Fogra White Paper

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Research
Testing
Certification

Security Elements – Security just by a window feature?

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About the White Paper

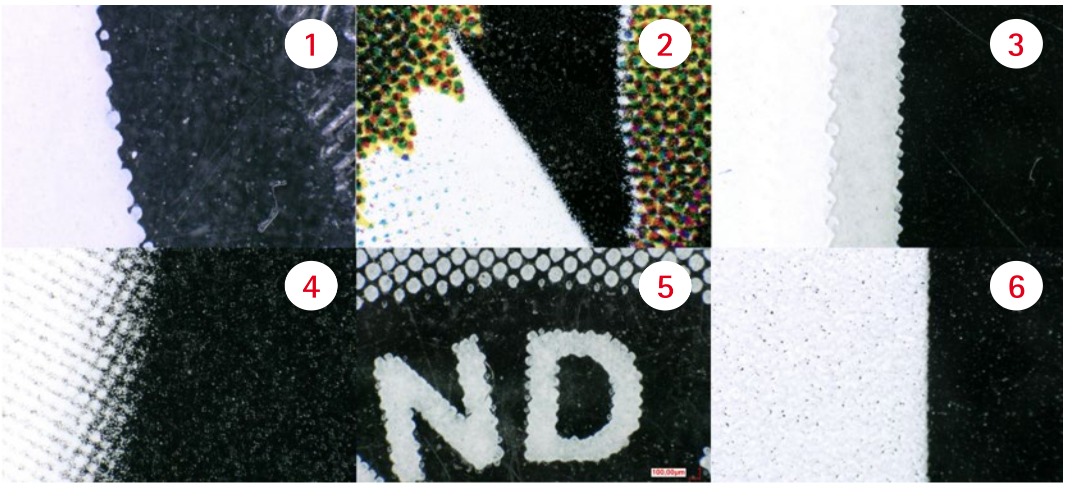
This paper provides current knowledge and research findings for the testing and design of security documents. It is published by Fogra to serve as an independent source for the corresponding industry.

Recently, the presence of a clear window is often requested in tenders for security documents. It is assumed that a clear window contributes to a high level of uniqueness and counterfeit protection. This document examines whether this assumption is correct.

It can be concluded that a clear window cannot be considered as a main security feature of banknotes and ID documents. It must be supplemented by further multilayer security features. This finding comes from 2 perspectives:

- measurement technologies to characterize the qualities of clear window transparency and/or overprinted film opacities;

- system availabilities to generate overprints on clear windows or clear films and their potential print qualities for counterfeits. Both original products (e.g. banknotes and identity documents) with clear windows and various test prints on clear films were used for the experimental investigations within the framework of the preparation of this White Paper. The measurement methods applied are briefly described and statements made about their ability to reflect visual properties. The availability of printing systems was researched through internet and manufacturer contacts.



Judge for yourself: Which parts of the image belong to an original banknote? If you are interested in an answer, please contact us.

What is a security window feature?

A window feature is a sharply or relatively precisely defined transparent area in a security document or banknote.

Such an element is exemplarily shown in figure 1 on a German passport. Generally, a transparent substrate is provided with a white background print on both sides with a specific opacity. The edge sharpness of the window, as well as the gradient of the opacity in the edge area, are also important for the characterisation of such an element.

With ID documents, however, different from banknotes, a window is created across several layers. This means that the production process is much more complex. For this reason, the samples were elaborated on mono-substrates as is usual for polymer or paper banknotes.

Materials and production technologies for clear windows

The typical banknote can be specified by:

- Grammage: 80-85 gsm
- Thickness: 90 - 100 µm
- Minimum opacity: 75%

It was found that many polymers (BOPP, PE, PET, PP, PVC etc.) can be used to create the clear window effect. Such foils can be easily ordered online in many suitable material shops. Due to this ubiquitous availability, the focus for this White Paper was on digital manufacturing processes and the related equipment.

Potential digital production technologies and numbers

In the following, available and typical production technologies are presented that are capable of applying white ink to polymer and producing a clear window. This categorisation is not the only possible but it provides a better understanding of the available options for creating this banknote feature. It must also be said that the researched combinations are not representing a complete list but reflects the findings from expert interviews, book reviews and online search.

