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E-beam origination technology:

Current state and development prospects.

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Abstract

We compare origination technologies of optical security elements. Electron-beam technology, albeit the youngest among them, has already moved to the fore in origination business. Optical security features made using e-beam technology are secured against fraud and are widely used to protect documents, banknotes, plastic cards, and brands.

Introduction

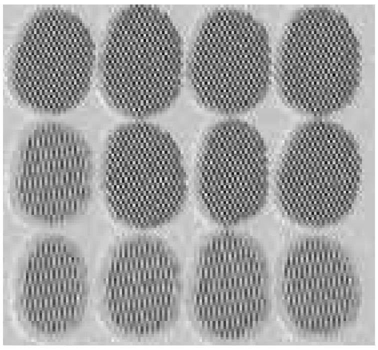
Optical technologies are currently widely used to protect banknotes, plastic cards, and brands. One of the first pilot projects involving the use of optical security features - holograms – was the Visa card project, which continues to use a 3D dove image. The project started more than 20 years ago, and the origination technologies of optical security elements has changed dramatically since then. Optically recorded features whose originals are synthesized using e-beam technology are in fact not holograms, but rather computer-synthesized flat nano-optical elements.

Origination technologies play a crucial role in protecting the optical elements, because it is the stage of origination that lays down the foundation of most of the security features. In this sense, electron-beam technology holds a special place. It is a knowledge-intensive and very rare technology.

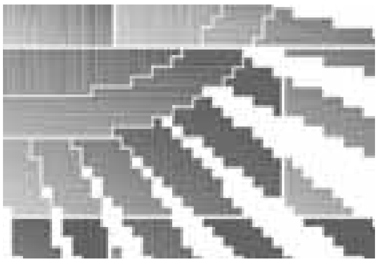
In this paper we try to answer the following question: Q: Can electron-beam origination technology be used to create security features for visual and instrument control that would be impossible to imitate using optical origination techniques?

Optical origination technologies

We have already mentioned the possibility of optical recording of 3D and 2D/3D holograms by means of laser radiation and optical tables. This technology, which was developed over 20 years ago, has since then been modernized and is still in use to this day. However, the so-called dot-matrix technology has become the optical origination technology of choice in the last ten years. The technology uses optical (laser) radiation to record the master hologram. The image is subdivided into circular or rectangular pixels and gratings are recorded into these pixels using interference of laser beams. Figure 1 shows a typical image pattern that can be seen through a microscope when looking at high magnification at a hologram originated using dot-matrix technology. Figure 2 shows a magnified image of optical elements originated using modern dot-matrix technology. The typical size of round pixels for dot-matrix technology is about 25 microns, which corresponds to a resolution of 1000 dpi. There have been reports about the development of dot-matrix technologies that can achieve resolutions as high



Figiure 1



Figiure 2

as 10000 dpi. The typical size of a rectangular pixel for modern dot-matrix technology is 8 microns. The minimum size of a dot that can be synthesized using this technology is 2 microns.

The first impression of Figs. 1 and 2 is that dot-matrix technology has a very limited potential as far as the generation of security features is concerned. However, this is not the case. These technologies have been progressing for over a decade and are now capable of synthesizing a large number of security features for visual inspection. These features include switch effects for 2D images, synthesis of 2D/3D and even 3D images.

As for expert control, optical security technologies make it possible to produce microtexts and even covert images that can be visualized using laser radiation and that are symmetric with respect to the zero order.

Figiure 3

In addition to dot-matrix there are other optical technologies, such as pixelgrams, direct exposure through masks, etc. Figure 3 shows schematically the synthesis of images using this technology. By changing the position of the optical element the observer sees kinematic effects of the motion of image fragments. All the above origination technologies use optical radiation and, like dot-matrix technique, have limited capabilities in terms of the synthesis of micro-relief compared with e-beam origination technology.

Despite the abundance of various optical origination systems, the technologies of the synthesis of hologram originals can be subdivided in two groups according to the physical nature of the radiation used. The first group includes dot-matrix, pixelgrams, exposure through masks, other similar techniques, which use optical radiation. The techniques of the second group use electron-beam technology to synthesize hologram originals.

Electron-beam technology has greater capabilities for the formation of micro-relief, and not only owing to its super high resolution. Optical origination methods can produce only image fragments with symmetric micro-relief. Unlike optical technologies, electron-beam technology allows creating optical elements with asymmetric micro-relief.

