Ink-Specific Handheld Readers and Security Variable Data Printing (SVDP)

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Abstract

Counterfeiting and other forms of fraud (smuggling, product diversion, product dilution, etc.) is a growing worldwide trade problem, constituting between 5-10% of world trade [1]. Repercussions of counterfeiting differ based on the product, but include reduced consumer safety, brand value erosion, and the funneling of large funds into criminal hands. Since printing is used for brand and product identification, pricing and product information, and retailer stocking, it is logical to use printing for security. Powerful variable data printing (VDP) technologies already exist for several printing methods, including inkjet (IJ) and liquid electrophotography (LEP). Using IJ and LEP technologies to provide package, pallet and/or product security is called Security VDP, or SVDP. In this paper, we describe how the use of security inks with narrow, reproducible excitation and emission bandgaps can be coupled to the development of ink-specific handheld readers (ISHRs). The ISHR is constructed by matching its light source (e.g. LEDs) to the excitation bandgap of the ink, and matching its filters to the emission bandgap of the ink. Its application to ultraviolet (UV), infrared (IR) and visible SVDP deterrents is provided, along with data from trials to co-qualify the inks and ISHRs on, for example, 2D Data Matrix bar codes and other counterfeiting deterrents. These readers can be made overt- or covert-ink specific, complementing the security of the inks with the security of the devices.

Introduction

In this paper, we describe how ink-specific handheld readers (ISHRs) are designed to provide accurate reading of security glyphs. The ISHR is constructed by matching its light source (e.g. LEDs) to the excitation bandgap of the ink, and matching its filters to the emission bandgap of the ink. In some cases, this can lead to a device that works on invisible bar codes but not on visible bar codes of the same scale.

We have begun developing ink-specific handheld readers (ISHRs) to further the utility of covert inks. In most cases, the specificity is designed to match the particular pigment(s) in the ink that give it a covert protection. To match the handheld reader to the pigment, one or more of the following must be implemented:

1. Customize the light source used to excite the ink/pigment.
2. Customize the image capture by filtering out wavelengths not associated with the dye/pigment emission.
3. Use lenses and optics that provide sharper focus at the bandgap of the dye/pigment.
4. Choose the substrate that gives the best readability with the security ink.

For (1), since the UV ElectroInk is maximally excited by 360 nm light, we used LEDs with a peak emission wavelength of 365 nm (the nearest readily available LED wavelength). For (2), we initially high-pass filtered at 405 nm. Greater specificity is achieved by high-pass filtering at 550 nm or above (since the peak emission wavelength for UV ElectroInk is 612 nm). Since handheld readers can be moved closer or further from the security glyph, we did not focus on (3). For (4), we tested multiple substrates to determine the best readability. These are summarized in Table 1.

Table 1: Elements of the ISHR and their Application to Reading Specificity

Light Source (LED)	Match LED emission wavelength to ink pigment absorption peak
Lens and Optics	Sharp focus at emission bandgap wavelengths
Filter	Bandpass for the emission bandgap of the ink
Ink and Substrate	Matched to prevent ink spread, smearing and substrate emission in the bandgap

Methods and Materials

Indigo Press Experiments: The Indigo ElectroInk Series 1 UV inks (which have a peak absorption/excitation at 360 nm) were tested by using printed 2D DataMatrix bar codes and an InData Systems 4600 reader modified to use 365 nm w.p.e. (wavelength of peak emission) LEDs—instead of the usual 405 nm w.p.e. LEDS—for its light source. The Data Matrix 2D bar code symbology is used here to ensure that both x and y directions are factored into the authentication. The following variations were used:

1. Substrates: White Teslin (Teslin® Synthetic Printing Sheet SP 1000 [2]), White Matte (HPIPP Coated Matte 135 gsm), White Glossy (HPIPP Coated Glossy 135 gsm).
2. Bar code, 2D DataMatrix symbology, with module (individual tile) sizes varied from 10 to 30 mil {10, 11, 12, … , 30 mil}.

Five sheets each were provided, affording sets of 50 prints each for the 21 different sizes of each of the three substrates. Thus, 3150 2D DataMatrix bar codes were printed and tested for successful reading by the InData Systems handheld bar code reader modified to read the UV ElectroInk (which has peak absorption at 360 nm). Reading was declared unsuccessful if no valid read signal could be obtained within 10 seconds. Various handheld positions relative to the 2D bar code were used when reading did not occur within the first 2-3 seconds—including varying the distance of the reader above the substrate (varying the "air gap" between the end of the handheld reader optic and the surface) and positioning the reader at a slight angle. Failure to read within 10 seconds for any of these positions was considered a failed read.

