Encoded cell grating array in anti-counterfeit technology

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The dot matrix hologram (DMH) has been widely used in anti-counterfeiting label. With the same technology and cell array configuration, we can encode to the incidence beam. These codes can be some image matrix grating with different grating gap and different grating orientation. When the multi-level phase diffractive grating is etched, the incidence beam on the cell appears as an encoding image. When the encoded grating and DMH are used in the same label synchronously, the technology of multi-encoded grating array enhances the anti-counterfeit ability.

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When we fabricate an anti-counterfeiting product, other than expecting special material and novel high-tech, it is more important to ensure that this product is not counterfeited in principle. In living, it is entirely possible, to introduce corresponding random gene handily only during fabricating process. Holography is one process of principle anti-counterfeiting in nature[1,2]. For example, in area of society commonality security, protected knowledge property rights, finance, name brands etc., they are used to protect the genuineness of the brand name and authenticity of a product against the spurious, imitation and duplicates. Although in principle hologram is impossible to be copied exactly, in vision effect, it is necessary to have clearly recognized character.

In this paper, we proposed using more than one method to encrypt a hologram, which is constructed by computer-generated images to decrease the cost of making a hologram with some special symbols. This dot matrix (digital) hologram (DMH)[3] allows the implementation of unlimited computer generated dots in hologram. These holograms are the result of designs comprising many tiny dots, where each dot is a separate diffraction grating. Under the white light, the hologram will reconstruct the encoded image. The special symbols are embedded in this hologram. These are various encoded gratings[4]. When they are irradiated by a laser beam, the special symbols will be shown. In comparison to the DMH, the front picture consists of more than a million very small diffraction grating cells within a few square millimeters. The later is only a few tens cells for the simple encoded pattern. It does not affect the DMH performance, and their process technologies are the same.

When a laser beam irradiates the cell grating array, the encoded array will diffract different patterns. These encoded grating periods and angles can be calculated using the following equations (shown in Fig. 1)

$$\sin\theta = \frac{D}{P} = \frac{\sqrt{(x_i - m_i)^2 + (y_j - n_j)^2}}{\sqrt{F^2 + (x_i - m_i)^2 + (y_j - n_j)^2}}, \quad (1)$$

where (x_i, y_j) is the coordinate of diffractive image in the x, y reference frame; (m_i, n_j) is the coordinate of a cell in the m, n reference frame.

The corresponding grating period would be

$$d = \frac{\lambda}{\sin\theta}, \quad (2)$$

and

$$\phi = 90^\circ + \delta = 90^\circ + \arctan\left(\frac{y_j - n_j}{x_i - m_i}\right), \quad (3)$$

here, λ is the laser wavelength, ϕ is the angle of inclination in a cell array grating. It can encode various patterns through programs using these equations.

The structure of cell array grating is produced by the electron beam lithography (EBL) system. In this technology, the etching depth of material will decide the diffractive property of the cell array grating. In order to give a symmetrical reconstructed pattern, we need to fabricate a group of Raman-Nath diffractive gratings. For asymmetrical reconstructed pattern, rather than choosing similar blazed grating, as shown in Fig. 2, it is the relation with the refractive index of material, mode of transmission and reflection, and choice of multi-level etc. that plays a key part. Here d is a grating period, L is the thickness of medium.

As a diffraction grating, $L = \lambda/[2(n-1)]$, where n is the refractive index of material. Figure 2(b) is a multi-levels diffraction grating (for example 4 levels), $L = 3\lambda/[4(n-1)]$. The diffraction efficiency from first order is[5]

$$\eta = \sin c^2(1/l) = \left[\frac{\sin(\pi/l)}{\pi/l}\right]^2, \quad (4)$$

where l is the number of level. When $l = 2$ or 4, $\eta_2 = 0.4$ and $\eta_4 = 0.81$ respectively. This technology is available

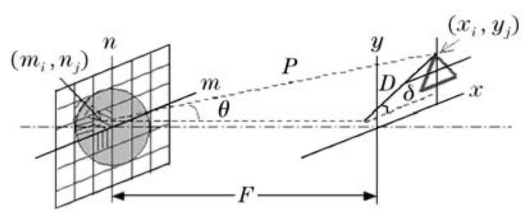

Fig. 1. Illustration of encoded cell grating array.

