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POLYMER NOTES AND THE MEANING OF LIFE

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POLYMER NOTES AND THE MEANING OF LIFE

Introduction

The Reserve Bank of Australia has spoken at many forums about how polymer notes have contributed to its objective of having a cost effective, clean, and counterfeit free currency note circulation. This objective seems like a pretty good 'meaning of life' credo for any note issuer. As a result of Australia's experience (and now that of an increasing number of other countries) many other note issuers are seriously considering how polymer notes can help them. It would be a gross dereliction of duty if they did not[1].

In summary, Australia's move from traditional rag security paper to *Guardian*® polymer substrate for its notes has resulted in a substantial increase in note life (by a factor of at least four), cleaner and more hygienic notes, and improved security.

The ability to transfer Australia's experience to other countries has been questioned by some, particularly traditional suppliers such as paper substrate manufacturers who have much to lose by the success of polymer substrate. The main arguments raised to support the contention that Australia's experience cannot be transferred are that:

- the lives of most of Australia's previous paper notes were unusually short relative to those of other countries. Specifically, this is said to be the case for the low to mid range denominations. This implies that there are very few other countries that had or still have denominations with lives in the six-months to two-year range. If this argument is correct then it implies that either the Australian environment and/or the way Australians handled their notes are more severe than in other countries, that Australia has much higher quality standards for determining if a note is fit for reissue than other countries, or that the quality in terms of durability of the paper substrate previously used for Australia's paper notes was exceedingly poor when compared to that of other countries;

- potential savings from the added durability of polymer substrate are, in fact, never realised. This argument is based on the claim that countries will increasingly need to reduce the interval between new series of notes in order to keep ahead of counterfeiters. In fact, it is claimed that the interval between series would become so short that polymer notes would not have completed one life cycle before a further new series of notes was required; and

- polymer notes are easy to counterfeit and, therefore, are not secure.

This paper examines these arguments and shows that they have no foundation and, consequently, many countries stand to gain from a move from paper substrate to *Guardian*® polymer substrate.

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[1] Even if countries decide not to use polymer substrate they probably will have already benefited from polymer because it is only as a consequence of polymer that traditional suppliers are now producing long-life papers, through the use of coatings or new fibres, and new security features. In our view, however, such alternatives remain poor imitations of what is possible with polymer.

Life of Australian Paper Notes and Paper Quality

The lives of Australia's paper notes before the conversion to polymer are set out in Table 1. Table 1 also includes figures on the lives of notes (in months) in 8 of the 13 countries that are represented in the Pacific Rim Banknote Printers Conference[2].

Table 1: Life of Notes (months)

Country	Denom1 (lowest)	Denom2	Denom3	Denom4	Denom5	Denom6
Australia	6	8	10	24	96	
Country 1	10	13	15	14	22	
Country 2	16	18	54	102	142	162
Country 3	9	17	26	22		
Country 4	9	12	16	26	30	
Country 5	7	9	13	15	27	
Country 6	8	8	10	19	17	18
Country 7	18	15	18	24	60	112

While only a relatively small sample, it provides an interesting cross section of countries by size, socio-economic and environmental conditions, etc. What is clear from the table is that whatever the handling, environmental or quality standards used in these countries, there is nothing unusual about having notes with lives of, say, two years or less. Table 1 shows that:

- all of these countries have between two and six notes with a life of two years or less.
- all of these countries have at least two notes with a life of 18 months or less;
- 75 per cent of all of these countries have at least one note with a life of around 12 months or less; and

[2] The remaining five countries have not made data available to the PacRim Conference. The countries that are members of PacRim are Australia, Brazil, Canada, China, Columbia, India, Indonesia, Japan, Korea, Mexico, the Philippines, Thailand, and USA.

- 63 per cent of all of these countries have at least two notes with a life around 12 months or less.

