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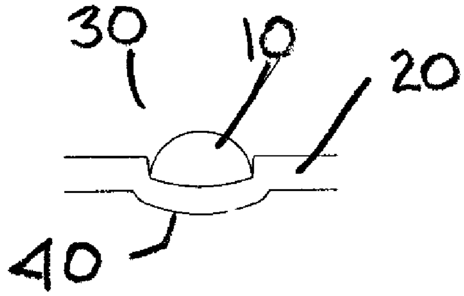

Figure 4

(57) Abstract: Curable ink deposits are printed onto a substrate in a predetermined pattern (e.g. screen printed). The curable ink comprises one or more monofunctional and/or multifunctional curable acrylates, wherein the individual monofunctional and/or multifunctional curable acrylates contributing up to 80% by weight of the ink have viscosities below 10,000 cP at 25°C, a low viscosity acrylate contributing to at least 10% by weight of the curable ink and a rheological additive. The curable ink deposits are then heated (optional) and cured (e.g. by exposing them to ultraviolet light, for UV-curable ink deposits). Preferably, intaglio calendering/printing is then applied to the substrate sheet, whereby a high pressure is applied to press the cured ink deposits into the substrate, creating protrusions of the substrate on the opposite side of the ink deposits. The ink may comprise a taggant for use as a security feature.

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IMPROVED PRINTING OF TACTILE MARKS FOR THE VISUALLY IMPAIRED

FIELD OF THE INVENTION

The invention relates to the field of printing and, more particularly, to improved methods for printing tactile marks for the visually impaired.

BACKGROUND

There is a need and desire to incorporate physical features into products handled by visually impaired people so that they can discern certain characteristics relating to such products. For example, it is important that visually impaired people be able to distinguish and use products such as security documents, in particular, different denominations of banknotes. For this purpose, currency-issuing national banks are implementing various features in the production of banknotes. Examples include varying the size of banknotes and using deep intaglio patterns and non-intaglio, deep embossments on the notes to create tactile marks which may be discerned by touch (i.e. by the user feeling the document in the area of such marks). However, varying the size of banknotes is not convenient for users, as it requires a special frame to compare the length of the notes. Further, the use of intaglio patterns and non-intaglio deep embossments has been shown to be inadequate, because the embossed tactile marks lose form and flatten over time, with use, so these marks do not provide sufficient durability to provide tactile reliability for such documents. The flattening of those known tactile marks occurs as a result of flattening of the embossments in the paper substrate, due to handling, exposure to moisture and repetitive folding.

A method of back-coating embossments was developed (see United States Patent No. 5,779,482 which issued to the assignee of this application) to provide tactile marks having improved durability, but there is a need for new methods to further improve the durability and production of tactile marks on commercial products. In particular, there is a need for improved methods for printing durable tactile marks on security documents such as banknotes, the tactile marks of which need to be able to survive the full normal circulation life of such banknotes.

SUMMARY OF THE INVENTION

In accordance with the invention there is provided a method for printing a tactile mark onto a substrate sheet such as a security document (e.g. banknote). Curable ink deposits are printed onto the substrate sheet in a predetermined pattern, for example, by screen printing. The curable ink comprises: (i) one or more monofunctional and/or multifunctional curable acrylates, wherein the individual monofunctional and/or multifunctional curable acrylates contributing to 80% by weight of the ink have viscosities below 10,000 CP at 25 °C; (ii) a low viscosity acrylate having a viscosity below 200 cP at 25 °C and contributing to at least 10% by weight of the curable ink; and, (iii) a rheological additive (silica gel and hydrogenated castor oil being examples). The curable ink deposits are then cured, for example, by exposing them to ultraviolet light if the curable ink is UV-curable, comprises a photoinitiator, or by applying an electron-beam to the curable ink deposits if the curable ink is curable using an electron-beam technique.

Preferably, intaglio calendering/printing is applied to the substrate sheet whereby a high pressure is applied by the intaglio calendering/printing to the cured ink deposits to press the cured ink deposits into the substrate sheet and create protrusions in the substrate sheet on the opposite side of the ink deposits.

An example of a UV-curable ink comprises: (a) an aliphatic polyester urethane acrylate component in an amount of about 0 - 25% by weight; (b) a low viscosity component selected from the group consisting of an acrylic oligomer, a tripropylene glycol diacrylate, a propoxylated glyceryl triacrylate and an isobornyl acrylate, in an amount of about 20% - 80% by weight; (c) a rheological additive in an amount of about 0 - 5% by weight; and, (d) photoinitiator components in an amount of about 1% - 10% by weight.

The UV-curable ink may also comprise a predetermined taggant the amount and/or pattern of which in the cured ink deposits is detectable, for use as a security feature. The taggant may be machine detectable for automated authentication of a security document (e.g. banknote) comprising the substrate sheet with tactile marks printed thereon. For example, the taggant may comprise particles with magnetic properties (e.g. carbonyl iron or magnetic iron oxides) having a size from 1-80 micrometers, and/or may comprise at least one fluorescent dye, or the taggant may be selected from the group consisting of elemental silicon, retroreflective glass beads, cholesteric liquid crystal pigments, particles with piezoelectric properties and optical-interference-based pigments with magnetic properties.

The step of printing the ink deposits may further include depositing microlenses onto the substrate sheet for use as a security feature, the microlenses providing an optical magnification of at least 2 and having a predetermined pitch which is close enough to a pitch of a background image of the substrate sheet to create kinetic Moiré effects.

Further in accordance with the invention, there is provided a security document (e.g. banknote) comprising tactile marks made in accordance with the foregoing methods.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing the steps of an exemplary method for producing tactile marks on banknotes, in accordance with the invention.

Figure 2 is a block diagram illustration of an exemplary silkscreen printing process for printing tactile marks onto a substrate sheet.