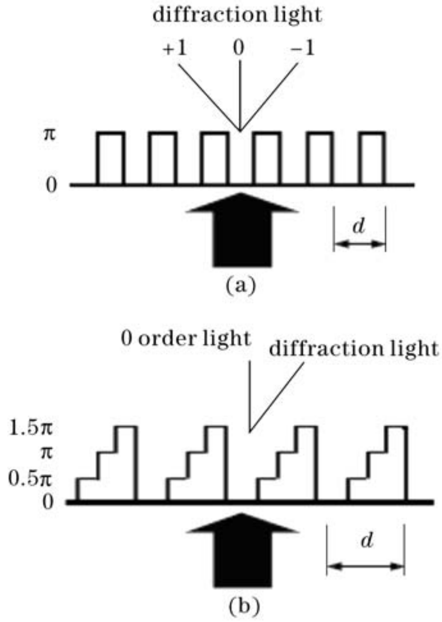

Fig. 2. Structure of cell array grating. (a) binary grating, (b) phase diffraction grating.

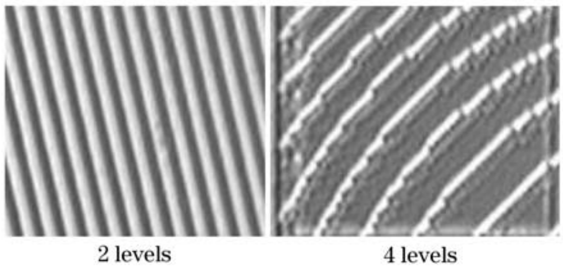

Fig. 3. Etching photo.

in the optoelectronics research center, city university of Hong Kong. This electron beam lithography system can provide resolution down to 30 nm line width. When the cell grating array needs 4—8 levels of the phase modulation in the 2π ranges, i.e., the varying depth is approximately 0.3—0.15 μm, the required etching precision is higher.

Figure 3 shows the etching photo from 2 levels and 4 levels respectively. We assume that the size of the cell grating array is 0.5×0.5 mm^2, the maximum size of the reconstructing image is 20 mm. When the diffractive angle is about $0°$—$30°$, the minimum grating period in this cell is about 1.3 μm.

In these experiments, we employed only 21 sloped directions (in Fig. 4). They are mixed with holistic or separate cells in DMH. It can be easily accomplished by computer programming. However, separate cells will bring some noise, and will be limited in reconstructing laser beam size. Due to a variety of grating periods and sloped directions, we will observe different colors on each cell. In the fabrication process, the 50-nm resolution of EBL is used to control the grating period. The beam energy will change the etch depth. Because this grating is made point by point, the fabrication time is longer. For example, a 10×10 mm^2 label needs about 50 hours (the cell size of DMH is 0.1×0.1 μm^2, so this DMH consists of one million very small diffraction grating cells).

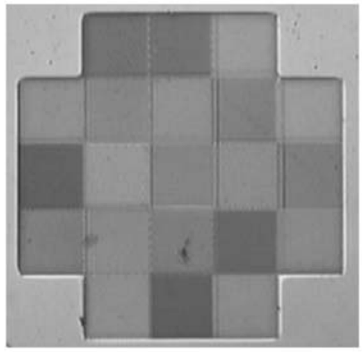

Fig. 4. Cell grating array (0.5×0.5 mm^2) embedded in DMH.

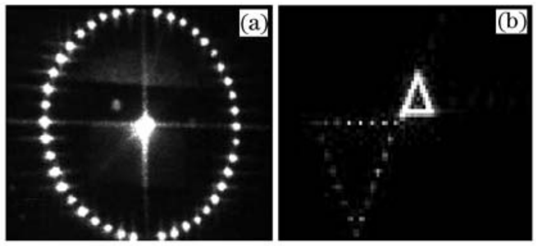

Fig. 5. The point ring from the binary grating (a) and a triangle from multi-levels grating (b).

Fig. 6. Illustration using CITYU emblem.

Figure 5 shows two different experimental results. Figure 5(a) is a reconstructed image from Raman-Nath grating. Figure 5(b) is a reconstructed image from four-levels diffraction grating. Due to the effect of multi-periods between each level, it will bring some noise in Fig. 5(b), but the diffraction efficiency from the main image is still very high.

In conclusion, these cell grating array can be embedded in a dot matrix hologram[6]. This hologram is a "CityU" emblem of the city university of Hong Kong. When illuminated by white light, this emblem is shown as a strong contour image from a certain angle and therefore, servings an anti-counterfeiting label. When using He-Ne laser to illuminate some coded positions, some embedding information can be revealed, as shown in Fig. 6. Because the process technology of dot matrix hologram and cell grating array are the same using EBL, they are fabricated synchronously. And the very small number of cells will not influence the original anti-counterfeit effect of DMH. When the multi-encrypting technologies are concentrated in an emblem, it will be more effective for the anti-counterfeiting.

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