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Comparison of Technologies for Card Printing Applications

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Abstract

The printing of identity cards differs significantly from other printing technologies in that the substrate is well-defined, generally PVC or polycarbonate, and relatively small, typically 2.125" x 3.370." Because the substrate is non-porous, the dyes and pigments used must penetrate into the substrate or be held in place by an adhesive or binder that adheres to the surface or penetrates into it. The simplest printing system capable of producing a printed plastic card is dye sublimation. In this process dyes penetrate into the substrate producing a durable dye-based image. Requirements for edge-to-edge printing as well as the need to print technology cards that may not be perfectly flat have led to retransfer dye sub printing systems, which uses an intermediate transfer ribbon. Finally, electrophotographic and inkjet systems are also present in the market. This presentation will provide a technological assessment comparing advantages and disadvantages of various printing systems, allowing the user to identify the preferred technology for different applications.

Introduction

Traditionally, a combination of offset and screen printing has been used to print plastic cards [1]. Offset printing with UV cured inks is used where fine detail is required, and screen printing with thermoplastic inks is used when holograms or other functional elements must be permanently affixed to the surface of the card. UV inks have greater latitude when printing on plastic since they cure when exposed to UV light, while thermoplastic inks require drying. These two printing systems are frequently used in combination to produce the desired results.

Applications for plastic card printing range from local membership cards to credit cards to driver's licenses to national IDs, and the security needs differ accordingly. For a local membership card a simple printed plastic card may be sufficient, while for national IDs much more sophisticated security schemes are required [2].

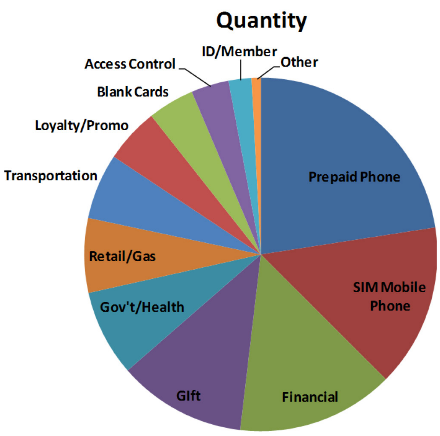

Figure 1. Market share for different applications. Replacement of traditional plastic cards with smart cards (ICMA, 2015.)

As with other printing applications, digital technology is encroaching into the traditional printing of plastic cards. In its simplest form, digital technology is used to personalize a preprinted plastic card with an account number or other identifying information.

For credit cards, digital printing technology allows consumers to select a specific design or even to have the card produced with their own photograph on it. For IDs and licenses digital technology is required since almost all of these cards are customized with the user's photo.

Many cards are produced each year, with a worldwide total of over 30 billion cards. This total amounts to more than five cards per person for everyone on the planet. Overall market is growing slowly at 1.5% per year. However, this slow growth masks a significant change, with the market transitioning from traditional cards (-6.8% CAGR) to smart cards (14.6% CAGR). Smart cards are plastic cards with built-in microprocessors, used typically for electronic processes such as financial transactions and personal identification. These cards are becoming more prevalent as applications take advantage of this technology to add features and improve security.

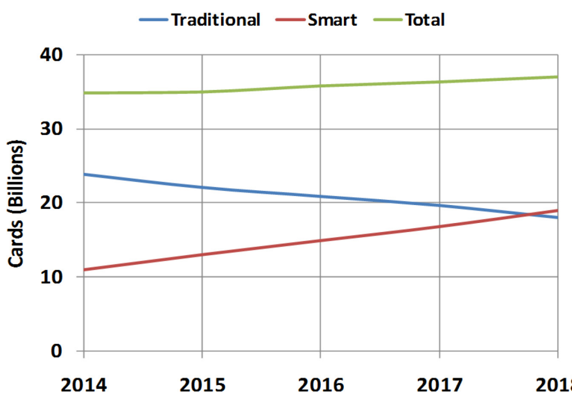

Figure 2. Replacement of traditional plastic cards with smart cards (ICMA, 2015.)

Smart cards are driving revenue growth within the card printing industry. These cards at more than $1 per card are much more expensive than traditional cards which cost only a few cents. Overall market revenue is growing rapidly at 11.1% per year due to the transition to smart cards.