Figure 3 is a profile view of a banknote to which ink (resin) has been deposited in accordance with the invention but it is to be understood that the dimensions (shape/height) of the ink deposit (dot) shown in this figure are exaggerated for illustrative purposes only, the dot actually being flatter than shown.

Figure 4 is a profile of a banknote to which ink (resin) has been deposited and intaglio printing has subsequently been performed to apply pressure to the ink deposit, in accordance with another embodiment of the invention (the dimensions of the ink deposit and the relief shape are not intended to be accurate but instead shown in exaggerated form for illustrative purposes only).

Figure 5 is a block diagram showing the steps of a further embodiment of the invention which includes features of signature mapping and self-verification.

Figure 6 is a graphical illustration of a magnetic response/signature in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

Means for improving the printing of tactile marks have been developed and are claimed herein. Specifically, an improved formulation for an ink, alternately referred to hereinafter as resin or varnish, to be applied to a substrate (such as a security document e.g. a banknote) to form tactile marks on the substrate, which provides improved adhesion and durability for the tactile marks, has been developed. Further, intaglio printing steps have been developed and added to the process for printing the resin to achieve tactile marks with two-sided tactility. Still further, optional security features have been developed for use in the production of security documents having the tactile marks printed on them according to the invention.

Figure 1 illustrates the steps of an exemplary, preferred method for producing tactile marks on banknotes. First, tactile marks are printed onto a banknote substrate sheet 100, preferably using flat screen or rotary screen silkscreen printing machines according to the printing methods which are well known in the printing industry. Alternatively, ink-jet printing, using dispenser heads typically used for dispensing of adhesives, such as dispensers manufactured by Pico Dosiertechnik GmbH (Germering, Germany) or pressure-jet printing, using miniature pressure-dispensers, such as liquid dispensing heads available from Fritz Gyger AG Swiss (Gwatt/Thun, Switzerland) may also be employed to print the tactile marks, all of which printing methods are well known in the printing industry. This is done by depositing onto the substrate 20 a predetermined amount of a curable ink 10, for each tactile mark being printed, the ink being comprised according the formulation described in the following. Once the ink 10 has been deposited onto the substrate sheets 20, the ink is cured by exposing it to a curing source. In the examples described herein a UV-curable ink is used, meaning an ink which is cured by exposure to ultraviolet light (UV). Heat curable inks are also known and inks which are cured by exposure to a combination of ultraviolet light and heat could be used as well. In addition, some inks may be cured by an electron beam curing method. In addition to the formulation of the ink, the length of exposure of the sheet to the ink after deposition, before curing, affects the degree of ink penetration into the paper, whereby a longer exposure will increase penetration.

In one example, illustrated by Figure 2, a full-scale press test was carried out using a flat-screen SPS Screen Press with SPS Turbostar Conveyer (both from SPS Rehmus, Wuppertal, Germany), operating at 2100 sheets per hour. A curing tunnel was equipped with two UV-mercury lamps, providing a total UV exposure of about 0.8 J/cm^2, as measured using an EIT Power Puck UV-exposure meter (available from EIT Inc., Sterling, VA). The patterns made in a 60-mesh screen, used in this printing, were circular with diameters of 1 mm. In the result, tactile marks were produced in the form of dots having heights from about 115 to 170 μm. More generally, the ink, when printed onto the substrate sheet at a rate of about 1000-7300 sheets per hour, has a viscosity from 2000-25000 cP at 25 ^oC and the ink deposits are cured by UV light exposure of about 0.2-3 J/cm^2. Although in this example the tactile marks formed dots, resembling Braille characters, it will be understood by the reader that many other printing options can be used to produce other forms of tactile marks, as desired for a given application. For example, other shapes, such as bars, ovals, stars or triangles may be used. Further, they may be applied in such a manner as to provide secondary tactile structure, such as humps or valleys, if desired for a particular application.

Additional effects can be achieved, if desired, by adding glass beads, plastic beads or crushed glass particles to the varnish. The beads or particles, in addition to increased tactility, can also provide optical effects, contributing to the overall security of the product. For example, a layer of glass beads can provide the optical Moiré effect, which cannot be copied on color copying machines, as described in Example 1 herein. The Moiré effect will be visible on substrates printed with parallel lines or shapes, if the repetitive distance between the lines is close to the diameter of the glass beads. Example 2 herein describes an example of the Moiré effect which uses glass beads having diameters of 38 micrometers. An additional advantage of using beads is that they provide a specific surface texture, which helps in tactile recognition of the marks by visually impaired people. The textured surface gives a significantly different feeling, compared to a smooth-cured dot surface. Therefore, due to the overt Moiré effect and the surface texture effect, an implementation based on beads present in the dots may be preferred for some document security applications.

The ink formulation developed for the printing of tactile marks 30 is particularly directed and suitable to produce durable tactile marks 30. The ink 10 used to print the tactile marks 30 is an energy curable composition, the properties, preparation and composition of which are significantly different from the conventional, known energy-curing screen inks. In particular, the viscosity of this ink 10 can be up to ten-times higher than the viscosity of conventional screen inks, and can be as high as 25,000 cP at 25 °C. The ink 10 used in the example is transparent or highly translucent and consists of urethane acrylate of high elasticity, epoxy acrylate for increased adhesion and rheology modifiers for control of the shape of the deposited ink (which is also referred to as resin).