Figure 1: Sample of a security windows feature using the German passport as an example.

The conducted market study revealed the ubiquitous availability of both foil materials and marking processes to apply white ink film. The results are provided in two ways: On the one hand, the different number of system and material configurations, termed combinations, will be estimated. On the other hand, the worldwide availability of capable printing presses will be estimated to deduce how many physical machines are ready to produce a clear window. To put this into figures, a conservative assumption of 20 substrates was made for all printing technologies. This results in an estimate of 50*20 = 1,000 combinations available for 50 different printers, for example.

Cumulating the 4,000-8,000 inkjet based combinations, the 3,000 electro-photographic combinations, the 9,000 thermal printers already sums up to 20,000 different combinations. Adding the not further studied conventional printing processes as well as the strongly increasing manual approaches this number can be raised to 30,000 different combinations in total.

With respect to the number of available printing systems, the 50,000 inkjet presses and the 40,000 electro-photographic (toner) presses show the massive presence of semi- and professional systems.
Since this already resulted in such enormous quantities for these printing areas, the numbers for the thermal transfer and sublimation areas were no longer surveyed.

The number of pure office related devices could not be substantiated quantitatively in this study. Two contrary trends can be identified anyhow. Based on many findings that office devices outperform the number of professional systems by orders of magnitude the number of office related printer is higher. However the fraction of office devices that can print white ink is notably lower and can be still considered as a niche application for office usage. Here the interviews revealed 3-digid growth of dealers per month that are incorporating white ink capability office devices.

Fogra used the following measurement methods to assess the suitability of the printing technology. The collected print samples are denoted in the following considerations for the three categories:

Designation	Description
A	Fogra test form printed by printer manufactures
B	Original banknotes
C	Fogra test form printed at Fogra equipment

Table 1: Designation and description of the samples in the White Paper.

Measurement methods for white ink opacity

Methods for measuring the transparency or opacity of printing inks and paints have been described in a number of publications [2, 5, 6, 10, 11]. Standard methods [1] for paints are based on the reflectance of the colorant when printed over a black background relative to the reflectance of the black background without coloration. This contrast ratio method described is widely used in the industry for evaluating opacity, but results can significantly vary depending on how it is used especially when white ink, printed on transparent substrates, is measured or when no standard test substrate is used. Methods of measuring opacity O and transparency are based on the reflectance of printed and unprinted areas of a substrate. Another method is the measurement of the regular transmission factor τ, from which the opacity is calculated as

Opacity (O) = 1-τ

This can typically be done with transmission densitometers, formerly being used to measure the tone values of transparent films. For instance, a clear film has a transmission of 91% (optical density D = 0.04) and a white ink a transmission of 60%. The corresponding opacity would be 40%. Reflectance and transmission are both defined as the luminous reflectance or transmission factor and expressed as the CIE Y.

Opaque white inks are formulated to be relatively opaque to light in order to hide any underlying matter, in contrast to "transparent" white inks which are formulated to permit transmission of light and are commonly used to extend coloured inks. For the purpose of the use, white ink is an ink formulated with an opaque white colorant that has a neutral colour and a reflectance factor greater than 80%, and which is intended to have high opacity. Various factors can affect the appearance of opacity on a given substrate, including the presence of optical brightening agents in the ink or substrate. This can be seen by measuring and viewing the opacity (or transmission) from both sides of the print. The measurement from the printed side shows a slightly higher reflectance and hence a slighter higher opacity. A new ISO standard was recently developed [3], which takes the reflectance of the used white and black backing into account and applies a nonlinear transformation to be more perceptually uniform. It will only be used next to the contrast ratio method for information purposes.

Measurement methods for spatial resolution

Measuring spatial (perceived) resolution, i. e. the capability of perceiving fine detail, is a measure of full system capability and depends upon characteristics of the printing system (substantially more than just its addressability), substrate, viewing conditions, and observer. Perceived resolution depends critically upon tonal differences between elements of an image – there will be no perceived detail, hence no measure of resolution, if there is no tonal difference in an image. The three major contributors to the perceived resolution of a printing system are the capability of a printing system to maintain a desired spatial separation between nearby elements printed on a substrate (the addressability of a printing system indicates what the minimum spatial separation could be), the capability of the printing system to carry tonal differences (contrast) between these nearby printed elements, and the capability of the human visual system to perceive the printed detail. The design of a test chart and an evaluation process for measuring the printing system's capability of carrying fine detail must reflect these major contributors.