Electron-beam origination technology for the synthesis of optical security features.

Electron-beam technology of the formation of micro-relief was originally developed for microelectronics, where it had to constantly compete with similar optical technologies. The resolution of optical technologies is limited by the wavelength of radiation used. To increase the resolution, the technology has to move to ever shorter wavelengths – to the ultraviolet and even soft X-ray domain of electromagnetic spectrum. Electron-beam technology differs fundamentally from optical technologies because it uses electron beam, which can be very accurately focused with electromagnetic lenses. Electron-beam lithography has a resolution of 50-100 nm (0.05-0.1 microns). Modern e-beam lithography systems for microelectronics can even achieve a resolution of 10 nm (0.01 micron), which far exceeds any requirements in tasks involving the synthesis of optical elements.

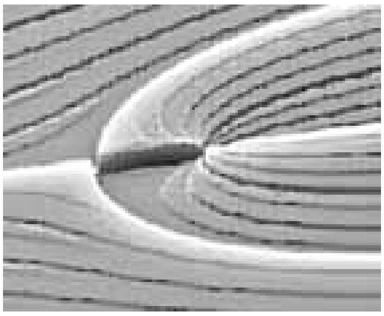
Figiure 4

Despite the abundance of various electron-beam lithographers, electron beam origination technology can be subdivided into two groups – Gaussian beam and shaped-beam lithographs. Gaussian beam systems use electron beam shaped in a round spot area, whereas shaped-beam systems can produce images made up of variously sized rectangles. These lithographers allow exposure time to be reduced substantially and are more complex than Gaussian beam systems. Figure 4 shows the appearance of a shaped-beam lithographer.

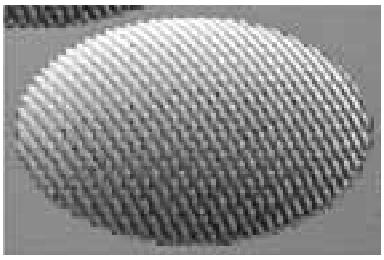
Electron-beam lithography systems are very complex devices. The technology of the formation of micro-relief is very knowledge intensive. Modern lithographers cost several million Euros, depending on the configuration. The high cost of equipment and the knowledge-intensive nature is a disadvantage for most of the technologies. However, in the case of security technologies this disadvantage is offset by their very limited use and the capability to offer secure protection against counterfeiting.

Nano-optics

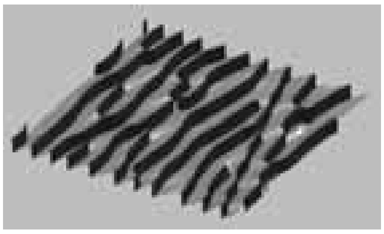
Electron-beam technology has stimulated the development of a new branch in optics - nanophotonics. Fresnel proposed flat optical elements as early as two hundred years ago. An optical element is called flat if the wavefront transformation in it occurs at micro-relief depths on the order of the wavelength. The high resolution of electron-beam lithography and its capabilities in the domain of precision formation of micro-relief contributed to the breakthrough in it. New optical elements produced using electron-beam lithography have been called nano-optical elements, because their micro-relief can be made with an accuracy of a few tens of nanometers. Figures 5 and 6 show the micro-relief of optical elements made using electron-beam technology. The elements have a complex micro-relief. Micro-relief is made with an accuracy of about 10 nm. The images of nano-optical elements shown in Figs. 5 and 6 are published with the permission of the Fraunhofer Institute (Germany).



Figiure 5



Figiure 6



Figiure 7

Electron beam lithography made it possible to turn a new page in the origination of security holograms. Originals made using electron-beam lithography, in fact, have nothing to do with holography. These are computer-synthesized nano-optical elements, which are in principle impossible to imitate by means of optical origination technologies. Figure 7 shows a fragment of the micro-relief of nano-optical security element made with the e-beam lithography system of Computer Holography Centre Ltd. The accuracy of micro-relief reproduction is of about 20 nm. Optical elements made using electron beam lithography are now widely used for the synthesis of both visual security features and for instrument control. Let us now consider in more detail the opportunities offered by the electron-beam lithography for visual inspection.

Electron-beam lithography for the synthesis of visual features

Electron-beam technology offers a wide range of features for visual inspection, which can not be simulated by means of optical hologram recording. Let us consider some of the features used in visual control:

Vertical true-color switch effect

The observer can see two different true-color images just by changing the position of the optical element. The vertical true-color switch-effect is used to protect banknotes of Sweden (Fig. 8). This effect it is difficult to forge or imitate by means of optical technologies.