More specifically, the ink 10 used in the example consists of a mixture of monofunctional and multifunctional UV-curable acrylates of low molecular weight, such that the viscosities of individual components contributing to 80% of the weight of the formulation are below 10,000 cP at 25 °C. Components with higher viscosities tend to leave tailing marks, which result when the separation of the ink deposited on paper, from the screen, forms a paper-to-screen-thread that falls down on the paper leaving a tailing mark. In the example of the formulation provided below, the main low viscosity component is an acrylic oligomer, CN2285 (available from Sartomer, Exton, PA), which has a viscosity of 350 cP at 25 °C. Monofunctional acrylates give linear polymers which, in fast-curing UV-curing systems, means that they are soluble in some organic solvents and they have low mechanical strength. Di- and multi-functional acrylates provide not only linear polymerization but also cross-linking, so they reduce or eliminate solubility in organic solvents and increase the strength of the UV-cured material. However, di- and multi-functional acrylates contribute to rigidity of the cured polymer. Although difunctional oligomers are not required for an elastic dot formulation, it may be beneficial to include them in some applications because then the properties may be controlled by adjusting the ratio of monofunctional material to di- or multifunctional material.

Surprisingly, the inventors discovered that the conventional, known adhesion promoters (e.g. Resin PKHB, available from Inortech, Montreal, Quebec, Canada) are not effective to produce sufficient adhesion of the tactile marks to a paper substrate. Instead, it was found that the adhesion of the printed resin dots to a paper substrate improved with an addition of a low viscosity acrylate, which partly penetrated through the paper. By low viscosity it is meant that the viscosity is below about 200 cP at at 25°C. In a preferred example, the ink composition contains at least 10% by weight of such low viscosity component, examples of which include oligomers, such as CN2285, or monomers, such as tripropylene glycol diacrylate (Sartomer™ SR 306HP), propoxylated glyceryl triacrylate (Sartomer™ SR 9020) or isobornyl acrylate (Sartomer™ SR 506A).

Examples ("A" and "B") of two ink formulations, which have been found to be suitable for the methods described herein, are set out below in the following tables:

1. Ink Formulation "A"

Component	**Wt. %**
Aliphatic Polyester Urethane Acrylate (example Bomar ™ BR 7432 G)	17.27
Acrylic Oligomer (example Sartomer™ CN 2285)	57.42
Isobornyl Acrylate (example (Sartomer™ SR 506A)	19.88
Hydrogonated Castor Oil (example Rilanit™)	2.43
Photoinitiator (example Irgacure™ 2022)	3.00
TOTAL	100.00

2. Ink Formulation "B"

Component	**Wt. %**
Bomar™ 7432 G	13.40
Photomer™ 6010	26.80

Photomer™ 4127	13.40
Sartomer™ CN 2285	26.80
Sartomer™ SR 506 A	13.40
Esacure™ KS-300	3.87
Esacure™ TZT	2.33
TOTAL	100.00

More generally, a preferred example of the ink formulation is comprised of an aliphatic polyester urethane acrylate component in an amount of about 0 – 25% by weight; a low viscosity component selected from the group consisting of an acrylic oligomer, a tripropylene glycol diacrylate, a propoxylated glyceryl triacrylate and an isobornyl acrylate, in an amount of about 20% - 80% by weight; a rheology modifier (additive) in an amount of about 0 - 5% by weight; and, photoinitiator components in an amount of about 1% - 10% by weight. However, for electron-beam-cured formulations, a photoinitiator component is not required. The rheological additive may, for example, be silica gel (e.g. Aerosil-200™ available from Evonik Degussa, Brampton, Ontario, Canada) or hydrogenated caster oil.

The paper-penetration parameter of the ink is controlled by means of the concentration of the low viscosity component in the formulation and by screen press parameters, such as heating of the deposited ink before UV curing and the linear velocity of the conveyer belt. An increase in the concentration of the low viscosity component, heating deposited ink before UV curing and slowing down the velocity of the conveyer may be employed to cause the paper penetration of the ink to become more effective. Therefore, changes of concentration of the low viscosity component in the formulation and control of press parameters provide opportunities to adjust the formulation to best fulfill the application requirements, that is, to achieve high adhesion and high durability of the tactile dots.

In a preferred example, an additional embossment step is carried out on the deposited and cured ink deposits (dots). In this additional step, the ink is partly pressed into the substrate by high pressure intaglio calendering, which is a process that is well known in the printing industry. In achieving this step, it was surprising to find that the very high pressure exerted onto the tactile marks by the intaglio calendering step does not significantly reduce the height of the screen-printed tactile marks. Nor was it found to cause damage to the degree of adhesion of the tactile marks to the substrate. Even more surprisingly, it was found that the high-pressure pressing of the tactile marks against a flat plate, during the intaglio printing step, results in significant tactility being created on the side 40 of the substrate, opposite the side on which the ink was deposited, as shown in Figure 4. Before the application of high pressure through the intaglio calendering/printing step, the cured ink 10 (see Figure 3) adheres to the flat substrate sheet 20. As a result of the intaglio printing application of high pressure, the compressed ink 10 is pressed into the sheet 20 (see Figure 4) such that a protrusion is formed in the substrate sheet on the opposite side 40 of the compressed ink and this provides an additional, significant tactile effect on that underside surface of the tactile mark which complements the effect of the tactile mark itself.

Examples

The following examples are presented to illustrate the claimed invention but are not to be construed in any respect as limiting the scope of the same.

Example 1

Substrate sheets in the form of banknote paper were printed with tactile marks by screen printing; then, the sheets were passed through a Super Intaglio press (manufactured by KBA-Giori, Lausanne, Switzerland). The plate area corresponding to the tactile marks was not inked. Instead, in this area, the intaglio calendering pressure was used to achieve protrusion of the tactile marks to the back side of the sheets (as shown in Figure 4). Other areas of the intaglio plate were inked as in conventional production for a banknote. Thus, the intaglio printing process proceeded normally in those other areas of intaglio printing, while the calendering pressure caused the tactile marks to partly protrude to the back side of the paper. As a result, significant relief shaped marks were produced on the back side of the substrate sheets, directly under the tactile marks. Since the protrusion of the tactile marks remained on the front side of the substrate sheets, the tactility could then be sensed, by feel, on both sides of the banknote paper. This is advantageous because people with impaired vision can sense tactility better using two fingers (i.e. passing over opposite sides of a banknote) rather than with one finger, as the case would be without high pressure embossing of the tactile dots. In this example, the intaglio compression caused loss of only about 20 μm of tactile mark height. On a sheet where the average height of the marks before compression was 170 μm, after compression the average total height of the marks was still 150 μm.

