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Hologram Origination Combining Rainbow and Dot-matrix Holograms

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This paper describes hologram origination process combining rainbow and dot-matrix holograms. Rainbow and dot-matrix holograms origination processes were combined to produce hologram showing different images. Both holograms were recorded consequently in a photoresist layer on the same sample. Dot-matrix hologram origination process was performed using laser diode PMMF 608-G at wavelength 405 nm. For rainbow hologram He-Ne laser (632.8 nm) and He-Cd (441.6 nm) lasers were used. The combined holograms viewed at appropriate angle showed dot-matrix and rainbow hologram images at the same time. Microanalysis of combined hologram surface demonstrated features, which are typical for both dot-matrix and rainbow holograms processes.

Keywords: rainbow hologram, dot-matrix hologram, laser interference lithography, diffraction efficiency.

1. INTRODUCTION

Holograms and Optically Variable Image Devices (OVID) are widely used for optical document security and brand authentication [1,2]. The dot-matrix hologram is one of the most used methods in optical document security [2 – 4]. Dot-matrix hologram offers range of kinematic and optical switching effects and provides increased flexibility for hologram designer if compared to traditional forms of holography [5, 6]. In contrary, the rainbow holograms after invention by Benton [7] were used for decorative purpose mostly due to their very good 3D image representation. On the other hand, since classic rainbow hologram recording includes two steps process with two different wavelength lasers, this type of hologram offer increased security for anticounterfeiting applications. However rainbow holograms recorded using only one wavelength laser was described in [8].

The demand on optical security is increasing year after year, therefore more complicated methods were developed to fulfill optical security and brand authentication market. Namely, the combination of different optical security methods in one hologram was successfully applied. For example, the dot matrix hologram was recorded by replacing Laser Interference Lithography (LIL) with Electron Beam Lithography (EBL) [9,10] therefore security features of dot matrix hologram were increased. The same authors described more complicated approach in [6]. In this work both LIL and EBL methods are combined for hologram formation on the same sample. Such combined approach and EBL application permitted further more reducing probability of counterfeit possibility. On the other hand the EBL is expensive process therefore it makes such approach complicated for hologram producers as well.

In this work we report the hologram origination process combining rainbow and dot-matrix hologram. Both hologram origination processes were used in one sample to offer at least two approaches of authentification and increased security features of final product.

2. EXPERIMENTAL

Both holograms were recorded consequently on the same sample in a positive tone photoresist ma-P1205 layer (thickness 500 nm) spin coated on a glass plate (50×50×3 mm). Optical set-up and dot-matrix hologram recording process in more detailed way is described in our previous work [11]. To reduce production cost of the hologram the He-Cd laser in original optical set-up was replaced with a laser diode PMMF 608-G. The rainbow hologram was recorded in two steps [7] where two different wavelength lasers were used: He-Ne laser (632.8 nm) [12] and He-Cd laser (441.6 nm) [13 – 15]. After both holograms were recorded the photoresist layer was developed in a Microposit® MF-26A developer for appropriate time [16 – 18].

To superpose two different holograms on one sample both holograms were designed and recorded separately. Fig. 1 illustrates process of the holograms design. At first, the virtual image for dot-matrix hologram (Fig. 1, a) was created using computer software CorelDRAW®, in this case a simple text – four characters "VMSF" were used. For the rainbow hologram the object with 3D features (an apple) and background (array of text "PALANGA") were chosen. Real image of the object in front of the background is acquired by a photo camera (Fig. 1, b) and saved on a computer. In the next step, the virtual image of the dot-matrix hologram was placed on top of the acquired photo image (Fig.1, c) using the same computer software. By this procedure the final view of combined hologram is determinate and the alignment between two images is established. At that point the designed model of combined hologram is finished and it can be used for the hologram authentification inspection.