Figiure 8

Switch-effect of 3D and 2D images

When the optical element is in normal position the observer sees a three-dimensional image. If the element is turned by 900 a different, two-dimensional image appears instead (Fig. 9).

Figiure 9

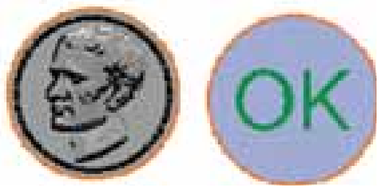
Switch-effect that appears when the element is turned by 1800

This switch-effect is fundamentally impossible to reproduce using optical origination technologies. Images originated using optical technologies do not change when the element is turned by 1800. Electron-beam technology makes it possible to create visual features where the image turned by 1800 does not match the image at 00. This feature can be exemplified by Decolor-effect (Fig. 10). In the normal position the observer sees the saturated color and contrast image, which, when turned by 1800, loses its color, becomes gray and disappears.

Bas-relief

Figiure 10

A new imaging technology, which gives the observer the impression of bas-relief, allows creating extra protection levels, such as an image that is visible in the second channel (Fig. 11).



Figiure 11

Kinetic effect of motion. Letter-lens effect

Figiure 12

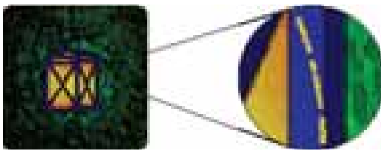
Various kinetic motion effects are currently commonly used to protect documents. Electron-beam technology offers similar visual effects. One of them is the Letterlens effect (Fig. 12).The observer sees at a point source inside the lens, which is actually a flat optical element, a letter or a symbol, which moves when the view angle of the optical element is changed. When the observer inclines the optical element full parallax motion effect is observed: the symbol or letter can shift both left/right and up/down directions.

Electron-beam technology for the synthesis of evidence for expert control

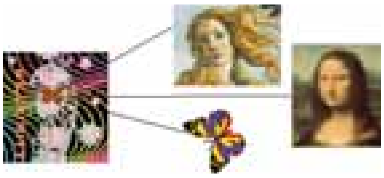
Electron-beam technology offers a wide range of features for expert control, which are impossible to reproduce by means of an optical hologram origination. Let us consider some of the features used for expert control.

Nanotexts and micro-images

The high resolution of electron-beam technology makes it possible to produce variously sized micro- and nanotexts with letters or symbols heights up to about 4 microns (Fig. 13). Another secure feature for expert control are true-color images with the sizes of 100-200 microns (Fig. 14):



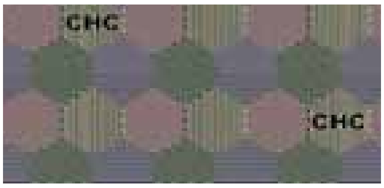
Figiure 13



Figiure 14

Shaped pixel technology

Electron-beam technology can be used to synthesize image made up of pixels of special shape, such as hexagons, as shown in Fig. 15. The pixel size in Fig. 15 is about 15 microns. This feature is easy to control and impossible to imitate with optical origination systems.



Figiure 15

Covert laser readable images (CLR)

CLR images have become an integral part of instrumental control. For more than a decade, the industry used the technology of the synthesis of symmetric CLR-images visualized by laser radiation. Electron-beam technology makes it possible to asymmetric micro-reliefs. When applied to CLR-images, this technology is called Multilevel CLR-image technology. In this case, the observer sees on the screen of the device for CLR image control two different images at once (Fig. 16). The micro-relief of Multilevel CLR-images can be synthesized with an accuracy of 15 nm. Such images are impossible to forge or imitate using optical origination technologies.

Figiure 16

Conclusions

E-beam technology offers a wide range of security features for visual and expert control and is well is protected against forgery. Mass replication of optical security features can be made with standard equipment for the reproduction of holograms.

The disadvantages of e-beam technology are its knowledge-intensive nature and the high cost of equipment. However, these disadvantages become an advantage when it comes to the production of security features. Very few companies in the world have the equipment and technology needed for e-beam, and one specializes in the production of top-level security hologram originals to order. Our customers include many Indian companies and we are always open for cooperation in the field of security technology.