Consequently, rather than Australia being unique because it had paper notes with relatively short lives, it was at that time, and still is now, quite common for other countries to also have paper notes with relatively short lives.

Prior to the move to polymer, Australia used wet strengthen, all cotton rag security paper incorporating a mould made watermark and embedded security thread. Various suppliers were used at different times including Portals, Arjo Wiggins, VHP, and Crane.

The broad specifications that determine durability for the rag paper substrate previously used by Australia were not dissimilar to those of many other countries and, if anything, would be classed as slightly above average based on the advice of the suppliers to the Bank. Table 2 summarises some of the basic specifications for Australia's former paper notes.

Table 2: Paper Quality

Weight (gsm)	**Thickness (microns)**	**Fold Resistance (MDF)**	**Porosity (mL/min)**	**Crumple porosity (mL/min)**	**Tensile Strength (N)**	**Mean Tear Resistance (mN)**	**Wet strength retention (%)**
83 +/- 3	100 - 110	3150 (mean MD and CD)	10	150	88 in MD 55 in CD	750	25

MDF – mean double fold; MD – machine direction; CD – cross direction.

There are three important observations that can be made on the data from Tables 1 and 2. First, life varies by denomination with lower value, high transaction notes having a shorter life than higher value notes. Second, most countries have four notes that have an average life of around two years or less. Third, the paper quality formerly used by Australia was not noticeably different to that of many other countries.

Therefore, it is hard to see why Australia's experience with achieving significantly greater durability with the move from rag paper to polymer substrate cannot be translated to other countries - maybe not all countries, but certainly most.

To the extent that environmental or handling conditions are more severe in other countries or paper durability or sorting standards are significantly greater, then the increase in life that might be possible with a move to polymer substrate in those countries may be less than that achieved in Australia. However, it is hard to imagine that a significant increase in life is still not attainable.

Achieving Cost Savings From Added Durability

Typically, circulation (by number of pieces) is dominated by the low to mid range denominations that are more heavily used in transactions and, therefore, have relatively shorter lives than higher value notes. Consequently, a large proportion of costs of purchasing new notes is related to low to mid range denominations. The life of these denominations with paper substrate is typically in the six months to two years range. Life for higher denomination paper notes can be as high as six to 10 years.

Because polymer substrate is more expensive than paper substrate, but by a factor considerably less than the increase in durability, a move to polymer substrate involves the note issuer in an initial greater outlay. However, this is more than offset over time with cost savings due to the need for fewer notes to replace notes that are unfit for circulation.

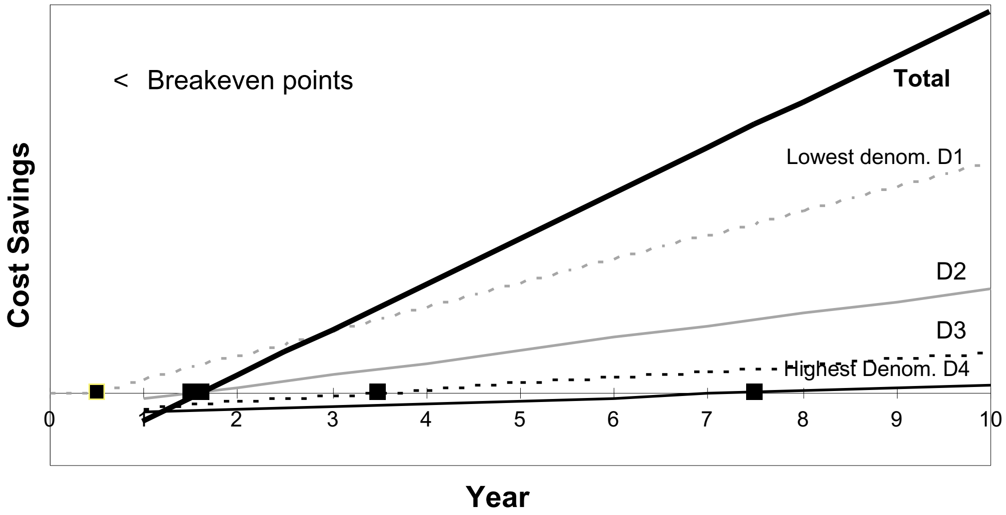
The best way of illustrating the potential cost savings from a move to polymer is by way of an example. For simplicity the following assumptions are made:

- that a new series of notes is to be introduced with a choice of using either paper or polymer substrate;
- that there are four denominations (D1, D2, D3, D4) in circulation each with, say, 100 million pieces in circulation;
- that polymer versions of each denomination last four times as long as the paper version of the same denomination, i.e. the life of each note is
  - D1 - paper 6 months - polymer 2 years
  - D2 - paper 1 year - polymer 4 years
  - D3 - paper 2 years - polymer 8 years
  - D4 - paper 4 years - polymer 16 years
- that there is no growth in circulation (although this biases the results against polymer) and that the note issuer has a policy of maintaining an inventory of new notes equivalent to, say, six months' issues of new notes as a contingency against supply disruption (many countries maintain higher contingency stocks than this);
- that notes are produced at the beginning of each period and the turnover from the old to new series takes place at the beginning of the first year;
- that the polymer notes cost twice as much as the paper notes (paper notes are given a unit cost of 1 so polymer notes are priced at 2).

Production requirements at the beginning of year 1 include the turnover stock for circulation, replacement notes for notes that will be destroyed during year 1, and the contingency stock. In subsequent years, production requirements will equate to the number of notes destroyed.

Attachment 1 summarises the costs to the note issuer for the different substrates. Graph 1 plots the cost differential between the paper and polymer options by denomination and for the four denominations in total.

Graph 1: Cumulative Cost Savings of a Move to Polymer



The results indicate:

- the breakeven points for the conversion of each denomination to polymer substrate occurs within twice the life of the equivalent paper note i.e. well less than one year for denomination D1 (remembering that the paper version lasted around six months and the equivalent polymer version lasted around two years). Significantly, the breakeven points for the low to mid range denominations occur remarkably quickly;

- the size of the savings are greatest for denominations with relatively low life;

- once savings start to accrue for the lowest denominations, these savings easily outweigh any higher costs still being incurred for the higher denominations prior to them reaching their breakeven points. For example, after just four years the cumulative savings across all denominations are in excess of one year's production of paper notes. Very importantly, such savings can be much more significant than indicated in Graph 1/Attachment 1 if the circulation volumes (in pieces) for the low to mid range denominations are greater than those of the higher denominations. As noted earlier this is typical of many countries. For example, all of the 13 countries represented in PacRim have circulations dominated by low to mid range denominations and most of these notes have lives of two years or less;

- an option that these significant cost savings opens up is that, if desired, the note issuer can use at least part of the savings from the lower denomination notes to pay for added security for the higher denominations. This is true even if the higher denominations, whether printed on paper or polymer, do not stay in circulation for even one full life cycle (see further below);

- even if notes are introduced sequentially rather than all at once, significant savings accrue quickly. Also, if there is a desire to release one or more higher value notes early, then by releasing just one low value note at around the same time or soon after then, again, savings accrue very quickly.

Applying the model described above but using actual life and circulation figures for the 8 PacRim members referred to earlier, produces breakeven points as outlined in Table 3.

Table 3: Payback Periods for a Range of Countries

Country	Breakeven Point
Australia	1 year
Country 1	1 year
Country 2	5 years
Country 3	2 years
Country 4	2 years
Country 5	1 year
Country 6	1 year
Country 7	3 years
Average	Approx 2 years

Two of the eight countries are often quoted as examples of countries with extremely durable paper substrate. Yet even for these countries the payback periods are only three and five years, respectively. The average breakeven point across all eight countries is under two years.