A test chart that explores modulation or contrast along one axis and spatial frequency along an orthogonal axis covers a large fraction of the major contributors to the perceived resolution of a printing system. Figure 2 shows the Contrast–Resolution test chart for use with ISO/TS 18621-31 [4] that is used to calculate the perceptual resolution score L-Score, originally developed by Fogra.

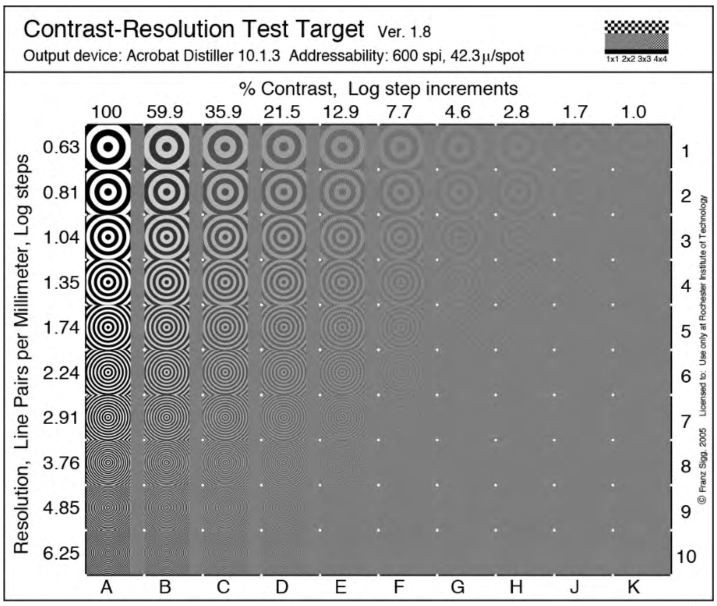


Figure 2: The Contrast–Resolution test target.

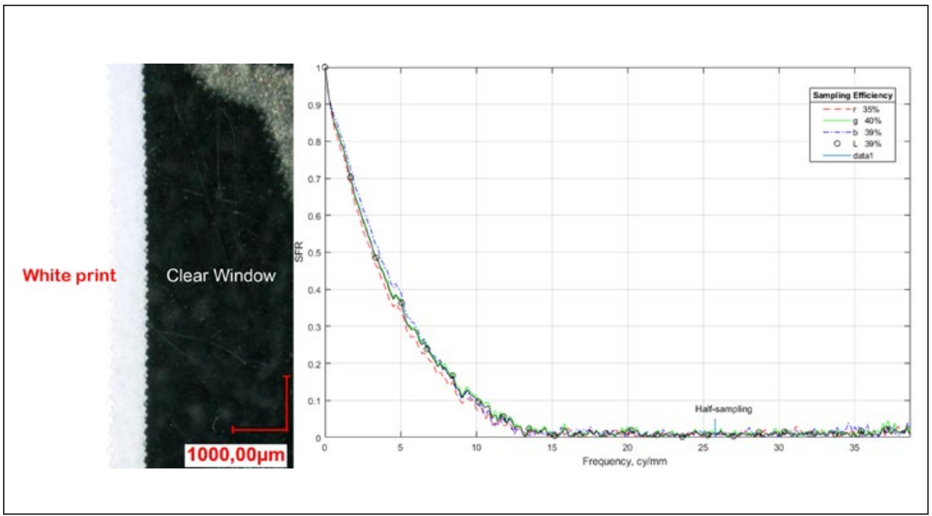


Figure 3: Selecting a slanted edged (tilted straight line) and corresponding spatial response (Down) by means of modulation via the line pairs per mm (cy/mm) on an original banknote.