Advantageously, for the production of tactile marks on banknotes, this intaglio calendering/printing step serves to accomplish two functions at the same time. It both achieves the underside protrusion for each tactile mark and, at the same time, performs the normal intaglio printing of images to the remainder of the document (i.e. since banknotes are normally printed with their desired patterns and features using the intaglio printing method due to the greater security it provides).

The tactile marks prepared according to the examples provided herein demonstrate significantly improved durability over current tactile marks made by embossment of a paper substrate. Physical resistance tests were performed on the UV-cured tactile marks by subjecting them to crumple, tumbling and abrasion tests. Chemical resistance tests were also performed whereby tactile marks deposited onto paper and polymer substrates were immersed in organic solvents.

In particular, a standard crumpling procedure was performed using an IGT Crumple Tester (from Research North America, Cherry Hill, NJ). Tactile marks deposited onto paper were crumpled 8 times, while the dots deposited onto a polymer substrate were crumpled 24 times. In both cases, the tactile marks remained on the substrate after the crumpling was finished. That crumpling test is used effectively for banknotes and is considered to be harsher than several years of circulation of a banknote. Other durability tests carried out on the dots were tumbling tests. The tumbling tests were carried out using a rubber-lined lapidary tumbler filled with 24 zirconium oxide cylinders, each weighing 31.5 g. A 4" x 4" cloth wetted with 5 g of artificial sweat was also placed inside of the tumbler. The tumbling test was carried out for two hours at room temperature and all of the tested tactile marks survived this test.

Abrasion tests were also carried out using a Taber Abraser, Model 503 (Taber Instrument Company, North Tonawanda, NY), with S-10 abrasive wheels loaded with

250g of weight for testing of tactile marks on a paper substrate, and 500 g for tactile marks deposited on polymer substrate. Two tests were done for each substrate: one with 100 rotations and one with 400 rotations of the abrasive wheels. The tactile marks survived the abrasive actions and retained an acceptable level of tactility after 400 rotations.

Chemical resistance tests performed on the tactile marks also showed them to be durable. The tactile marks survived a 30 minute exposure (at room temperature) to each of methanol, ethanol, tetrachloroethylene toluene and heptane, without noticeable damage.

The easy-to-feel tactility of the UV-cured dots produced according to the foregoing descriptions, and their strong adhesion, assist visually impaired people in validating security documents such as banknotes and, therefore, serve to provide a certain level of security to those banknotes. Thus, the tactile marks themselves, and the tactile perception they enable, provide a first level of security. Additional steps may be taken as detailed in the following to provide higher levels of security, if desired.

Optionally (see Figure 5, for example), a higher level of security may be provided by adding to the ink used for the tactile marks an amount of a predetermined (i.e. pre-selected) taggant. For example, one of the well-known fluorescent ink components may be added to the ink, and then the printed tactile marks made from that ink are tested for the presence of that pre-selected fluorescent additive. Similarly, particles detectable using magnetic fields could be added to the ink, for example ferromagnetic particles such as carbonyl iron particles. In one example a security feature was provided in this manner by generating a random signature from large (about 30 – 40 μm) clusters of fluorescent and magnetic particles in the ink. This signature is then applied to the document so that this information can be later used to verify the authenticity of the document. The signature may take the form of a self-verification number or may identify statistical characteristics of the clusters, for example. Alternatively, the signature may correspond to a signal generated from signal-creating clusters of fluorescent and/or magnetic particles in the printed ink. This provides security to the document, because the random characteristics of clusters and particles, such as position and intensity, are practically impossible to duplicate. Therefore, on presentation of the document, it can be verified to be authentic if the presence of such characteristics is confirmed.

The following materials are suitable as taggants:

1. Magnetic materials: Fine particles of carbonyl iron, magnetic iron oxides, particles with permanent magnetization (eg. $CoFe_2O_4$), may be added as taggants. For example, soft iron particles known as carbonyl iron, with average sizes of 4.5 μm (available from the BASF Corporation, Florham Park, NJ), may preferably be used as soft-magnetic taggants or mapping materials. More generally, particles with magnetic properties having a size from 1-80 μm may be suitable for use. Concentrations of carbonyl iron as low as about 0.65% wt., expressed as a weight percent of the resin, are easily detectable with permanent-magnet-backed standard electrodynamics reading heads. Even if the iron particles are well dispersed, a unique magnetic signature with fined lines can be obtained. Higher concentrations of carbonyl iron particles, approaching about 2.5 % wt., were found to demonstrate the presence of self-agglomerated clusters of iron particles.

2. Fluorescent pigments or dyes: Fluorescent dyes or very fine particles, about 1 μm or smaller, could provide the effect of fluorescence. Examples of such pigments are Scanning Compounds 4 and 6 (available from Angstrom Technologies, Florence, KY). Conversion of the fluorescent particles into clusters, for example by attaching them to much larger particles of silica-gel (silica-gel with sizes from 5 to 50 μm) makes the mapping-signature approach, based on fluorescence, much easier to implement. Fluorescent particles with larger sizes (from 5 to 50 μm), are also available and are suitable for making of mapping-based fluorescent signatures. The conversion of small fluorescent particles or dyes into clusters can be accomplished by mixing all the components in a solvent and filtering off the fine particles. The clusters will remain on the filtration paper. After drying the clusters, they are suitable for addition to the UV-curing ink for making of tactile marks. Making combination clusters, containing both magnetically-detectable and fluorescent particles within the same cluster is also possible. Other alternatives for signature-mapping include combinations of mixed clusters with "pure clusters" and should be easily conceptualized by a person skilled in the art of security-related taggants.