What is the risk that a further new series of notes will be introduced before the savings from a move to polymer are realised? The examples above show that the risk is zero. Significant benefits will accrue very quickly and before the need for a new series even if this was to happen as early as five years after the introduction of polymer. As noted above, most cost savings will come from the lower denominations and the life of polymer low denominations will still be within the likely time cycle for new series. The full potential savings for every denomination may not accrue, but this would also be the case with paper notes as some high value paper notes have a life longer than five years and would have to be prematurely destroyed due to the introduction of the new series.

The Reserve Bank of Australia has never advocated that the move to polymer substrate was to achieve added durability for higher value notes. Our decision to use polymer for Australia's currency notes was based purely on improving the security of notes. Added durability, particularly of the lower denomination notes was a secondary benefit, but one that in the event proved to be very significant. To the extent that the better security of polymer (see below) opens up the possibility of longer intervals between new series of notes, then the added durability of higher value notes is an advantage.

A number of further points can be made:

- new series are generally not introduced without considerable lead time and planning including making economical use of existing stocks of notes;
- new series are generally not introduced at times of a single counterfeiting crisis as this can be counter productive;
- claims by paper manufacturers that countries will need to change series every five years to stay ahead of counterfeiters appears to be an admission that paper substrate is losing it effectiveness as a secure substrate;
- it is also unrealistic to assume that every country will be changing its series of notes every five years as suggested by some paper suppliers for economic reasons. There will be pressure from note issuers to find better security solutions that make longer intervals between series feasible because the cost to the community, both direct and indirect, of frequent series changes will become unacceptably high. While some countries might go through more frequent changes of series during a period of underlying fundamental change eg after a long period of no change as occurred with the US, or after institutional change such as the creation of the Euro, ongoing, frequent changes in series are not sustainable.

A more likely scenario than very frequent change in series is that countries will leave their lower denominations unchanged, because they are at little risk from counterfeiting, and 'upgrade' existing higher denomination notes. But, even here polymer substrate offers a clear advantage over paper substrate if countries want to follow this route. This is because, if designed appropriately at the start, an upgrade program based around 'value adding' in the clear window (see below) rather than changing the existing print can minimise the cost of change to the community. This happens because machine authentication is largely based around spectral properties of traditional print or covert features such as taggants in inks used for the print.

Also, the paper suppliers who advocate changing series every 5 years have not yet identified new families of security features that can sustain the introduction of a new series of notes every 5 years. At the moment advances in security features from traditional paper suppliers are based around marginal enhancements of old features.

Security Of Polymer Notes

As an issuer, the Reserve Bank of Australia took the decision to move to a polymer substrate and forgo watermarks and threads for one reason and one reason only - as a means to increase the overall security of our notes.

However, security value is a subjective issue. Even very good security features will ultimately be counterfeited but that does not immediately mean that they have no ongoing value. We certainly still see value in intaglio print on polymer notes and have even looked for new ways to enhance intaglio print through the ICE and TIDE features (see below for an explanation of these features).

Watermarks and threads can still play a role in the fight against counterfeiting when included in paper notes. However, the substrate for notes needs to open up new approaches to security. At the moment, watermarks and threads indirectly, because they require the use of paper substrate, restrict innovation and limit the quality of other print or add-on features. The protection offered by these two features against counterfeiting is not so great that they cannot be sacrificed for other features that are possible with polymer substrate. Polymer substrate offers the potential for significant ongoing innovation, improved quality of features, improved durability of security features relative to the life of the note, and the incorporation of different technologies that make counterfeiting using just print or traditional add-on features less likely.

The genesis for polymer banknotes in Australia dates back to 1966. In that year, Australia moved to a new series of paper banknotes which included what was then considered to be state of the art security features including a rag paper substrate with mould-made watermark and embedded security thread. The worst fears of an issuer were realised when, within one year, high quality counterfeits of the $10 denomination were produced and widely circulated. Not surprisingly, the confidence of the Bank in existing banknote technology was severely shaken.