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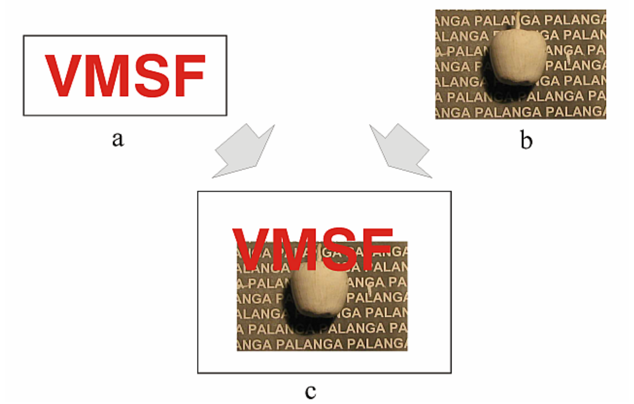


Fig. 1. Design process of combined holograms: a – virtual image for dot-matrix hologram produced using computer software, b – real image acquired by photo camera: the object (apple) is in front of the background (array of text "PALANGA"), c – designed model of combined hologram

In Fig. 2 the origination process of separate holograms is illustrated. The virtual image of text "VMSF" (Fig. 2, a) is used to record dot-matrix hologram (Fig. 2, b), as it was described in our previous work [11].

The rainbow hologram recording process is performed in two steps – at first the 3D hologram of a real object and background is recorded on photo plate "MIKRAT LOI-2" [19] using He-Ne laser as described in [12]. After developing and bleaching procedures the transparent 3D hologram (Fig. 2, c) were used to record separated rainbow hologram (Fig. 2, d) with a He-Cd laser [7]. The image of used transparent 3D hologram is presented in Fig. 2, c. Separately recorded and developed rainbow hologram is presented in Fig. 2, d.

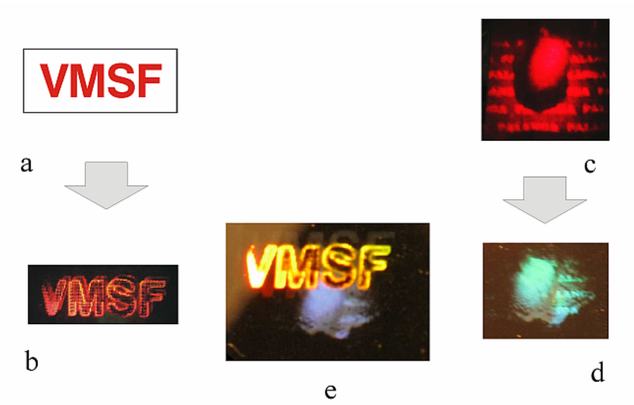


Fig. 2. Separately recorded dot-matrix (a, b) and rainbow (c, d) holograms and two images of combined hologram (e)

After separated holograms were produced, both recording processes were repeated on the same sample. At first, the dot-matrix hologram were recorded (but not developed). Then the rainbow hologram was recorded in the same area of the sample and both holograms were developed (Fig. 2, c).

To determine appropriate exposure dose for both holograms, series of dot matrix holograms with different exposure dose were recorded in the same area with the rainbow holograms. Developing time and exposure dose for the rainbow hologram was kept constant and time of exposure of the matrix hologram was varied. Diffraction efficiency of holograms was measured using a custom made stand with He-Ne laser as described in [11, 14, 16, 20].

3. RESULTS AND DISCUSSIONS

Since both holograms were recorded on the same sample, the developing process was performed at the same time for both holograms. Therefore the appropriate dose of exposure should be chosen for the holograms to insure good diffraction efficiency of the final product. If holograms are recorded separately, it is possible to compensate shortage of exposure dose by increasing the developing time. If both holograms were produced on one sample, there is no possibility to compensate any mistakes in exposure dose because increasing developing time for one hologram will overdevelop another one. Fig. 3 represents the dependence of diffraction efficiency of dot-matrix hologram on exposure dose. From this picture it is clear that best diffraction efficiency is achieved when dose of exposure of matrix hologram varies from 32 mJ/cm^2 to 42 mJ/cm^2.