3. Elemental silicon: Elemental silicon in various particle sizes (including nanoparticles) can be used for signature-mapping purposes in the same way as the above-mentioned fluorescent pigments. Nano-particles of elemental silicon can provide sharp fluorescent peaks at essentially any desired visible wavelengths. Both, nano-particles and larger-size particles of elemental silicon can be converted into clusters for signature-mapping. Elemental silicon particles of various sizes and with various dopants (available from Nanostructured & Amorphous Materials, Inc., Houston, TX) provide fluorescence, which is dopant-dependent. The doped or undoped elemental silicon particles are suitable for signature-mapping purposes.

4. Fluorescent nano-particles: Fluorescent nano-particles, such as EviDots™ (available from Evident Technologies, Troy, NY) can be used to create "very high resolution fluorescent signature-mappings", potentially suitable for a forensic-level authentication.

5. Taggants containing two areas with fluorescence of different color: Taggant particles having two different areas with different fluorescence could provide authentication verifiable using UV-light and a magnifying glass. For example, if the two areas provide, correspondingly, red and yellow fluorescence, the color will appear as orange to the naked eye. However, under a magnifying glass, the taggants will be visible as consisting of red and yellow segments, located in close proximities. Taggants of this type are available from ARmark Authentication Technologies (Glen Rock, PA) and, as fibers, from Shanghai KOS Papermaking Anti-Counterfeit Technology (Shanghai, China).

6. Retroreflective glass beads: As taggants, retroreflective glass beads could be identified using a source of light or a simple handheld authenticator, such as Model 101X authenticator (available from TSSI Systems, Ltd. Swindon, United Kingdom). Retroreflective beads are also available in a fluorescent version (GL-0327 from MO-SCI Specialty Products, L.L.C., Rolla, MO). The retroreflective beads, both fluorescent and non-fluorescent, could be used for a signature-mapping approach.

7. Cholesteric liquid crystal: Standard cholesteric liquid crystal pigments or cholesteric liquid crystal particles with magnetic properties may also be used as taggants, where the cholesteric liquid crystal materials, in addition to magnetic properties, demonstrate optical interference effects resulting in angle-dependent apparent colors. Examples of such pigments are described in U.S. Patent No. 6,875,522 B2 (Seto/SICPA, 2005) and U.S. Patent No. 7,169,472 B2 (Raksha/JDS Uniphase, 2007). Cholesteric liquid crystals can also be used as semi-covert taggants, as described in Example 4.

8. Particles with piezoelectric properties: Crystalline barium titanate particles may be used as taggants (barium titanate particles with various degrees of crystallization are available from MO-SCI Specialty Products, L.L.C., Rolla, MO) in the tactile dots. Application of an alternating external electric field to tactile dots with barium titanate particles will cause transduction from the AC electrical field into mechanical vibrations of the particles with proper microcrystal/grain orientations relative to the direction of the AC field. The vibrations, which may be of sonic or ultrasonic frequency, may be used as an additional overt or covert characteristic for use in the identification of banknotes (or, more generally, security documents). The piezoelectric effect may be enhanced through orientation of the BaTiO3 micrograins using a process known as electrical poling. The poling process requires application of an electrical field of about 1 kV/mm (at 90 °C). This process can be applied during screen printing process, immediately before exposure of deposited dots to the UV light.

A person skilled in the art of taggant applications can easily find other combinations of the listed above taggants and recording methods.

Tactile marks comprising machine-readable or detectable taggants (magnetic or fluorescent particles or clusters and retro-reflective beads), as described above, may be used to generate a unique, and therefore secure, fine-detail-signature or map. In one example, the signature/map consists of a table of values corresponding to machine-readable positions and intensities of peaks of characteristics of the taggants, being the positions and intensities of the peaks of magnetic signals. This table of values can then be converted into a code, preferably with encryption, and recorded as a hidden magnetic barcode on the banknote. Hiding of the barcode is achieved by overprinting of the magnetic barcode with an obscuring ink, an example of which is an ink containing titanium dioxide pigment, and matching the color of the over-coating with the color of the background.

A low-cost but high security solution is provided by a detector which reads both the signature/map of the taggant and the barcode. An example of such a solution uses a soft-magnetic taggant (such as carbonyl-iron particles) and an ink-jet printed barcode containing also soft-magnetic particles to generate the barcode signals. Another example, uses fluorescent taggants, whereby an optical detector detects the characteristics to determine the signature from the fluorescent taggant and reads the printed signature in the form of a fluorescent barcode. An invisible fluorescent barcode can be printed using invisible fluorescent inks and, therefore, does not require masking to hide it within the banknote design.

This means that using a signature/map to define characteristics of taggants in tactile marks provides a high level of security because reproduction of such signatures/maps is very difficult to achieve, without prohibitive cost, by known technologies .

In addition to the foregoing security features incorporated into the ink of the tactile marks, the step of printing the tactile marks provides further opportunity to add security features. The silkscreen process provides an opportunity to print optical elements, known as microlenses. The microlenses consist of glass beads deposited through shapes designed on the printing screen. The glass beads, with diameters from 20 µm to 100 µm, are tightly spaced (side-by-side), preferably in a single layer. These glass beads, when deposited on line-work consisting of thin lines, with a pitch close to the diameter of the glass beads, create Moiré patterns. These Moiré patterns appear to the outside observer as moving shapes, when the observer changes his or her angle of observation. The area where the microlenses are printed will have a different tactility or touch than the remaining part of the banknote. The moving Moiré patterns provide additional street-level security to banknotes.

The following describes two application examples by which these security features were implemented, the first, example "A", providing a high level security and the second, example "B" providing a relatively low cost solution.