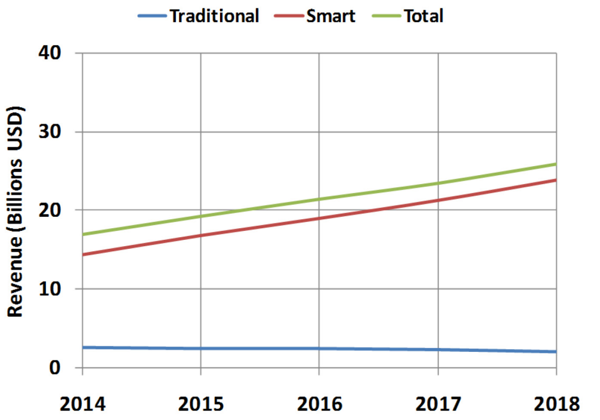

Figure 3. Growth in card printing market size due to increased cost of smart cards. Traditional cards cost an average of $0.11, compared to the higher average cost of $1.30 for smart cards (ICMA, 2015.)

Smart cards are complex. These cards may require more than 30 different steps for production and may contain up to 12 separate components, including software and plastics [3]. Printing is only one or two, in the case of preprinted cards, of the production steps, but it must be compatible with the rest of the manufacturing process. Requirements for plastic cards are defined in ISO 7810, 7811, 7816, and 14443.

Market Requirements

Security

Security requirements may be addressed prior to card printing with preprinted cards featuring unique printed features or during printing with specialized materials. Specialized materials include inks with unique spectral features, including fluorescence, and overlaminates with holographic features. Security cards typically feature an array of features to prevent counterfeiting and deter unauthorized use [4-6]:

- Photo
- Signature
- Hologram
- Microprinting
- Embossing
- Security patterns (guilloche)
- Laser engraving

Fluorescent UV printing is commonly included on security cards. These features may be included on preprinted cards. They may also be added during personalization with fluorescent thermal transfer printing or specialized inkjet inks.

Figure 4. Visa logo and fluorescent ID badge with fluorescent printing across the photo.

Newer security systems take advantage of the ability to add personalized security features that correspond to other aspects of the card [7]. These features better protect a card against alteration than static features linked solely to the card. For example, HID's vanGo cards use low-power lasers to image a metal foil substrate on the card, producing a metallic image that duplicates the photo present on the card.

Figure 5. HID vanGO metallic image.

Lasers maybe used to add unalterable information to cards, since the laser thermally alters the plastic card, rather than simply applying ink to it [8]. Laser engraving is dependent on the substrate (typically polycarbonate) rather than on the printing process used to add additional details, such as a color photo. Thermal transfer printing typically requires a retransfer printer since direct thermal printing is not generally compatible with polycarbonate substrates.

Figure 6. Laser engraving helps protect the U.S. green card from counterfeiting.

Image quality

Image quality requirements are somewhat contradictory, with the photographic portion of the card requiring high-quality continuous tone and the text portion requiring high-contrast, high-resolution printing. These conflicting requirements may result in the use of multiple printing systems to produce a single card. Often, they lead to compromises, which affect overall card quality.

For dye sublimation printers, a combination of dye based CMY ribbon panels with a resin based black panel best addresses these conflicting requirements. For other systems half-toning combined with variable dot size is required.

Higher resolution gives improved image quality. For this reason, thermal printers are currently transitioning from 300 dpi to 600 dpi, allowing more effective reproduction of small text sizes and Kanji characters [9].

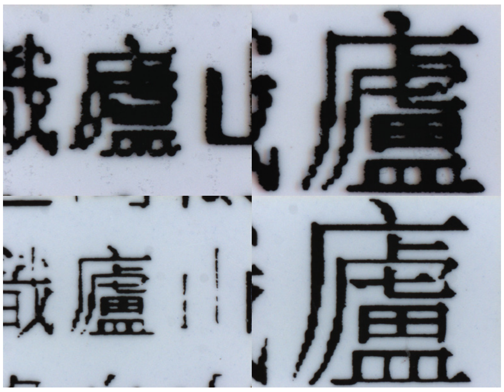

Figure 7. Thermal resin retransfer comparison between 300 and 600 dpi for Kanji characters.

Durability

Durability addresses multiple requirements as well, with cards needing to resist alteration and to hold-up under relatively heavy usage. Expected lifetime ranges from gift cards at one year to credit cards at three to four years to IDs and driver's licenses which may be expected to last up to ten years.