After the successful reads were tabulated, a lower (and where applicable, upper) S50 and S90 were calculated. S50 is the first (or last) module size (in the range 10-30 mil) at which 50% of the printed bar codes (or more) can be successfully read. S90 is the first (or last) module size (in the range 10-30 mil) at which 90% of the printed bar codes (or more) can be successfully read.

2D bar code test pages were generated using B-Coder Bar Code Graphic Generator Version 4.0 [3]. These 2D DataMatrix bar codes were created using the Symbology.DataMatrix menus in the B-Coder Professional software, with Comment Line "xx mil" and Bar Code Message (payload) "TestPatternSet3_yyMil_x". They were copied from the B-Coder software and pasted into Microsoft WORD using Edit.PasteSpecial.Picture(Windows Metafile).

HP Inkjet 45 Cartridge Experiments: HP 45 cartridges were used to print three different thermal inkjettable inks. HP Office paper was used as the substrate for each of these tests, and the inks were (1) HP 51645A black ink, (2) Nanogate ITO (Indium Tin-Oxide nanoparticulate) C5000-S22N [4], and (3) VersaInk Magnetic [5]. The same Data Matrix 2D bar code symbology sizes (10-30 mils) were printed for each ink, although smaller sample sizes were used (5-10 at each size).

Results

The S50 and S90 results are shown in the Tables 2 (Indigo Press s2000) and 3 (Inkjet).

Table 2: 2D Data Matrix bar code reading results for the Indigo Press s2000 and different substrates

SUBSTRATE	S50 (mils)	S90 (mils)
Teslin [2]	11-30+	12-30+
HPIPP Coated Glossy 135 gsm	12-30+	12-30+
HPIPP Coated Matte 135 gsm	12-30+	12-30+

All three substrates used with the Indigo Press s2000 and the UV ElectroInk read with 90% or above accuracy for modules sized at or above 12 mils. The teslin substrate read with good (60%) accuracy with a module size of 11 mils.

The inkjetted inks were not generally readable for module sizes below 20 mils. In the case of the Nanogate ITO C5000-S22N ink, a narrow range (22-23 mils) read successfully. This is likely because this ink is a pale blue color, which limits its readability due to low relative contrast with the (white) substrate. The narrow range in which the feature is readable may provide an advantage to the brand owner, since the counterfeiter must correctly produce bar codes in this narrow range to provide a readable glyph. The ink is, however, relatively conductive (our measurements showed a resistance of approximately 1 M /square) with simple room air "curing", and so may have a secondary use as a deterrent readable by an electromagnetic reader.

Discussion and Conclusions

Table 2 shows that each of the three Indigo ElectroInk/substrate combinations provides accurate 2D bar code readability for bar code module sizes of 12-30 mil. The reading is probably limited on the low end by the (small) size of the individual modules, and on the high end by the (large) size of the overall bar code (this is addressable through reduction of the size of the payload, which was 23 bytes for the test set, allowing readability to at least 30 mils).

Table 3: 2D Data Matrix bar code reading results for the HP 45 Thermal Inkjet (TIJ) Cartridge and different inks (HP Office paper substrate)

INK	S50 (mils)	S90 (mils)
HP 51645A Black	21-30+	22-30+
Nanogate ITO C5000-S22N [4]	17, 20-28	22-23
VersaInk Magnetic [5]	25-30+	25-27, 29

The different values for S50 and S90 for the two printing technologies (liquid electrophotography using the Indigo and thermal inkjet using the HP 45 cartridge) were obtained using the same 2D bar code set and the same InData Systems handheld reader. For bar codes with individual modules between 12-20 mils in size, a UV bar code can be printed over the visible bar code, and the successful "read" signal (if obtained) will be from the covert bar code rather than the visible bar code. That is, we have the 12-20 mil module size range for which visible bar codes will not authenticate but overprinted UV bar codes (which can have an entirely different payload) will with the handheld device. The casual counterfeiter will see that the bar code is read, but copy the visible code which is a decoy.

Additional advantages in using an ISHR include the ready availability of LEDs across the range of 365-800 nm. LEDs themselves provide a quick path to deployment, as the FDA has provided: "Since your product is a Light Emitting Diode (LED) [and] is not a Laser, your product is not actively regulated by the Food and Drug Administration" [6]. Filters are also readily avialble across the 365-800 nm range.

The use of 2D bar codes to test the ink/substrate/reader combination is advantageous since bar code reading is available on many commercial handheld scanners and because these bar codes test the reading sensitivity in both the x and y directions. Thus, the ranges for S50 and S90 can be relatively compared across all tested combinations of ink, substrate and reader to craft the most effective combination for deterring would-be counterfeiters. As an example, using a teslin substrate with small module size on the Indigo will discourage some counterfeiters, since other ink/substrate combinations will not read successfully.

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