Example "A"

1. Transparent tactile marks are deposited onto substrate sheets of banknote paper using:
   a. Silkscreen printing, using flat-screen or rotary screen printing machines.
   b. Ink-jet printing, using dispenser heads typically used for dispensing of glue, such as dispensers manufactured by Pico Dosiertechnik GmbH (Germering, Germany); or
   c. Pressure-jet printing, using miniature pressure-dispensers, such as liquid dispensing heads available from Fritz Gyger AG Swiss (Gwatt/Thun, Switzerland);

   whereby the composition of the marks includes a taggant, as described above, for example sparsely dispersed, i.e. very low concentration (0.1% or less), carbonyl-iron particles of 4.5 micron (average) size. The soft-magnetic taggant (carbonyl-iron) provides a source of magnetic characteristics used to define a signature/map. The composition of the marks also includes an invisible fluorescent taggant, for example 0.1% of high intensity invisible fluorescent pigment (Lumilux™ CD-777 from Honeywell, Morristown, NJ). The intense fluorescence of the transparent marks is used for simple point-of-sale verification. Since the magnetic particles will be at a very low concentration, other taggants may be added, if desired, to further increase the level of security. For example, retroreflective beads, retroreflective beads with fluorescence, other fluorescent clusters or particles, recordable or permanent-magnetism magnetic particles, magnetic clusters or magnetic optically variable (interference) pigments.

2. Microlenses are deposited using the same process by which the tactile marks are deposited (printed). With appropriately selected pitch of the background image, close to the diameter of the glass beads, the microlenses/beads will create kinetic Moiré effects. The resulting kinetic Moiré effects as well as the different tactility of the microlenses area (compared to the remaining part of the banknote) create additional street-level security for the banknote. The microlenses are selected to provide an optical magnification of at least 2.

3. The mark depositions are cured using UV-light or by an electron beam curing method.

4. Intaglio printing is applied to the substrate sheets as described herein, whereby the tactile marks are compressed into the sheets to form protrusions on the sheet at the opposite side of the tactile marks, and desired patterns are intaglio printed onto the banknote in other areas of the banknote. The intaglio calendering function can be substituted with a similar process providing the calendering effect.

5. The taggant (or multiple taggants) is scanned by means of a scanner appropriate for the characteristic (i.e. physical effect) of the taggant, and the measured characteristics are used to define a signature/map, which, preferably, is encrypted to produce a self-verification number. If more than one taggant is used, multiple verification numbers may be produced and recorded as self-verification numbers.

6. The self-verification number is recorded on the banknote. The preferred method for recording the self-verification number is by a magnetic barcode using ink-jet printing. The recorded barcode is preferably masked by over-coating using an ink containing titanium dioxide and matching the background color. Any additional self-verification codes may be recorded by appending them to the main magnetic barcode verification number, or by recording them on the banknote by other means, such as invisible (fluorescent) two-dimensional barcodes or holographic microperforations.

7. The printed substrate sheets are cut into single banknotes and the self-verification feature is tested using a quality control machine.

8. Once in circulation, the banknotes can be verified in point-of-sale locations using a simple automatic currency detector which, magnetically or optically, determines and compares a signature/mapping of the taggant characteristics of the tactile marks with the recorded self-verification number. Commercial banks and the central bank can also test secondary signatures/maps by comparing

them with recorded secondary verification numbers. Optionally, the process may include addition of a code corresponding to the serial number of a banknote to facilitate tracing of the flow of the banknote even at the point-of-sale level and enable a bank to automatically track its inventory of banknotes within a branch. This may also be used to capture persons involved in bank robberies and/or to trace illegal transactions.

Example "B"

For the low-cost implementation, the production process is essentially the same as in the high security implementation of Example "A", except that the taggants are selected to be detectable with low cost detectors and the signature/mapping is omitted. The preferred taggants for the low-cost implementation are based on larger-size (about 10 μm) soft-magnetic particles or soft-iron clusters. Fluorescent pigments of high intensity can be used to provide detection by low-cost UV-based currency detectors; i.e. the currency detectors verify the presence of a soft-magnetic material and measure the approximate position, magnitude and variability of the magnetic signals.

Example 2

Ink formulation "B", 10 parts (wt.), was mixed with 10 parts (wt.) of glass beads of 38 μm size (available from Prizmalite Industries, New York, NY) and the mixture was deposited on a paper substrate using a manual screen frame. The paper substrate had a square-pattern of dots with a pitch of 25 micrometers. The area covered with the microlenses (glass beads) demonstrated the Moiré effect, which means that a moving image was observed while tilting the printed sheet.

Example 3

Ink formulation "B", 100 parts (wt.), was mixed with 0.654 parts (wt.) of carbonyl iron particles (average particle size 4.5 μm, available from the BASF Corporation, Florham Park, NJ), resulting in 0.65% (wt.) concentration of soft-iron particles in the UV-curable resin. The resulting mixture containing sparsely-dispersed particles had a slightly off-white color. The UV-curable material was then screen printed on a paper substrate and cured using UV-light. The cured dots were moved through a testing device consisting of an electrodynamic magnetic reading head, which had a static, rare-earth magnet (bias magnet) facing the magnetic sensor. The sample was moved between the magnet and the reading head. The generated signal was recorded using a Tektronix™ oscilloscope, model TDS-5104. Figure 6 illustrates an example of a magnetic response/signature of two tactile dots from this experiment. The results were found to be reproducible for the same sample. Samples of other prints made under the same conditions demonstrated totally different locations of peaks and different ratios of their heights.

