The use of vacuum deposited coatings for security applications.

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ABSTRACT

It is estimated that 5% to 7% of world trade is made up of counterfeit or pirated goods. The higher margin of branded goods makes them a prime target. To help protect these goods a variety of security devices have been developed of which some require a vacuum coating process step.

The best know security device is probably the hologram or similar Optical Variable Devices (OVDs). OVDs require either a thin metal or a high refractive index coating that may also need to be patterned.

Currency is also a popular target for counterfeiters. Here too vacuum deposited coatings have been used to good effect. Coatings that show a colour change with angle cannot be scanned and printed or colour photocopied. There are various ways of incorporating these optical variable coatings such as inks, threads, planchettes or hot stamped foils.

Another aspect of security where vacuum deposited coatings are used is for the tags that are deigned to protect goods against theft. The structure of these tags depends on the underlying technology used, i.e. radio frequency, electromagnetic, magneto-acoustic or magnetic.

In this paper I will describe a number of the uses of these technologies where vacuum coatings are used and describe some of the benefits and limitations. There are some less well know applications of vacuum coatings for forensics which will also be described.

INTRODUCTION

A recent research programme carried out by the European Crimes Division concluded that more than 40,000 people in Russia die each year from counterfeit Vodka. In the UK fake Stolichnaya Vodka was found to contain high levels of methyl alcohol that, it is claimed, can cause blindness. In India a study undertaken in 1999 showed that 63% of Whiskey sold was counterfeit.

A further piece of work, done in Europe by the Centre for Economics and Business Research, estimated that the worldwide impact of counterfeiting to be $1Trillion. This figure is higher that the more widely reported $250 - $350Bn per year.

It can be seen from this information that to increase consumer safety and reduce the level of counterfeiting there is an opportunity for any good anti-counterfeiting or brand authentication device.

There is a similar problem with theft and tampering of products.

There is a large range of devices that are available that can be used in different forms to suit different market needs. An example of this would be holograms that can be used as part of a marketing strategy as a glitzy part of the packaging. They can also be used as part of the company branding and part of the product authentication. The positioning of the hologram can be across the closure of the package hence making it also the tamper evident feature.

This group of security devices have a generic title of Optical Variable Devices (OVD) and I will present some details of some of these devices.

Product theft from stores relies on Electronic Article Surveillance (EAS) devices. These are labels that are placed within or stuck onto the outside of products that if not deactivated at the checkout will trigger an alarm on leaving the store. Only some designs of these EAS tags require vacuum deposited coatings and these will be described.

Other uses of vacuum deposited coatings for security include the area of forensic science. There are two applications both used to increase the contrast of fingerprints that enable a permanent photographic record to be made.

Finally a use of transparent conducting coatings in window security will be described.

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OPTICAL VARIABLE DEVICES.

These can be divided into other groups such as Diffractive Optical Variable Image Devices (DOVID) and Interference Security Image Structures (ISIS).

There is a range of different products that are on offer with different levels of security and where the image can be integrated into the overall design of the package, document or product. The images can also be designed to contain covet information as well as the overt image. Below is a list of the DOVIDs that are typically used.

- 2D Holograms
- 3D Holograms
- 2D/3D Holograms
- Stereograms
- 2D animated holograms
- Kinograms
- Pixelgrams / Exelgrams
- Dot Matrix holograms
- Combinations of some of the above

The method of manufacture for most of these DOVIDs starts with the origination of the artwork and the particular technique of converting the artwork into an exposed photopolymer plate that is developed and then metallized to make the master. This master is then copied many times to produce the many generations of shims that are used in production. The shims are mounted around a roll that is used to emboss the surface structure into the polymer surface. This is done using heat and pressure or pressure plus UV curing in some cases to fix the surface relief pattern into the polymer web surface. This polymer web then is metallized. Embossed holograms are all white light transmission holograms that are metallized such that the transmitted light reflects back to the viewer.

The options fall into four broad categories which are,

- Reflective
- Semi-reflective
- Patterned
- Transmissive

The reflective have an opaque mirror-like metal deposited on the surface. Originally there was only aluminium used to provide the highly reflective back surface but this has progressed to the position today where there are a number of options depending on the desired end product. Chromium and gold are also used as reflectors. The chromium giving better corrosion resistance required for some applications. The DOVIDs that appear on banknotes have to withstand many tests including being stable to both acid and alkaline solutions for 24 hours. The aluminium did not meet the grade and more stable metals such as chromium were used instead.