Table 1. Plastic Card Usage Scenarios

Application	Expected Lifetime	Material
Gift and loyalty cards	1 year	PVC
Credit cards	3-4 years	PVC/PET multilayer construction
Drivers licenses, IDs, secure entry cards	5-10 years	Polycarbonate, Teslin multilayer construction

Substrate stability is first factor in overall card stability, since if the substrate fails, it doesn't matter how stable the image is. In many cases, composite constructions are used to optimize substrate stability [10].

Image stability is the second factor. Here the primary difference is related to dyes and pigments, with pigments showing greater resistance to fade and other environmental factors. For cards that will be exposed to light, such as employee badges, pigment-based systems will last significantly longer than dye-based systems.

Preventing alteration and tampering requires materials that are more easily destroyed than changed. Laminates are designed to permanently adhere to a card surface and to be destroyed if they are removed. Materials must resist intentional alteration as well as damage from handling. These requirements for durability are far more severe than typical photographic requirements.

Ink adhesion to the substrate requires either that the ink penetrate into the substrate or that it be held there with an adhesive overlaminate. Either system will work. Relying on ink penetration is the lowest cost solution since it avoids the need for an overlaminate. However, an overlaminate improves durability and if the overlaminate includes unique holographic patterns, security as well.

In some cases, the overlaminate may also facilitate the printing process, since it may be easier to print to a flexible film than to a rigid plastic card. For thermal printing, improved print quality is particularly evident, since it is difficult for a rigid printhead to conform to any nonunifomity that may be present in the plastic card due to embedded electronics, magnetic stripes, and other security features which may be included in the plastic card. Printing to the overlaminate, rather than directly to the plastic card, increases substrate flexibility, since the ink no longer has to adhere directly to the plastic card.

The most comprehensive set of requirements and test methods is available through ANSI/INCITS.

Table 2. ANSI/INCITS 322:2015 Test Methods

5.1	Peel Strength - 90° peel angle
5.2	Adhesion Crosshatch Tape Test
5.3	ID-1 Card Flexure
5.4	ID-1 Card Static Stress
5.5	ID-1 Card Stress and Plasticizer Exposure
5.6	Impact Resistance
5.7	Elevated Temperature & Humidity Exposure
5.8	Surface Abrasion
5.9	Bar Code Abrasion (1D)
5.10	Magnetic Stripe Abrasion
5.11	Image Abrasion
5.12	Temperature & Humidity Induced Dye Migration
5.13	Plasticizer Induced Dye Migration
5.14	Ultraviolet (UV) Light Exposure
5.15	Daylight Exposure Image Stability - Xenon Arc
5.16	Laundry Test
5.17	Embossed Character Retention – Pressure
5.18	Embossed Character Relief Height Retention – Heat
5.19	Corner Impact Test
5.20	Wet Abrasion Test
5.21	IC Card with Contacts Micromodule Adhesion
5.22	Water Soak Test
5.23	Dimensional Change after Elevated Temperature Exposure
5.24	Three Roller IC Card Test
5.25	Hole Tear Test

In some cases, tests are conducted in combination in order to identify any possible interactions between the factors. For example, UV light exposure may make a card significantly more brittle and vulnerable to cracking.

Table 3. ANSI/INCITS 322:2015 Test Sequences

6.1	Card Structure Integrity Test Sequence
6.2	Card Flexure and Peel Strength Sequence
6.3	Elevated Temperature/Humidity and Peel Strength Sequence
6.4	Wet Abrasion and Peel Strength Sequence
6.5	Card Flexure, Wet Abrasion and Peel Strength Sequence
6.6	Ultraviolet Light Exposure and Corner Impact Sequence

These test methods address the need for image stability, as well as the need for stability of the underlying substrate. A second set of test methods is available in ISO 10373-1 and ISO 24789-2.

Table 4. ISO 10373-1:2006 Test Methods

5.1	Card warpage
5.2	Dimensions of cards
5.3	Peel strength
5.4	Resistance to chemicals
5.5	Card dimensional stability and warpage with temperature and humidity
5.6	Adhesion or blocking
5.7	Bending stiffness
5.8	Dynamic bending stress
5.9	Dynamic torsional stress
5.10	Opacity
5.11	Ultraviolet light
5.12	X-rays
5.13	Static magnetic fields
5.14	Embossing relief height of characters
5.15	Resistance to heat
5.16	Surface distortions and raised areas

Table 5. ISO 24789-2:2011 Methods of evaluation for card service life (CSL).