Example 4

Ink formulation "B", 100 parts (wt.), was mixed with 6.01 parts (wt.) of LC-528 cholesteric liquid crystal pigment (purchased from Wacker GmbH, Stuttgart, Germany), resulting in 5.67 % (wt.) concentration of LC-528 in the UV-curable resin. The resulting mixture was almost transparent. The UV-curable material was then screen printed, as tactile dots, on a paper substrate with slightly tinted but still very light-coloured printed background. The printed dots were then cured using UV-light. The presence of the pigment in the cured dots was almost unnoticeable. The optical effect appeared when a left-circular polarization filter was placed over the dots. The dots became well visible and a strong color shift was observed with different angles of observation. This effect of strong visualization of the nearly-invisible pigments and strong enhancement of their color shift, using an appropriate circular polarization filter can be utilized as a simple point of sales test of authenticity of banknotes.

Various exemplary embodiments have been disclosed by the foregoing and are to be considered as illustrative only, not restrictive or limiting of the scope of the invention. It is to be understood by the reader that various changes and modifications can be made while still making use of the claimed invention and without departing from the scope thereof. The scope of the invention is defined only by the appended claims. All variations and equivalents coming within the meaning of the appended claims are intended to be embraced within the scope of the present invention.

WE CLAIM:

1. A method for printing a tactile mark onto a substrate sheet, comprising the steps:

   (a) printing curable ink deposits onto the substrate sheet in a predetermined pattern, the curable ink comprising:

   (i) one or more monofunctional and/or multifunctional curable acrylates, wherein the individual monofunctional and/or multifunctional curable acrylates contributing to 80% by weight of the ink have viscosities below 10,000 CP at 25 °C; and,

   (ii) a low viscosity acrylate having a viscosity below 200 cP at 25 °C and contributing to at least 10% by weight of the curable ink; and,

   (iii) a rheological additive; and,

   (b) curing the curable ink deposits.

2. The method of claim 1, further comprising controlled heating of the ink deposits prior to the curing to cause an increase of penetration of the ink deposits into the substrate sheet.

3. The method of claim 1 or 2 whereby the curable ink is UV-curable and further comprises a photoinitiator; and, the curing step comprises exposing the curable ink deposits to ultraviolet light.

4. The method of claim 1 or 2 whereby the curable ink is curable using an electron-beam technique and the curing step comprises applying the electron-beam to the curable ink deposits.

5. The method of claim 3, further comprising the step of applying intaglio calendering/ printing to the substrate sheet whereby a high pressure is applied by the intaglio calendering/printing to the cured ink deposits to press the cured ink deposits into the substrate sheet and create protrusions in the substrate sheet on the opposite side of the ink deposits.

6. The method of claim 5 whereby the ink deposits are printed by screen printing.

7. The method of claim 6 whereby the substrate sheet is banknote paper.

8. The method of claim 6 whereby the substrate sheet is for use in a security document.

9. The method of claim 7 whereby the UV-curable ink comprises:

(a) an aliphatic polyester urethane acrylate component in an amount of about 0 – 25% by weight;

(b) a low viscosity component selected from the group consisting of an acrylic oligomer, a tripropylene glycol diacrylate, a propoxylated glyceryl triacrylate and an isobornyl acrylate, in an amount of about 20% - 80% by weight;

(c) a rheological additive in an amount of about 0 - 5% by weight; and,

(d) photoinitiator components in an amount of about 1% - 10% by weight.

10. The method of claim 9 whereby the rheological additive comprises silica gel or hydrogenated caster oil.

11. The method of claim 9 whereby the UV-curable ink, when printed onto the substrate sheet at a rate of about 1,000 – 7,300 sheets per hour, has a viscosity from about 2,000 – 25,000 CP at 25 °C.

12. The method of claim 10 whereby the UV-curable ink deposits are cured by providing a total ultraviolet light exposure of about 0.2 – 3 J/cm^2.

13. The method of claim 3 whereby the UV-curable ink further comprises a predetermined taggant the amount and/or pattern of which in the cured ink deposits is detectable and compared with a self-verification code, for use as a security feature.

14. The method of claim 7 whereby the UV-curable ink further comprises a pre-determined taggant the amount and/or pattern of which in the cured ink deposits is detectable and compared with a self-verification code, for use as a security feature.

15. The method of claim 14 whereby the taggant is machine detectable for automated authentication of a banknote comprising the substrate sheet with tactile marks printed thereon.

16. The method of claim 13 whereby the taggant comprises particles with magnetic properties, having a size from 1-80 micrometers.

17. The method in claim 16 whereby the particles with magnetic properties are selected from the group consisting of carbonyl iron and magnetic iron oxides and their signature is recorded on the banknote paper as a self-verification code.

18. The method of claim 13 whereby the taggant comprises at least one fluorescent dye.

19. The method of claim 13 whereby the taggant is selected from the group consisting of elemental silicon, retroreflective glass beads, cholesteric liquid crystal pigments, piezoelectric particles and optical-interference-based pigments with magnetic properties.

20. The method of claim 3 whereby the step of printing the ink deposits further includes depositing microlenses onto the substrate sheet for use as a security feature.

21. The method of claim 20 wherein the microlenses provide an optical magnification of at least 2 and have a predetermined pitch which is close enough to a pitch of a background image of the substrate sheet to create kinetic Moiré effects.