It was desired to protect some information, which was printed or written onto documents, from alteration. Adding a security device next to the information did not stop attempts to make alterations and so the DOVIDs were developed to enable the devices to be hot or cold stamped over the critical information. This required that the metallization be either semi-reflective or transmissive. The semi-reflective coatings are metals that are deposited in a thin layer to be only 5% - 10% reflective. This allows reasonable visibility of the underlying information. The DOVID can still be seen and at some angles the grey metallic reflector is the more dominant effect.

Patterning the metallization can make a similar effect. In this case the metal is deposited as a thicker layer to be optically opaque. After metallization where the metal is required to be retained a lacquer is printed on the metal surface and then the surface is immersed in a bath to etch away the areas of un-protected metal. This too allows a view of any information positioned under the DOVID. The reflectivity of the opaque metal is higher than for the semi-reflective type and hence the DOVIDs appear much brighter but the view of the underlying information is discontinuous. Also not all applications want to have the attention focussed only on the one security device. A schematic of this is shown in Figure 1.

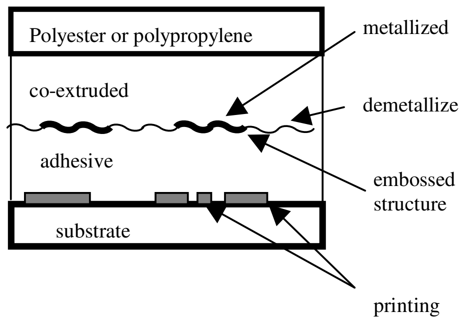

Figure 1.
A schematic of a semi-transparent demetallized hologram.

The fully transmissive DOVIDs can be seen on a number of passports, driving licences and other higher security documents. These are often used as an overlay where a polymer laminate covers the whole of the area and the DOVID is on selected areas of the laminate and it is used to help verify the underlying information is authentic. Typically these transparent DOVIDs, instead of a metal coating, have a high refractive index material coated over the surface. Typically these are materials such as titanium dioxide, zinc sulphide and zinc oxide. The mismatch in the refractive index between the coating and the polymer is sufficient to provide enough reflection from the interface to view the DOVID. The larger the refractive

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index mismatch the higher the reflection. This performance is traded off against the ease of use in manufacturing. The titanium dioxide has a high refractive index but is hard and brittle. The zinc sulphide is soft which allows, in some applications, the coating to be applied before the embossing is done. The softer coating will more easily deform and is less abrasive of the embossing shim. The zinc sulphide can be deposited much faster than the more difficult titanium dioxide and hence the cost per DOVID can be lower.

One special version of a DOVID is the Zero Order Diffraction devices. This is worth a mention because the spacing and height of the structure tends to be a tenth that of the other diffraction devices. This along with the fact that structure that once coated gets buried in the bulk of the polymer makes it more difficult to replicate or reverse engineer[1]. The advantage of the ZOD to the user is that it is more easily seen in poor light conditions. The structure is shown in Figure 2.

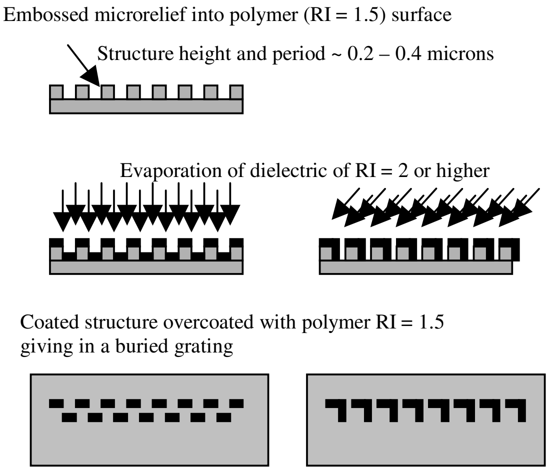

Figure 2. A Zero Order Diffraction (ZOD) device.

TAMPER EVIDENT DEVICES.

There are many different ways of producing tamper evident devices. Many of them work by irreparably damaging the device when opening the package. Having the device built up on a very frangible substrate can do this, or the weakness in the substrate can be added by putting in a series of slits at the point of application making it impossible to tear the device off intact. Many of these methods rely on having a very good adhesive that is resistant to heat, steam, freeze sprays and shear loads, all of which will be tried as ways of removing the device intact. If the adhesive can be made with two different strengths it is possible to change the fracture interface such that when the device is removed a message will appear.

