

Interference filter with amorphous silicon layer and direct laser recording on it

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Abstract. The interference spectral filters with amorphous silicon layer deposited by magnetron sputtering on the reflective metal layer on a glass substrate are developed. Interference filter select from white light source components corresponding to quasi-monochromatic wavelength with a narrow bandwidth. The thickness of the amorphous silicon layer determines the center wavelength of the pass band of the filter. It proposed to use interference filter with amorphous silicon layer for direct laser recoding on it. Results on direct laser recording on amorphous silicon layer of the interference filter by single-mode Blu Ray laser ($\lambda = 405$ nm) with high contrast reflected image are demonstrated.

1. Interference spectral filters on the amorphous silicon films

The interference spectral filters obtained by magnetron sputtering of amorphous silicon films to the metal layer on the glass substrate are developed. Photo of interference filters with the amorphous silicon layer with different bands of light reflection is shown on figure 1. These filters have a very narrow bandwidth in the visible region of spectrum.

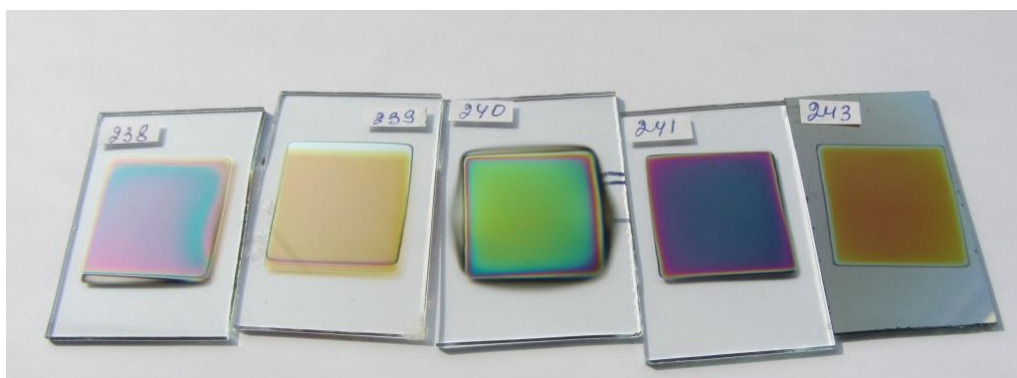


Figure 1. Photo of interference spectral filters with amorphous silicon layer with different color bands of reflected light.

The structure of the developed interference filter with amorphous silicon layer is shown on figure 2. Amorphous silicon film thickness d determines the principal wavelength of the band pass filter.

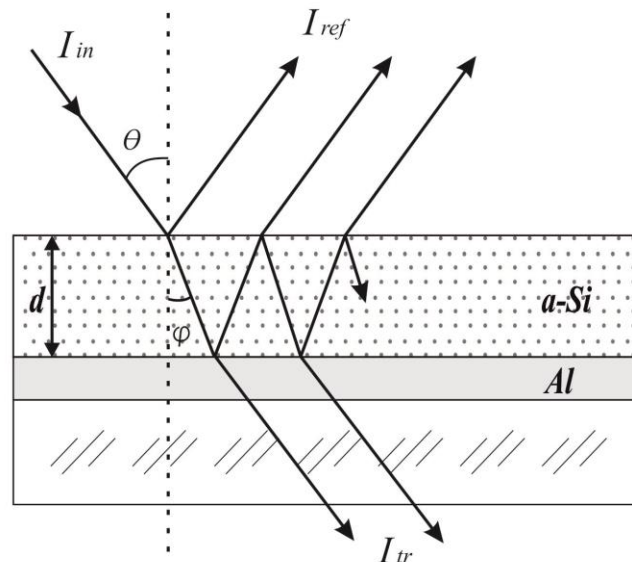


Figure 2. The structure of an interference filter with a-Si layer.

Interference filters with amorphous silicon layer reflect a part of the incident white light spectrum due to the phenomenon of multiray interference in thin dielectric films.

Multiray interference occurs when a light wave passing through the amorphous silicon layer with thickness d and refractive index n . θ and φ - angles of incidence and refraction rays at the upper boundary ($\sin\theta = n\sin\varphi$). The path difference for rays will be

$$\Delta = 2nd \cos \varphi \quad (1)$$

The reflection wave from the upper boundary of the layer in accordance with the Fresnel formulas its phase is changed to π . Therefore, the phase difference δ of folded waves is

$$\delta = (4\pi/\lambda_0)nd \cos \varphi \pm \pi = k\Delta \pm \pi \quad (2)$$

here λ_0 - wavelength in vacuum, $k = 2\pi/\lambda_0$

The multiray interference light intensity of the transmitted and reflected waves is described by the formulas Airy:

$$I_{tr} = I_{in} \frac{(1-R)^2}{1+R^2-2R \cos \delta} = I_{in} \frac{1}{1+(4R/(1-R^2)) \sin^2(\delta/2)} \quad (3)$$

for reflected wave

$$I_{ref} = I_{in} \frac{2R(1-\cos \delta)}{1+R^2-2R \cos \delta} = I_{in} \frac{(4R/(1-R^2)) \sin^2(\delta/2)}{1+(4R/(1-R^2)) \sin^2(\delta/2)} \quad (4)$$

The interference spectral filters with the amorphous silicon can be used in spectroscopy, fabrication of laser, for direct laser writing, laser marking and security applications.