Despite claims about the difficulty of duplicating or simulating watermarks and threads the security value of such features is greatly diminished if the counterfeiter does not need to reproduce them to pass the counterfeit or can create a passable simulation with little extra work. Watermarks can, for example, be simulated quite effectively with oil-based inks, and passable print simulations of threads, and even actual threads, are quite common. Consistent with the earlier comment, this does not mean that watermarks and threads are useless, but when faced with a choice of using these features at the expense of new options possible with polymer, the decision was clear-cut for the Bank.

Australia now has a reasonably long experience with polymer notes in circulation - around nine years. Australia is established proof that polymer notes work in a general functional sense, and work well. The added durability of polymer notes is an established fact. As to security, the Bank is very pleased with the level of security afforded by polymer notes in the fight against counterfeiting.

Polymer notes are not impossible to counterfeit, as is true for any technology. Nevertheless, by increasing the range of skills and number of steps required, the use of polymer substrate has made it more difficult, time-consuming and costly to produce a counterfeit banknote. One of Australia's major achievements is that the introduction of polymer notes appears to have all but stopped the 'casual' or 'crime-of-opportunity' counterfeiter.

This is an encouraging outcome since Australia's polymer notes (other than the recently released commemorative $5 note) incorporate only the most basic security features. There have been many new developments since Australia's polymer note series was released, an aspect often overlooked by critics. Attachment 2 outlines in greater depth why we believe polymer notes have greater security potential than paper notes.

Summary

The ability to transfer Australia's experience with polymer notes has been questioned by some. This paper has demonstrably shown such claims cannot be substantiated. It has been shown that the typical profile of circulation in most countries involves large numbers of notes with lives in the six months to two years range. As a result the payback period for a move to polymer substrate is remarkably short and for most countries it will be less than two years.

While assessing security value of alternative substrates is more subjective, it must be recognised that advances in security are occurring at a fundamental level with polymer notes whereas it is only happening at the margin with paper notes.

In the future, security features will rely less and less on printing technologies, and more upon unique features incorporated within the various layers of the note and integrating these together in novel ways. It is our belief that polymer substrates are here to stay because they offer the best opportunity for innovation in banknote security. The added durability of polymer notes and consequent cost savings to note issuers are important additional advantages.

Interest around the world in polymer has surged since Australia completed the introduction of its polymer note series in 1996. Since then nearly 10 per cent of all note issuers around the world have released a polymer note and this trend shows no sign of abating.

It is fair to say that polymer and paper substrates each have their own advantages and disadvantages, but as we move into the 21st century, it is clear that *Guardian*® polymer substrate will become the next generation substrate for banknotes.

SECURITY OF POLYMER NOTES

As the Bank sees it, fundamental to the security of polymer banknotes are four factors:

- the control of transparency (from perfectly clear to opaque);
- ‘value-adding’ in and around the clear window(s) in the note;
- the enhanced performance of many traditional security features on polymer compared to paper; and
- the ability to incorporate ‘self-authenticating’ features and thereby integrating the various layers of the note.

The latter factor allows a device to be built into the note to verify another feature. Through this process, there is a close integration of substrate features with traditional print and add-on features. It is this innovation that makes the loss of traditional watermarks and threads easy to accept.

Security

........in the substrate

In essence, polymer substrate is a structured clear film that is opacified using a specially developed coating. By varying the thickness of the coating, the transparency of the substrate can be controlled from perfectly clear (no coating) to fully opaque. This has resulted in new and effective, yet conceptually simple, security features. The most obvious are clear window(s), half window(s)[3] and shadow images.

The presence of the clear window makes it easy for the public to do a first-level visual as well as tactile check on the authenticity of a note during casual observation and handling. In contrast, visual authentication of watermarks and threads in paper notes requires much closer and deliberate examination. Despite claims to the contrary, polymer notes do have a distinctive feel. This feel does not just come from the film but is the result of the interaction between the film, the special opacifying coating, the traditional inks and the overcoating.