22. A security document comprising tactile marks made in accordance with the method of any one of claims 1 through 21.

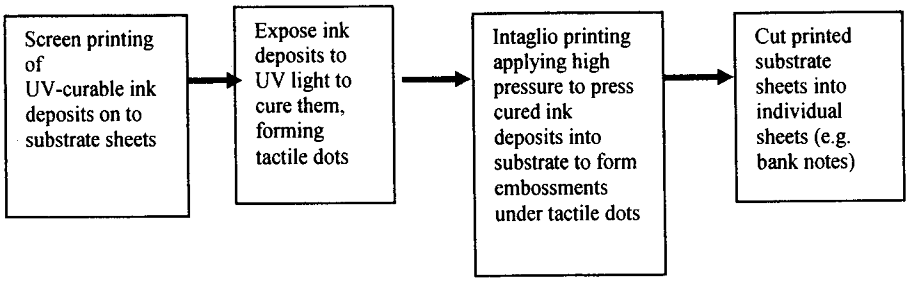

Figure 1

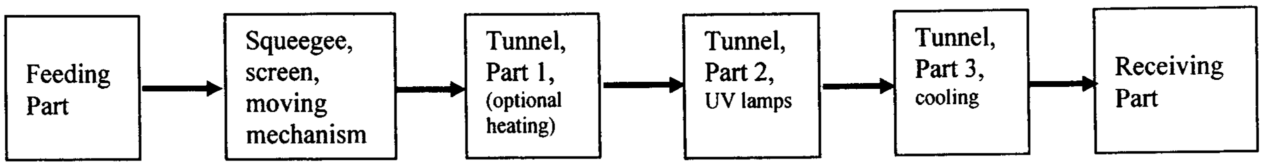

Figure 2

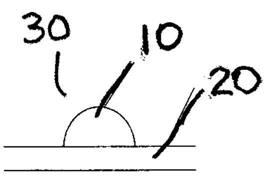

Figure 3

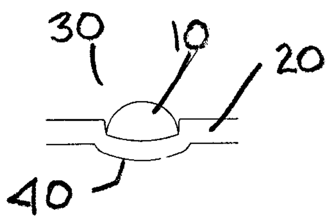

Figure 4

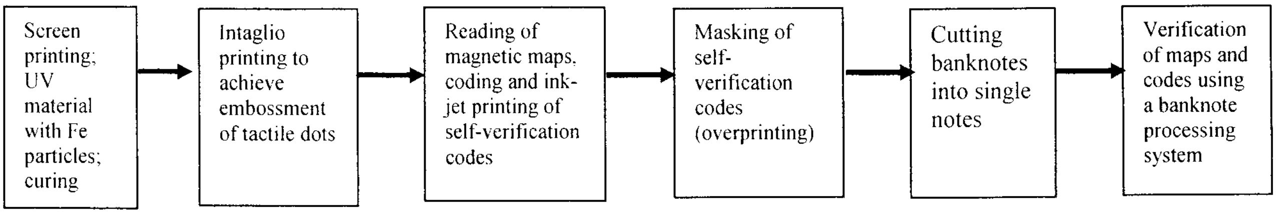

Figure 5

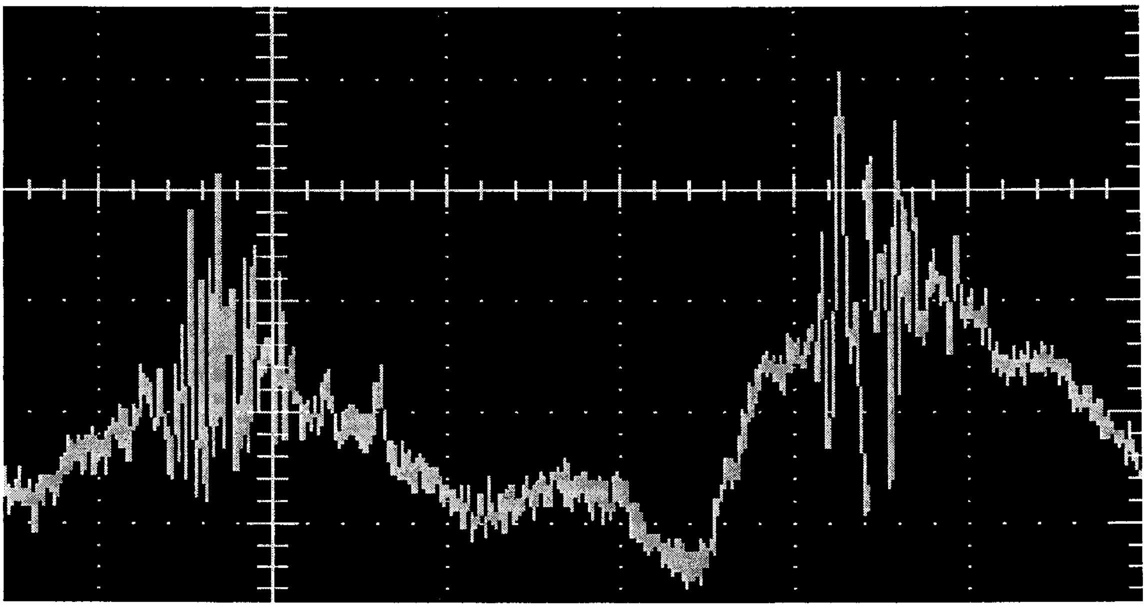

Figure 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2008/002240

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***B41M 3/16*** (2006.01) , ***B41M 3/14*** (2006.01) , ***B42D 15/00*** (2006.01) , *G09B 21/00* (2006.01)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: ***B41M 3/16*** (2006.01) , ***B41M 3/14*** (2006.01) , ***B42D 15/00*** (2006.01) , *G09B 21/00* (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Canadian Patents Database, Qweb (FamPat), Delphion
Keywords : tactile, curable, ink, acrylates, rheological, "flow thickener", "flow thinner", viscosity, taggart, magnetic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US6,787,583B2 (VEYA, P. et al.) 7 September 2004 (07-09-2004) * Abstract; Col. 3, line 27-34; Col. 4, line 64 to Col. 5, line 4; Col. 5, line 13 to line 27*	1, 3, 4, 22
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A	US5,512,122A (SOKYRKA, H. W.) 30 April 1996 (30-04-1996) * Abstract, Col. 4, lines 1-5; Col. 29-50; Fig. 2*	1
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[ ] Further documents are listed in the continuation of Box C. [X] See patent family annex.

*	Special categories of cited documents :	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier application or patent but published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
4 June 2009 (04-06-2009)	4 September 2009 (04-09-2009)

Name and mailing address of the ISA/CA	Authorized officer
Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001-819-953-2476	William Tse 819- 934-6355

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