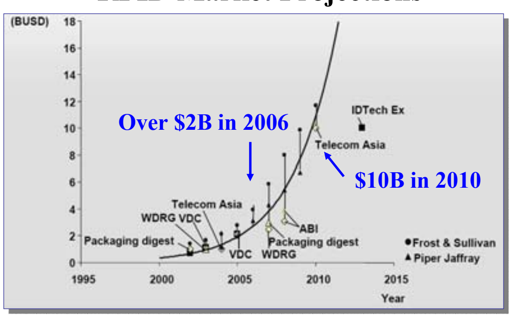
RFID – Next level of Smart Packaging

- History
- Basic principles & frequencies
- More than a bar code
- EPC vs. UPC



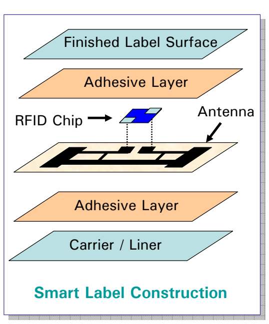
Non line-of-sight technology

RFID Market Projections



Estimates compiled from: VDC, IdTechEx, TelecomAsia, Packaging Digest, Frost & Sullivan, WDRG

Smart Labels



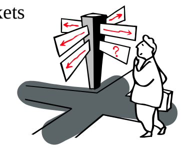
➔ **HF (13.56MHz)**
- Shorter read range (< 1m)
- 256 bit of user accessible memory
- Inductively coupled

➔ **UHF (860-960MHz)**
- Longer read range possible (> 3m)
- 96 bit of user accessible memory
- Capacitively coupled (far field)

EPC Class	*Description*
Class 0	"Read Only" Passive Tags
Class 1	WORM Passive Tags
Class 2	Rewritable Passive Tags
Class 3	Semi-Passive Tags
Class 4	Active Tags

Item level tagging

- LF (125 kHz)
- HF (13.56MHz)
  - ☑ Garments, books, pharmaceuticals, tickets
  - ☑ Good performance on liquids
- UHF (860-960MHz):
  - ☑ Lower cost
  - ☑ New global EPC Gen.2 standard
  - ☑ Near Field UHF



UHF works for item, case and pallet tagging

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RFID Tags in the Supply Chain

Palette / Box level tagging

Truck / Container level tagging

Item level tagging

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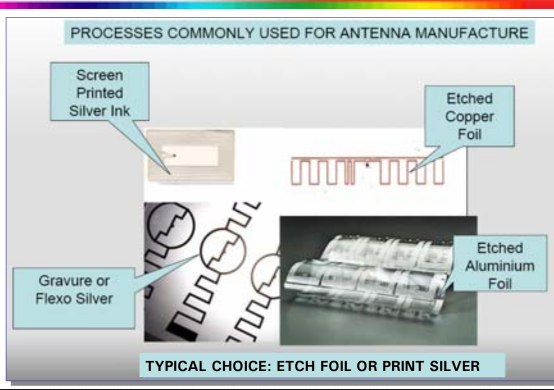

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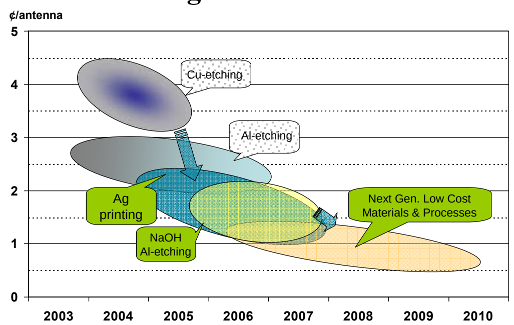
Reducing the cost of antennas



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Getting to the 5 ¢ RFID tag

- UHF vs. HF
- Where the 5 cents go:
  - ☑ RFID chip ($$$) / strap ($$$$)
  - ☑ Antenna ($)
  - ☑ Adhesive & Substrate ($)
- Conversion cost
  - ☑ Printing, Strap or Chip attach

Dilemma: Use Inlay or Print antennas?

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Water Based Flexographic Ink

- Fast drying Ag ink
- Successful printing on:
  - ☑ Paper
  - ☑ Cardboard
  - ☑ Plastic substrates
- Print Speed > 100 m/min.

A good option for printing RFID antennas

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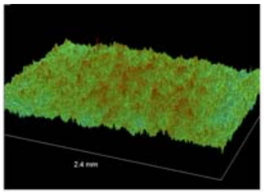
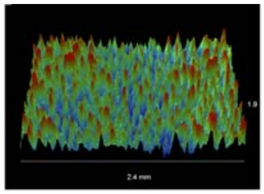
Print quality / Optical Profilometry



Sun water based flexo silver ink printed on 60lb coated paper at over 150 fpm



Competitive water based flexo silver product printed on glossy label stock

Ink composition & Printing process matter

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RFID Tag Performance

Sample	*Substrate*	*Sheet Resistance (Ω / □)*	*Read Distance (m)**
Commercial Alien "I" tag	PET	N/A	4
W/B flexo Ag 50 m/min. - 20 BCM	60lb Coated paper	0.13 (0.01)	4
W/B flexo Ag 50 m/min. - 20 BCM	60lb uncoated paper	0.21 (0.01)	4
W/B flexo Ag 50 m/min. - 20 BCM	Coated Cardboard	0.15 (0.02)	4
W/B flexo Ag 50 m/min. - 20 BCM	Thermal Paper	0.45 (0.05)	4

**Read distance measured with Alien Lepton straps using linear polarized antennas & ALR9800*

No difference based on read distance

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Sample	*Substrate*	*Sheet Resistance (Ω / □)*	*Link Margin (db)**
Commercial Alien "I" tag	PET	N/A	13.8 (2.6)
W/B flexo Ag 50 m/min. - 20 BCM	60lb Coated paper	0.13 (0.01)	16.0 (0)
W/B flexo Ag 50 m/min. - 20 BCM	Thermal Paper	0.45 (0.05)	8.8 (1.4)
W/B flexo Ag 50 m/min. - 20 BCM	Coated Cardboard	0.15 (0.02)	12.5 (4.0)
W/B flexo Ag 50 m/min. - 20 BCM	Primed Uncoated Cardboard	0.26 (0.01)	11 (3.5)
W/B flexo Ag 50 m/min. - 16 BCM	Melinex 359	0.30 (0.01)	13.5 (3.5)

**Link margin measured at 3ft with Alien Lepton straps using circular polarized antennas & ALR9800*

Similar or better link margins achievable

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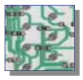
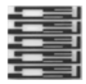
Conductive inks beyond RFID


PCB


Displays


Solar Cells


Diagnostic


Heaters


Capacitors


Smart Cards


Passports

Broad range of applications acessible

Some Challenges Ahead

- Chip/strap attach speed vs. press capability
- Integration into current operations
- Capturing the value
- Intellectual Property
- From RFID to Printable Electronics
- High resolution printing

Growing opportunities for "electronic" inks

Conclusion

- Innovation in Inks & Coatings
- Nanotechnology
- Active & Smart Packaging
- Printing RFID antennas
- Trends in RFID
- Printable solutions

Inks & Coatings are key tools to grow…

Thank You

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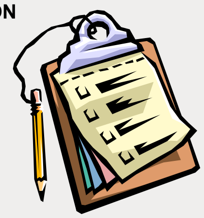

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