As outlined above, the clear window(s) or half window(s) are created through print over a clear film. ‘Value-adding’ can enhance the sophistication of the clear window further. An example is permanently embossing a transitory image in the window. Such an image switches from being visible to invisible or switches from one image to another as the note is tilted. The optical effects achieved cannot be reproduced by reprographic techniques. Our experience has shown that embossing, though simple, is a very effective feature.

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[3] Half windows are created by opacifying only one side of the note in a certain area. This allows, for example, a feature embedded under print on one side of the note to be only seen from the other side of the note

Even more sophisticated security can be included in the clear film or substrate with the use of a Diffractive Optical Element or 'DOE' feature. This highly sophisticated feature, unique to polymer substrate, is a 'virtual hologram' which can, for example, be permanently incorporated into the film in the clear window and is extremely difficult to simulate. The DOE, which can be embossed, or etched using a laser into the clear film or a coating, is virtually imperceptible (it can be as small as 5 mm^2 and appears like a small translucent patch), but projects an image of a chosen design when light passes through it. For example, by holding the clear window up to the eye and looking through the DOE feature at a point source of light (eg a spot light in a restaurant or another car's headlight when in a taxi) the projected multi-coloured image can be seen. It can be seen that this feature can be of help in situations where watermarks and threads and other traditional features are of no help whatsoever.

It is difficult to dispute that the clear window and various ways of 'value-adding' within the window produce security features that are far more effective than watermarks and threads.

The opacification process is also ideally suited to incorporating machine-readable threads. While printed rather than embedded, such threads can also carry 'visual information', to add to the optically variable features of the note in transmitted and reflected light.

For some, the fact that a coating creates the opacity is seen as a disadvantage as offset or screen printing might be used by a counterfeiter to opacify clear plastic. This has to be weighed against the advantages of clear windows, half windows and the other security features that are built around the clear window. We believe the 'package' created by using a clear film with opacifying far outweighs the disadvantages. For example, as already outlined, the clear window provides a casual check, yet transitory images or the DOE feature in the clear window give a more sophisticated check and can permanently securitise the substrate.

It is also claimed that because the opacification is achieved through coating the film, the substrate is not customised as paper is through a unique watermark or thread. It is further claimed that the opacification layers can be removed and the film re-opacified to that suitable for another country. Counterfeits would then be printed on genuine film (as distinct from substrate). A number of points need to be made here. First, embossing of the film with either a DOE feature or a transitory image customises the film in the same way as does a watermark and thread. Orell Füssli's *Microperf*® is another feature that can very effectively customise the film.

Second, covert or machine-readable features are easily added to the substrate to customise it. As with Australian notes, a simple form of this is that the serial number of any note (or some other design element) can be printed with ink that penetrates into the film in such a way that even if all the surface ink of the note is removed, the serial number can be read from the film under UV light.

Third, there are various low-level authentication indicators with polymer that police and other authorities can use to check if the substrate is genuine *Guardian*® polymer substrate eg stretch properties that derive from the special production process for the film or the infrared fingerprint of the film which is a function of the materials used in the production process.

Fourth, as with a counterfeiter printing on genuine paper substrate, a counterfeiter using genuine polymer film still must simulate all the traditional print or add-on security features plus any unique polymer features. If paper suppliers claims are correct that by just having access to genuine polymer a counterfeiter can produce passable counterfeits then this implies that the paper suppliers believe all of the traditional print and add-on security features on paper notes are worthless. It should also be remembered that, increasingly, genuine banknote paper is used in counterfeit notes.