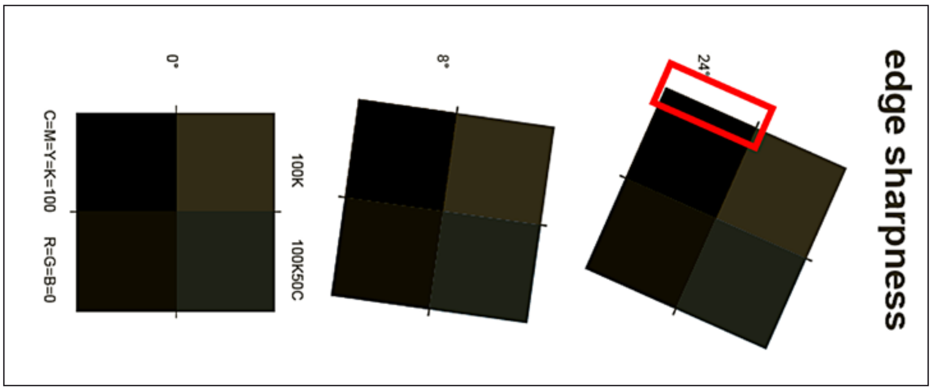


Figure 4: Edge sharpness control element used in the Fogra Image Quality test form and hence present on all „A" type samples. In this case only the 24° tilted, 100% tone value is used (red marking).

In the Contrast–Resolution test chart each circularly symmetric element explores a particular sampled contrast and spatial frequency – the individual patches in the target. The spatial frequency of separation of these circularly symmetric marks and spaces in each patch is varied logarithmically along the vertical axis of the target, whereas the contrast, or depth of modulation, is varied logarithmically along the horizontal axis. This logarithmic spacing mimics the largely logarithmic response characteristics of the human visual system. This representation of contrast versus spatial frequency resembles the Campbell and Robson illustration flipped on its side. The circularly symmetric shape, and the range of values explored in the Contrast–Resolution test chart are well suited to the characterization of digital printing workflows. The evaluation is based on a scan with a qualified scanner but can also be done visually by manually counting the visual discernible circles and apply the formulae specified in [4].

In order to compare both, originals and collected samples by the same method the slanted edge evaluation in relation to [9] was used. It analyses the spatial frequency response (SFR) of an edge. The steepness of the response correlates with the resolving power of the sample under test. First the sample is scanned with a high resolution and then a region of interest (ROI) is selected and evaluated, see Figure 3.

In addition to the visual inspection the samples ("A", "B" and "C") are subject to the slanted edge evaluation. The 50% SFR-values are determined for individually identified slanted edges in case of the originals and the 24° tilted squares used in the Fogra test forms, see Figure 4.

In addition, the L-score values are measured for all type "A" prints to better understand the perceived uniform spread within the rated examples and to use this for qualifications. All measurements are taken from the printed side. Opacity method 1 reflects the transmission method, method 2 reflects the standard contrast method and the third method includes the new, more uniform method for perception according to [3].