5.1	Xenon arc light exposure
5.2	Surface abrasion
5.3	Magnetic stripe abrasion
5.4	ICM adhesion
5.5	Plasticised vinyl storage
5.6	Wear and soil test
5.7	Temperature and humidity aging
5.8	Temperature shock
5.9	Temperature and humidity cycling
5.10	ID-1 card flexure
5.11	Temperature and humidity aging followed by peel strength testing
5.12	Cross-cut test

These test methods are particularly useful, because when used in combination with ISO 24789-1, they can predict whether a particular card is suitable for its intended application [11]. ISO 24789-1 uses a probabilistic approach to determine the appropriate test conditions given the expected usage in a particular application. Specific application profiles are available for:

- Healthcare card
- National ID card
- Transportation card
- Access card
- Magnetic stripe based campus card
- Driving license
- Banking card

Comparison of Printing Technologies

Dye sublimation is the lowest cost simplest solution to printing plastic cards. Retransfer printing is one step up, eliminating some of the disadvantages inherent with printing directly to a rigid plastic card. Retransfer printing is also more expensive than direct-to-card printing because of the added system complexity and additional materials required for the retransfer process. Advantages of retransfer printing include:

- Edge-to-edge printing
- Compatibility with technology cards
- Tamper resistant

The disadvantage of all dye sublimation printers is the requirement do for a single use ribbon. All printed information is recorded on the ribbon creating a security risk and the process inherently involves significant waste since only a small percentage of the material on the ribbon is actually used to produce the printed card.

Electrophotography is suitable only for specialized applications, since electrophotography is unable to print directly to PVC cards, which make up the bulk of the market. Typically electrophotography is used to print directly to flexible materials which are then laminated to a plastic base. In addition, the lack of a narrow-format printing engine limits its application to high-volume card producers and prevents it from being used in applications that require immediate card production. Electrophotography addresses the following market requirements:

- Low operating cost
- High-volume, central issuance
- High-security composite construction

Like electrophotography, inkjet applies colorant only to printed areas of the card, eliminating the waste that occurs with thermal transfer systems. Aqueous inkjet requires coated substrates, while solvent and UV cured inkjet inks may be used with many uncoated substrates, reducing cost and improving flexibility. Unfortunately, inkjet printheads are generally more expensive than thermal printheads limiting their ability to enter some markets. Inkjet technology is able to personalize cards with both the account number and a photograph. For applications that do not require true embossing, the raised text that results from UV ink is an advantage in that it can simulates an embossed effect [12].

Figure 8. UV inkjet is used to print photographs and account information on financial cards.

High-speed inkjet systems can rapidly personalize plastic cards at up to 40,000 cards per hour [1]. These systems use card-wide arrays of inkjet printheads to achieve high-resolution across the width of the card, without the need to move the printhead back and forth in a scanning system.

Inkjet technology has many advantages for printing plastic cards:

- Low-operating cost
- Direct-to-card printing
- Tactile features

In general, inkjet systems are restricted to high-end central issuance systems, although there are some low-cost exceptions to this rule that rely on the use of coated cards to absorb ink and facilitate the drying process. This requirement has limited market acceptance since coated cards are significantly more expensive than uncoated cards and are not available for the wide variety of card types that are used for different applications. These systems are, however, relatively fast, and they do eliminate the security risk associated with dye sublimation or resin transfer ribbons. Consequently, they may be suitable for some specialized applications.

Conclusions

The best printing system for a particular market depends on the market requirements. It is determined through a thorough understanding of the cost, quality, security and durability requirements for that market [13].

Table 6. Advantages and disadvantages of various card printing technologies.

	Dye Sub	Resin Transfer	Electro-photography	Inkjet
Security	Depends on added features and application requirements.			
Durability	Medium	Medium	High	High
Text Quality	Low	High	High	High
Photo Quality	High	Low	Medium	Varies
Operating Cost	High	High	Low	Low
Capital Cost	Low	Low	High	High

All card printing systems are able to produce highly secure cards, since security can be integrated into card manufacturing as well as into the overlaminates that are applied to the card. In addition, all systems are compatible with laser engraving to produce unalterable cards, provided the correct materials are selected at the outset.

Card printing systems have a clear trade-off between operating cost and capital cost, with more expensive systems having lower operating costs. In addition, systems that are able to print high quality text are in many cases less able to print high-quality photos, since the requirements to produce clear text are different than the requirements to produce continuous tone photos.

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