2. Direct laser recording on a-Si layer of the interference filter

Method of direct laser recording on an amorphous silicon layer is based on the phenomenon of the direct formation of a micro relief by focused laser radiation. There is laser induced transition from amorphous to polycrystalline silicon by local laser heating and temperature rise. Previously, we

demonstrated the possibility of direct laser writing on the a-Si films by laser radiation with different wavelengths [1]. Direct laser recording on amorphous silicon film is attractive for diffractive structures recording without wet chemical processing and it brings new possibilities of diffractive structures fabrication with the use of laser writing device [2]. The use of high-speed scanning system of interference lithography (SIL) [2] forming diffractive structures by consecutive writing of moderate-size fragments or cells is expected to assist in solving the problem of deposition of antireflective diffractive coatings onto large-size surfaces of solar panels. Early, we demonstrated direct laser recording of dot holograms on amorphous silicon film by pulsed UV laser with $\lambda = 355$ nm [3].

In this paper we demonstrate possibility of direct laser recording on a-Si layer of the interference filter. Results of direct laser recording on amorphous silicon film of interference filter using single mode Blu Ray laser with $\lambda = 405$ nm is shown on figure 3. The Latin letter L is chosen for test direct laser recording on a-Si layer of interference filter. The experimental results demonstrate change in transmission of the amorphous silicon layer after its exposure by focused laser radiation. Registration layer becomes more transparent in place interacted by laser radiation. Early, measurements of absorption spectrum demonstrated that amorphous silicon layer's refractive index is changing after exposure by focused laser beam [1]. Thus, in the area of interference filter exposed by focused laser radiation multiray interference is not working and we could see contrast image of letter L in the reflected light on the blue background from the interference filter.

For direct recording on amorphous silicon the Mitsubishi 120mW single mode Blu Ray laser is used. Laser beam is collimated by aspheric lens after laser diode and then it is focused by micro objective to recording media. Computer controls laser pulse duration and their frequency. For direct laser recording the amorphous silicon films with varying thickness deposited by magnetron sputtering on a glass substrate are used.



Figure 3. Direct laser recording on the a-Si layer of the interference filter by Blu Ray laser with a $\lambda = 405$ nm.

As seen from photo on figure 3, direct laser writing on layer of a-Si interference filter provides a good contrast of the image in the reflected light due to the refractive index change and the transparency of the recording layer, the formation of the relief structure after interaction by laser radiation.

The relief formed by direct laser recording on a-Si layer of interference filter is studied on scanning electron microscope. A relief structure formed by a focused laser beam on a-Si layer is shown on photo taken on scanning electron microscope (figure 4).

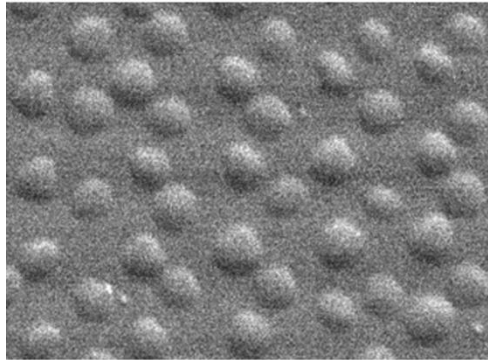


Figure 4. Photo of relief structures formed by a focused laser beam on a-Si layer taken on scanning electron microscope.

It's shown that under interaction of *a*-Si film by focused laser beam the local crystallization appears and relief is forms with height ~ 100 nm. Diameter of hemispheres induced by focused laser radiation of Blu Ray laser on a-Si layer is about 40 micron.

The drawback of single mode laser diode used for experiments was a short length of coherence and it dependence from output radiation power. Thus, it was difficult to record dot holograms by Blu Ray laser for fabrication of master matrix hologram for embossing holograms reproduction. Therefore, it will be useful to use Blu Ray laser with the greater length of coherence for dot holograms recording.

Direct laser writing on the amorphous silicon film could be used for fabrication of diffractive optical elements (DOE), security applications.

Summary

The interference spectral filters with amorphous silicon layer deposited by magnetron sputtering on the reflective metal layer on a glass substrate are developed. Direct laser recoding on amorphous silicon layer of interference filter is proposed. Results on direct laser recording on amorphous silicon layer of the interference filter by single-mode Blu Ray laser ($\lambda = 405$ nm) with high contrast reflected image are demonstrated. Laser radiation induced relief formation on a-Si layer is studied on scanning electronic microscope. It makes attractive use of direct laser recording on amorphous silicon for laser marking, DOE fabrication and security applications. Use of single mode Blu Ray laser opens opportunities to design compact laser device for micro structures fabrication for different applications.

References

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