This latter idea has been used to change the fracture plane within a multilayer vacuum deposited coating to produce a message. This cannot be put back together again because any adhesive used will not match the refractive index of two layers and will always give an extra reflection [2,3].

INTERFERENCE SECURITY IMAGE STRUCTURES

The type of iridescence effects that are seen in mother-of-pearl, fish scales or oil on water can be reproduced and enhanced using multilayer coatings to produce OVDs. In controlling the refractive index, thickness and absorption of the layers it is possible to produce a specific colour change with viewing angle. The best example of where this technology has been used is in the high security area of an anti-counterfeiting device on currency. Flex Products Inc. produce a five-layer coating stack on a polymer web that is then stripped off and milled to size. SICPA Spa then formulates these flakes into ink. And sold for use in high security application such as banknotes. In the USA the new series notes feature a green to black colour change. Different colour changes are available and these Optical Variable Inks are used on the currency in over 60 countries. The basic colour change effect can be obtained with only three coating layers but because the flakes can fall either way up the coating is deposited symmetric about a centre opaque reflecting layer as a five-layer structure[4]. This is shown in Figure 3.

It is possible to use the three layer structure and hot or cold stamp it onto a surface however in the case of banknotes that have some severe testing it was found that the material was much more durable if it were incorporated into an ink.

The Canadian banknote used a hot stamped multilayer structure to good effect[5]. This structure used an all-dielectric design, alternating high and low refractive index materials. The advantage of this type of structure is that because the absorption is low the brightness of the structure is better than the design using an absorber however the higher costs of having so many more layers can make this design too expensive. Figure 3 shows this type of design.

In depositing multilayer coatings it presents the opportunity for controlling the coating density and the adhesion characteristics and a weak interface can be designed into the structure making the coatings useful as tamper evident devices. An example of this is also shown in Figure 3.

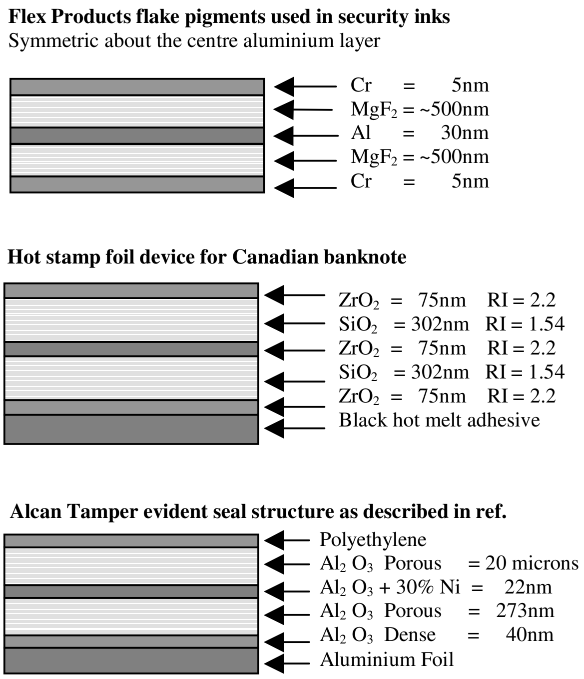

Figure 3. The structure of Optical Variable Devices.

RETROREFLECTORS

Retroreflectors have been available for many years. All of you will be familiar with their application for road signs. This same basic technology can be used for security applications. The transparent beads allow the viewer to see through to the underlying image or information by diffuse reflection from a viewing angle of near normal to the surface. When viewed at an angle with a light source the retroreflected image becomes easily visible.

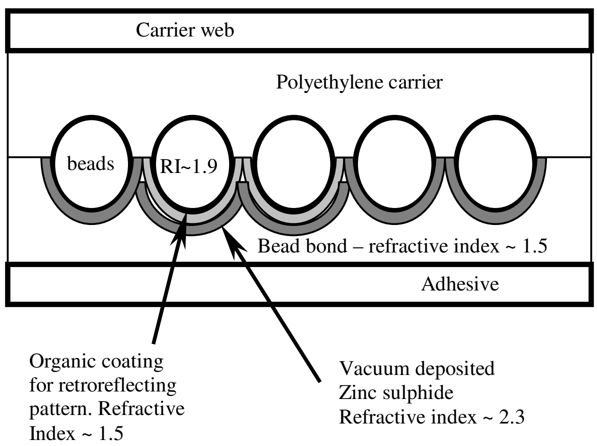

Figure 4. A schematic of a retro-reflective device.