With respect to substrate security, it should also be noted that, as indicated earlier, *Guardian*® has many advantages:

- polypropylene will not run through a modern colour photocopier or laser printer. This forces counterfeiters to use alternative plastics (or paper) if they choose these means of printing;

- alternative plastics (including commercially available polypropylenes) are generally not available in the thickness needed and so have to be laminated together. The use of adhesives to laminate generally causes a loss of clarity in the window or alternatively poor adhesion and a change in feel;

- many plastics do not have the clarity needed to start with or cannot be easily opacified without loss of clarity of the window and poor ink adhesion;

- if an attempt was made to remove an area of ink from an already opacified plastic, such as ‘plasticised papers’, the resulting ‘window’ lacks clarity and the removal cannot be done with the precision needed to create complex windows, vignettes within the window or shadow images; and

- alternative plastics have a distinctly different sound and feel.

Security

........in the print........in add-ons

It is easy to think that the efficacy of printed features and add-ons is independent of the substrate to which they are applied. However, printing on polymer substrate enhances the performance of a range of traditional features. The non-fibrous nature of the substrate results in a surface that is smooth and even. This permits greater fidelity of traditional prints (offset and intaglio), and some unique features. One of these is the Intaglio Contrast Effect (ICE). A reflective metallic ink patch is printed on the film or substrate in a registered position. When an intaglio design is printed on top of the patch using a special brightly-coloured ink, the print will exhibit a colour shift, exhibiting one colour when viewed directly and a more intense colour when viewed from an oblique angle. The effect cannot be achieved on a paper substrate.

Another example is the Transparent Intaglio Disappearing Effect (TIDE) that uses a clear intaglio print over a metallic patch to create unique effects. The image appears then disappears depending on the angle at which the note is held. Also, traditional optically variable inks (OVIs) produce far better colour switching on polymer, whether printed by screen-printing or intaglio printing techniques.

It is said that polymer does not emboss to the same extent during intaglio printing as paper substrate. This is true, but the embossing in clear areas of polymer is permanent whereas it soon disappears in paper with use.

The optical effects of diffractive optically variable devices (DOVDs) are enhanced when applied to polymer substrates, again because of the flat smooth surface. Also, including a DOVD in the window means that it can be seen from both sides; in addition to doubling its visual effectiveness, this makes it particularly difficult to replicate. Furthermore, features such as Orell Füssli's *Microperf*®, which comprises a pattern of tiny holes that become visible when the note is held to the light, can be enhanced. On polymer, the perforations have greater uniformity creating a more precise image and the perforations will retain their definition throughout the life of the note that adds to the security value.

What is clear is that modern reprographic techniques can make passable simulations of traditional printed features, be they on paper or polymer substrates. It is also clear that counterfeiters are now simulating traditional add-on features, and again this is independent of substrate. The banknote of the future needs something more.[4]

Security

........fully integrated

As noted earlier, a significant security advantage of polymer banknotes is achieved through a close integration of substrate features with traditional print and add-on features. 'Self-authenticating' features, which are unique to polymer, are examples of this. Self-authenticating features can be incorporated into polymer notes by converting the clear window into a device for verifying another feature in the note. For example:

- the window could contain a 'screen' for identifying features such as Joh. Enschedé's *μ-SAM* feature printed elsewhere in the note's design;

[4] This is not to say that traditional features should not be used. They can be an effective counter against some forms of reproduction, and the evidence shows that while counterfeiters may do some features very well, their ability to simulate other features, including some simple ones, can be quite poor.

- the window can incorporate a filter for a pair of metameric inks printed elsewhere on the note;
- the window acts as a magnifying glass so that microprint can be easily read; or
- a hidden image could be incorporated into a clear window or a demetalised area of a DOVD which is only revealed when a polarising filter in another window on the note is held over it.

Self-authenticating features, which allow a banknote to be authenticated by the public without use of an external aid or tool for verification, reveal a degree of complexity that can never be achieved with paper. Such features can be based around many existing technologies that have not been able to be used with paper substrate. Self-authenticating features add enormously to the effort and expense a counterfeiter must go to produce a simulation.