	White colour (M1, wb)			Opacity 1	Opacity 2	Opacity 3	L-Score	SFR (at 50%)
ID	L*	a*	b*	%	%	%	1	LinePairs/ mm
B-1	88.8	-1.7	8.0	77	86	NA	NA	4
B-2	85.7	-1.9	-7.8	77	87	NA	NA	2.6
B-3	91.9	0.4	-0.4	55	70	NA	NA	3.2
B-4	95.0	-0.9	3.8	58	54	NA	NA	2.8
A-10	92.6	-0.4	1.7	73	89	94	NA	NA
A-11	92.8	-0.4	1.7	74	89	94	NA	NA
A-12	92.8	-0.4	1.7	73	86	95	NA	NA
A-13	92.9	-0.3	1.8	73	88	94	NA	NA
A-14	93.8	-0.6	0.8	73	87	94	NA	NA
A-15	93.7	-0.6	0.8	73	88	94	NA	NA
A-1	92.47	-0.23	4.11	50	67	77	21	2.4
A-2	92.36	-0.21	3.99	64	79	63	20	4.1
A-3	78.84	-1.28	-1.7	52	55	47	51	4.9
A-4	78.87	-1.29	-1.78	52	55	47	52	4.1
A-5	92.7	-0.6	-0.8	62	95	87	50	5.1
A-6	92.9	-0.7	-0.9	64	94	89	47	5.6
A-7	92.7	-0.7	-0.9	60	96	86	NA	6
A-8	93.6	-0.2	-0.2	55	97	76	NA	6.5
A-9	92.8	-0.4	1.5	58	98	81	NA	5.9
A-16	89.8	-0.5	1.7	51	64	78	56.3	2.5
A-17	90.5	-0.5	0.5	61	73	86	65.8	2.5
A-18	90.6	-0.6	-0.3	67	82	90	65.8	2.8
A-19	90.6	-0.7	-0.8	73	88	93	65.8	4
A-20	90.5	-0.7	-1.1	77	91	95	65.8	5.9
A-21	92.8	-0.6	0.7	64	79	88	25	2.8
A-22	92.5	-0.7	-0.7	77	90	95	41	4.4
A-23	92.3	-0.8	-0.8	74	90	95	65.8	4.6
A-24	92.3	-0.8	-0.7	74	90	95	56.3	3
A-25	92.4	-0.7	-0.8	74	90	94	62.7	4.4
C-1	96.6	-0.4	3.0	45	57	61	61	3,9
C-2	95.0	-0.3	3.2	40	52	62	63	5
C-3	95.9	-0.4	2.9	35	45	50	60	6,2
C-4	96.86	-0.28	2.95	82	96	97	97	NA
C-5	95.64	-0.34	2.04	67	97	88	89	NA
C-6	92.22	-0.04	1.7	52	63	68	80	NA

Table 2: Comparisons of measurements made for colour, opacity using three methods to show the impact of the used method and the spatial resolution using L-Score for the available test forms and the spatial frequency response at 50% luminance modulation. Some test forms have been slightly scaled which disallows the L-Score measurement and some test forms are missing the required slanted edge, hence the pertinent measurement was not available (N/A).

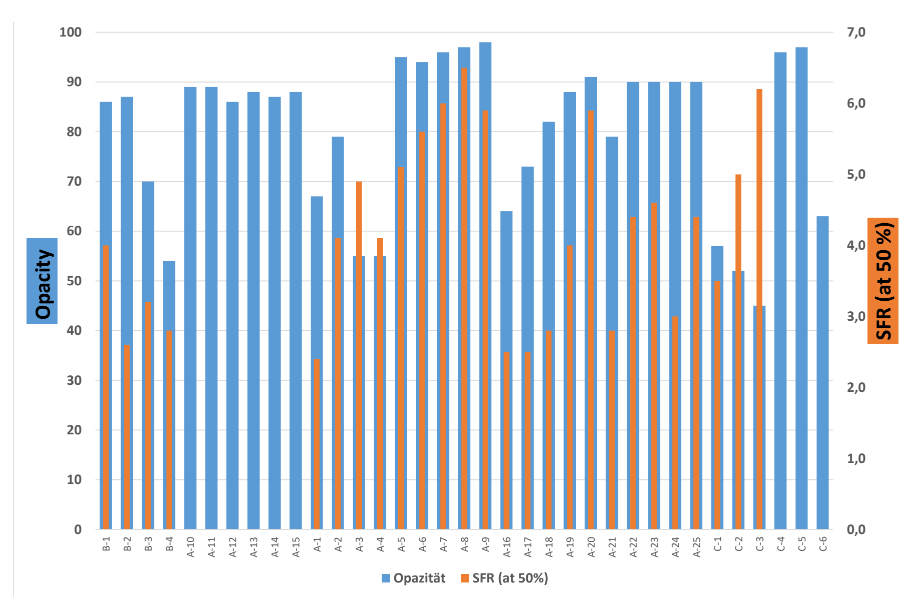


Figure 5: Comparison of the spatial resolution (SFR), i.e. the edge sharpness and the opacity of typical banknotes (B1,B2, B3, B4 grey backgrounded) and printed samples.