The construction of the device uses differences in refractive indices of transparent materials to produce the reflective surfaces in the same way as other ISIS devices and hence if there is any attempt to tamper or remove the device a new interface to air will be produced. This new interface ruins the optical match and the effect is lost and cannot be re-introduced. This type of product is shown as a schematic in Figure 4. Typically it is used for temper evident labels [6].

ELECTRONIC ARTICLE SURVEILLANCE (EAS)

There have been a number of EAS technologies around for more than 10 years. Some have not required any vacuum deposited coatings. The two that did require vacuum deposited coatings were one of the magnetic tags and one of the radio frequency (RF) tags.
The structure of the magnetic tag is shown in figure 5. The soft magnetic material is the one that is vacuum deposited.

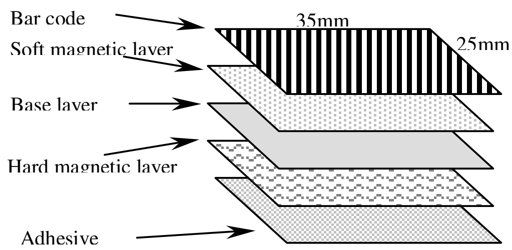

Figure 5. A schematic structure of a magnetic EAS tag

The RF tag used a patterned circuit as shown in figure 6. This was made from a sheet of metallized foil and the circuit pattern was printed on as a protective layer and the rest of the metal etched away. Alternatively solid aluminium foil was used a patterned. Conducting inks can now be used to print the circuit directly on the web thus making the process simpler and cheaper and this has superseded the vacuum coating and demetallizing.

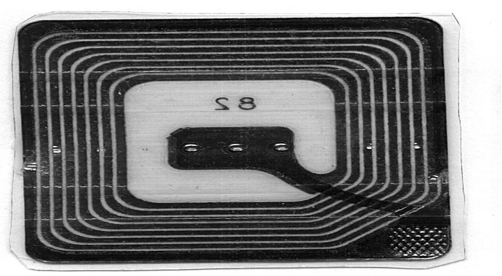

Figure 6. An RF EAS tag.

The newer smart cards that contain a microchip to store information also take advantage of this cheaper route to

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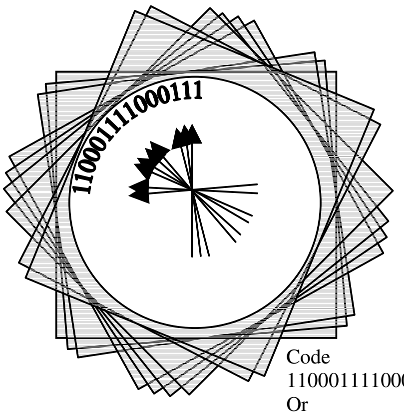
manufacture and have been designed to use conducting printing inks for the aerial part of the circuit.

There is now a new technology that requires metallized web[7]. This has a sputtered soft magnetic alloy sputtered on the polymer web. This metallized web is cut and laminated into a tag of many layers, typically 6 or 9. Each of the layers is oriented differently and as such can be addressed independently. The minimum angular separation is 3.75 degrees and hence it is possible to have each layer in any one of 48 orientations. This is shown schematically in figure 7 If the orientation is present it records as a '1' and if it is missing it records on the scanner as a '0' thus building up a digital code.

Each layer of the laminate is at different orientation.
Each layer is a polyester film coated with a with a sputtered magnetic metal alloy.



Code
110001111000111
Or
111000111100011

Figure 7. A magnetic multilayer EAS tag.

The scanner uses a rotating magnetic field to interrogate the tag at a speed of up to 400 tags per minute. If the tag in matched in orientation there is an electrical blip generated in the detector. It is this detection system that determines the minimum rotational difference between layers of the 3.75 degrees. These tags have been used permanently sewn into garments and bedding for hotels as a method of identifying the article and ensuring they as sent through the correct washing cycle. This was used to reduce the number of misidentified items down from the previous 20%, trials as still continuing. The tags lasted for at least 35 washes before some delamination occurred. This needs to be improved to a minimum of 50 washes at temperatures of up to and beyond 100 Deg C and also steam pressures of up to 32 bar.