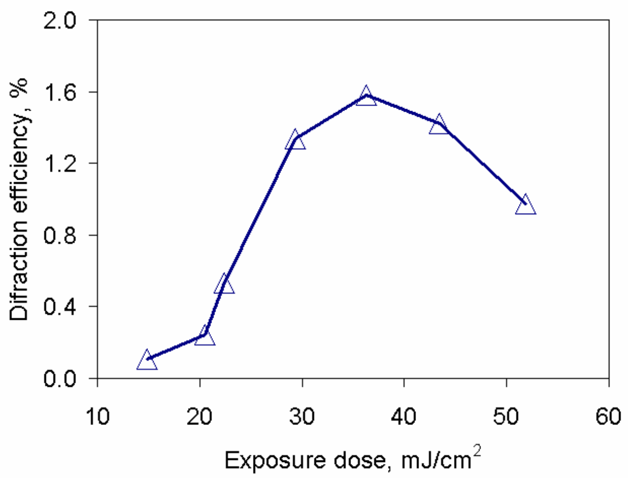


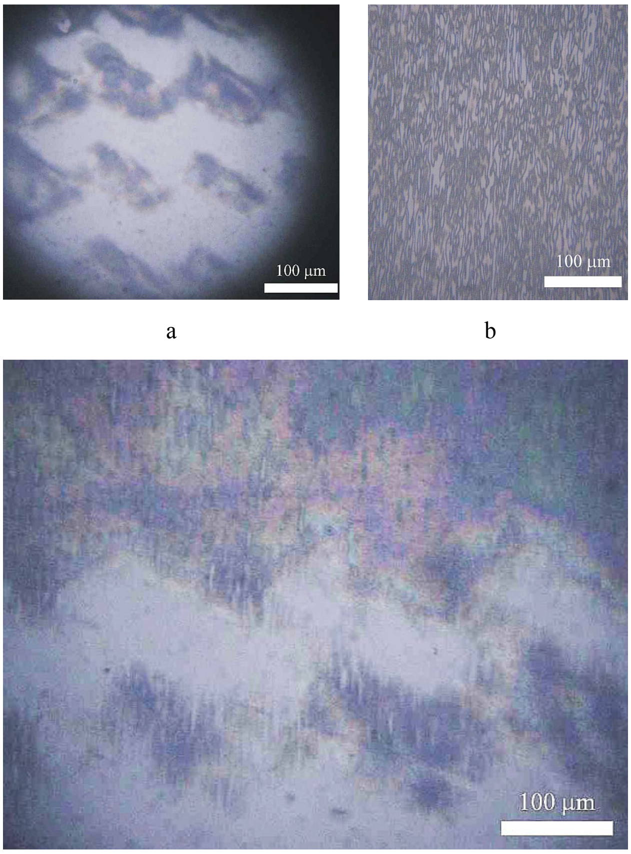
Fig. 3. Dependence of diffraction efficiency of dot-matrix hologram on exposure dose

When the separated dot-matrix hologram (Fig. 2, b) was viewed at different angles it showed the designed image (Fig. 2, a) with the effects typical for dot-matrix holograms: color changes, switching on and off. Separately recorded and developed rainbow hologram (Fig. 2, d) showed image of the object in front of background with 3D features – when angle of the view was changed, the object changed its position with regard to background.

From the picture above one can see that images of the combined hologram (Fig. 2, e) represent exactly the same images as in the designed model.

Three main features were checked when the combined hologram was viewed at the appropriate angle. At first the images of combined hologram (Fig. 2, e) represent the same images as in the designed model (Fig. 1, c). At second, the dot-matrix image is overlapping with the rainbow hologram image (see Fig. 2, e) at the same place as in the designed model showing the correct alignment. And finally, when viewing angle was changed it was found that both images present typical features, namely dot-matrix hologram exhibits color changing and switch off-on effect and object in the image of rainbow hologram was changing its position regarding to the background.

The produced combined holograms were analyzed to reveal their microscopic features. Micrographs of two separated holograms are presented in Figs. 4, a, and 4, b). In the first micrograph (Fig. 4, a) the array of dots can be seen – this feature is typical for the dot-matrix holograms [11]. And contrary, in the second image micrograph (Fig. 4, b) system of well-defined vertically orientated strips can be observed – this feature is well known for rainbow holograms [21]. In the area where both holograms overlap both features can be seen: in the upper region the strips from rainbow hologram and in the area below – dots from dot-matrix hologram (Fig. 4, c).



a b

c

Fig. 4. Micrographs of the separated (a, b) and combined (c) holograms (scale bar length is 100 μm)

All stated above features can be presented in one hologram if two different methods of hologram origination are combined. If these images were made by a single process it could not show all the features that are typical for different methods. Combining two different methods of hologram origination in one sample enables to increase security features of the final product. The proposed combination of different optical security methods appears to be efficient like others using electron beam lithography [6] and other origination techniques.

4. CONCLUSIONS

The hologram origination process combining rainbow and dot-matrix holograms is presented. Two different approaches for authentification inspection were checked. The features typical for both images were identified by viewing hologram at different angles: dot-matrix generated image showed colour changes and switch off-on effects and rainbow hologram image demonstrated its 3D features. Overlapping area of microscopic features typical for both dot-matrix and rainbow holograms were detected in the original. It is demonstrated that alignment issues of both images as well as exposure dose are important in defining quality of the final product.

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