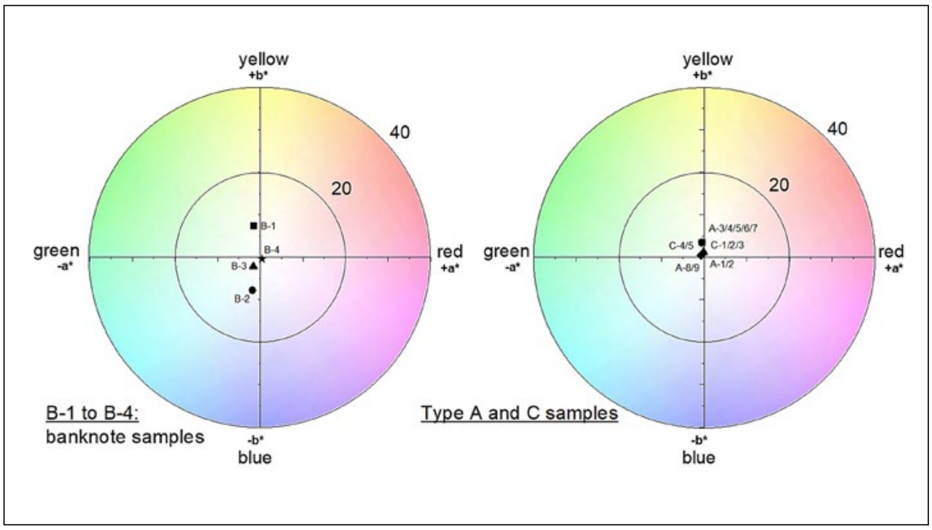


Figure 6: Display of colour measurements in two-dimensional colour space. The lightness value of the measurements of the originals and the produced samples are in the same range, as can be seen in Table 2.

Conclusion

The clear window is considered an important security feature of banknotes and ID Documents. Based on Fogra's extensive experience and network, including expert interviews and internet research, it was reliably proven that there are over 1000 system combinations that can produce such see-through effects. The study included printers for home and office use as well as for semi-professional use.

In addition, a sample set of different production technologies from external suppliers and samples created by Fogra were included in the study. Measurements and visual inspections were carried out with regard to colour tone, opacity (show-through) and sharpness of detail. It could be shown that many available digital print combinations comply with the tolerance ranges specified by typical window techniques e.g. for banknotes and ID documents for all three benchmark criteria. It is therefore relatively easy to produce clear windows with materials and production technologies that are freely and cheaply available internationally. This is the case with most professional printing systems and increasingly with office-type equipment [12]. This trend towards ubiquitous and easily applicable techniques for the production of clear windows is also supported by the fact that the use of thermal transfer technologies for home use is increasing, that white ink is being used in the growing label printing market, and that conventional printing techniques (e.g. flexo and gravure) involving the application of white ink to see-through films are becoming more common (this aspect is not discussed further in this White Paper).

For all these reasons, it can be concluded that a clear window cannot be considered as a main security feature of banknotes and ID documents. The security argument of difficulties in printing on polymer substrates could also be clearly rejected. In most cases, both the opacity and the detail resolution as well as the abrasion resistance of the prints produced surpass the quality of the original banknotes.

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Fogra conducts application-focused research in the fields of printing and media technologies. In many cases Fogra has been involved in the development of forward-looking and globally acknowledged process and quality inspection standards. The international membership is made up of companies from across the entire spectrum of the industry, from producers of printed and electronic media to equipment manufacturers. Fogra sees itself as a modern service provider that carries out inspections tailored to the industry's needs, that advises companies on questions of quality and that mediates in technical disputes. Fogra's capital consists of a massive body of knowledge combined with a high degree of technological expertise and a detailed understanding of current developments.

About the Security Application Laboratory within Fogra

The Fogra Security Application testing laboratory was founded in 1992. Since then, 20,000 tests have been completed. The laboratory has 220 customers from 50 countries and offers more than 100 accredited tests for passports and smart cards. For more than 25 years, the laboratory has been accredited according to the DIN EN ISO/IEC 17025 standard. This ensures the quality of the test results as well as technical credibility and competence. For security applications, members and customers are supported with individual testing services.

The Fogra Security Applications testing laboratory is the only accredited laboratory in the world with all three flexible accreditation levels for the full range of passports and smart cards testing.

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