FORENSICS - FINGERPRINTING.

There are two different applications of vacuum coating that are used in the forensic area of fingerprinting.

The first was derived from a forensic scientist who observed the appearance of fingerprints on what had appeared to be clean surfaces following the deposition of a thin coating in a small vacuum system. This process was developed and became a standard technique for highlighting fingerprints on certain difficult surfaces such as polyethylene.

When a surface is touched by fingertips there will, in many instances, be left behind small traces of grease or salts that have been exuded from the skin. These pores are sited within the ridges of the finger surface. These ridges make up the characteristic pattern of the fingerprint. The deposits will have a different surface energy compared to the rest of the surface. What was found was that when a very thin deposit of gold, of the order 0.1nm, was deposited on the surface the gold nuclei migrated to one or other of the surfaces thus highlighting the fingerprint pattern. This very thin gold only provides the nucleation site and zinc is then deposited to build up the coating to a thickness where the contrast between coated and uncoated surface is good enough to be photographed as a more permanent record. This technique also has the advantage that the coating can easily be removed using dilute acetic acid that allows the surface to be returned to its original state[8].

The second use of vacuum deposition for forensic work is in the manufacture of high performance fingerprint powders. Powders have a series of requirements that they should meet.

Powders should be;

1. Adhesive - easily adhered to fingerprint residues
2. Not caustic - no damage is done to the underlying surface
3. Mix well with other powders
4. Give good contrast - for photographing or lifting and photographing
5. Nondeliquescent - must not become liquid or melt during use
6. Not disappear on lifting tape
7. Not be gritty
8. Not clump or ball - maintaining fine size
9. Inexpensive
10. Non toxic
11. Heavy enough to develop a strong image by contact
12. Pass the slide test - when slid over a latent impression, weight and passage of the powder should develop the latent without additional or forced development.

We will all have seen the films where a cleanroom suited scenes of crime officer (SOCO) dusts a surface that is believed to have a fingerprint present. In real life it is slightly different. If the fingerprint is from a large greasy

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finger onto a light coloured, flat, smooth surface then dusting using a camelhair brush with carbon black is fine. However there are many more surfaces that are coloured, rough and textured and where there may be only a very light fingerprint residue left. In this case the standard fingerprint powder may not be appropriate and a higher performance powder has advantages.

Vacuum depositing metal films onto a polymer web and later stripping the metal from the surface by dissolving away a release layer has been done for many years[9]. The metal flakes that are produced can then be milled or ground to a smaller more regular sized flake. This type of product has been produced and used as pigments for very bright metallic inks and paints. These flakes have a very bright reflective performance due to the flatness of the flakes. This brightness and the light weight gives them an advantage over the flakes available previously which were manufactured by flattening small spheres of metal and grinding and milling down to size and shape. Aluminium and brass are two of the flakes that have been produced by this method. It would also be possible to produce coloured flakes by this method using interference layers over the thin metals.
The flake size that has been shown to work well is of an average 10 microns diameter and half a micron thick. This flake powder can be mixed with a 50 micron near spherical iron powder. This mixture if brought near to a magnetic wand will be picked up by the wand. The iron powder will trap some of the non-magnetic aluminium or brass flakes in the clump of powder. This powder ball is very mobile and light and when brushed across a surface the disturbance of the ball will shake lose some of the non-magnetic flakes and leave them behind on the surface. These flakes will adhere to the grease from the fingerprint. Any not adhering can be blown of brushed away. The flakes because of the high aspect ration will tend to lie flat and hence will exhibit quite high reflectance giving a good contrast ratio. This can either be photographed in-situ or lifted on tape and the tape photographed.

An additional advantage of this material is that by applying the flake from the powder ball there is less powder that is airborne and hence makes a safer working environment for the SOCO team[10].

TRANSPARENT CONDUCTING COATINGS.

Transparent conducting coatings of Indium Tin Oxide (ITO) or thin semitransparent metals on polyester web have been used as part of window security systems. Not only does the lamination of the polyester resist the shattering of the window but also the change in conductivity of the coating is used as a method of detecting that the window has been broken which can then automatically trigger alarm systems.

SUMMARY.

There are many applications of vacuum deposited thin film coatings as has been shown. For anyone starting out in this market area a good review of available technologies is given in the book Optical Document Security [11] and a good listing of the standard terminology & a checklist of technology requirements is given in the annual book of ASTM standards [12].

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