The research of the properties of thin films of molybdenum to form the contact masks for diffractive optics elements

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Abstract. Researched the parameters of the microstructures, obtained by laser termochemical space recording in films of molybdenum with a thickness of 17, 35 and 70 nm, deposited on a glass and quartz substrates. Graphs of the spatial resolution of the microstructures as a function of the laser power are plotted for different substrate materials. It is shown that a higher spatial resolution of the microstructures can be achieved in the molybdenum films with a 17 nm thickness.

Keywords: microstructure, laser ablation, thermal recording of a molybdenum film, glass and quartz substrates

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Introduction

It seems promising to use in various fields of science and technology of diffractive optical elements (DOE), which are plates formed on their surface microstructure [1, 2]. The most important stage of manufacture of the microreliefs is get contact mask resistant to plasma-chemical processes necessary to transmit the calculated microstructure of the DOE in the substrate. Previously this had been circulated lithographic (wet) technology [3–8].

At the present time to reduce the dimensions of the microstructures, the widely used method of formation of topological drawing directly in the source layer of the material of the contact mask without the use of photoresists. It is based on local processing of thin films of chromium focused laser radiation [9, 10], under the influence of which is thermochemical conversion of the surface layer of the work material.

The disadvantage of this technology is the low resolution of about 0.8 μm. Therefore urgency to the task of developing techniques that allow to overcome this barrier. This result is possible through search and application of materials with contrasting characteristics to selectively use a maximum of activating radiation. In this respect, a well-known series of works, where instead of chrome offers a variety of alternative materials, such as silicon, indium phosphide and the oxides of various metals [11–13]. Unlike standard technologies they propose to form a microstructure by evaporation (ablation) of material.

In [14] have demonstrated the possibility of ablation of molybdenum films with a thickness of about 0.5 μm picosecond laser beam with a wavelength of 1064 nm, deposited on a sublayer of silicon nitride thickness of about 140 nm. The grounds were glass substrate of a thickness of 3 mm.

Based on [14], we proposed an approach based on the ablation areas of the film of molybdenum exposed to laser radiation [15].

The purpose of this work is to study the feature of the contact mask, obtained by laser ablation of films of molybdenum, depending on the thickness of the films, which will produce the optimum conditions of carrying out the process.

1. Methods and materials

The base served as an optically smooth substrate made of glass and fused quartz brand KV of size 50×50 mm, thickness 3 mm. Film of molybdenum with a thickness of 17, 35 and 70 nm were deposited by magnetron sputtering method on the "Caroline D-12A" under the following conditions: the power of the magnetron is 700 W, the temperature of the substrate is 200°C, a pressure of argon to 2.0·10-1 Pa. The time of deposition was determined by the finite thickness of the films and ranged from 2 to 8 min.

Patterns in the films formed on the laser writing station CLWS-200 [16–18].

Recording was conducted under the following conditions: operating wavelength of the laser radiation is 488 nm; maximum power supplied to the recording head 100 mW; record structure – concentric rings with a pitch of 3 μm and an outer radius of 3 mm; the magnitude of the power for each ring decreased from 100 % at the point of greatest radius to 0 in the centre with a step of 0.5 %. The speed of rotation of the sample – about 10 s^{-1}. the Specified parameters of the process corresponded to the maximum power density of laser radiation $E_{max} = 2 \cdot 10^7$ W/cm^2. The effect of laser radiation led to local evaporation thin film of molybdenum over the entire thickness.

The morphology and elemental composition of the surface of the nanostructures were studied using scanning electron microscope (SEM) Hitachi TM3030 with integrated EDS spectrometer.

2. Analysis of the results

In Fig. 1 shows the dependence of the width of the lanes from the laser output power for a radius record of 3 mm. Dependence obtained for quartz and glass substrates. The width of the recorded tracks in the first place, depends linearly on the laser power. When they are the same width for quartz substrates requires approximately 20% more power, due to the difference in the thermophysical properties of quartz and glass. Quartz, having a larger thermal conductivity, assigns laser energy from the field of film. Film thickness of 17 nm show higher spatial resolution, 2500 mm^{-1}, against 1500 mm^{-1} for films with a thickness of 35 nm. The permissions that are close to the maximum was reached in the power density in the range (0,7...1,2)·10^7 W/cm^2. Note that this is significantly less than the theoretical values obtained, for instance, in [11].

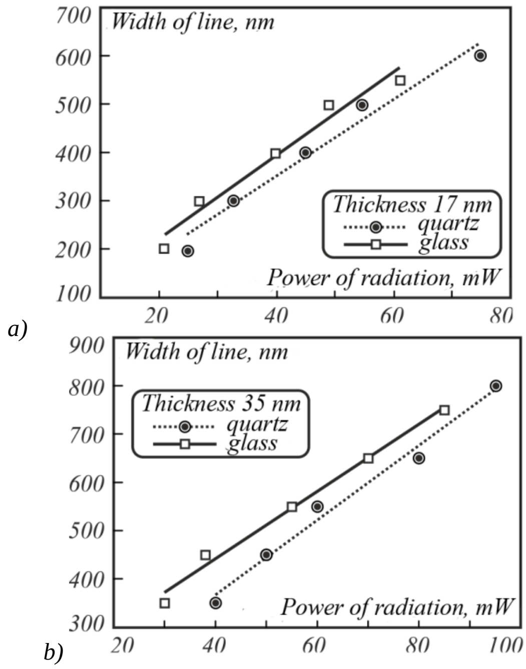


Fig. 1. – The dependence of the line width of the nanostructure on the power of laser radiation for films with a thickness of 17 nm (a) and for films with a thickness of 35 nm (b)

Presented on Fig. 2 pictures of SAM films with a thickness of 35 nm, exposed to the laser beam, allow the edges of the tracks to watch the products of destruction as representing a zone of thermal influence. Most likely, their emergence with the removal of a significant portion of the substance from the area of reactive ablation recoil pressure PA-world jet [19]. As shown earlier, their height does not exceed the thickness of the film [15].

For films with a thickness of 17 nm, the formation of degradation products is not typical (Fig. 3). This can be explained by the fact that the energy of laser radiation is enough for a quick and complete evaporation of the material at the point of impact. For these two cases are well for-markedly boundary of the critical power at which the evaporation of the metal stops. Also around tracks observed subtle trace of a width equal to the diameter of the laser spot. Probably, this area needs to impose restrictions on the minimum recording period. For films with a thickness of 70 nm of the radiation energy is insufficient for the formation of tracks even in areas with a minimum radius of recording (Fig. 4). It is important to note the following. For systems with circular scanning absorbed by the material energy (dose) of laser radiation at a constant power density varies with the radius record, since the radius of the record specifies an effective time of exposure. The decrease of power density from the edge to the center with simultaneous increase of exposure time to have an opposite effect on the magnitude of the radiation energy. However, in our case a decrease in the size of the track as you approach the center, that allows claim about the decrease of the absorbed energy.

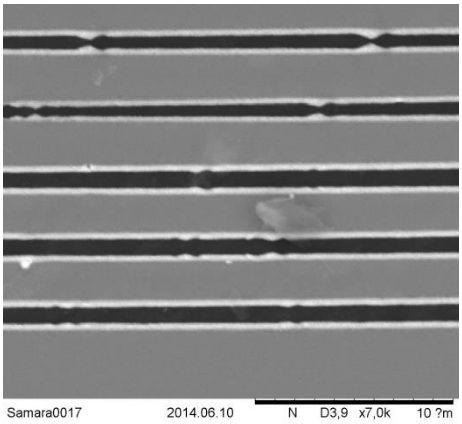
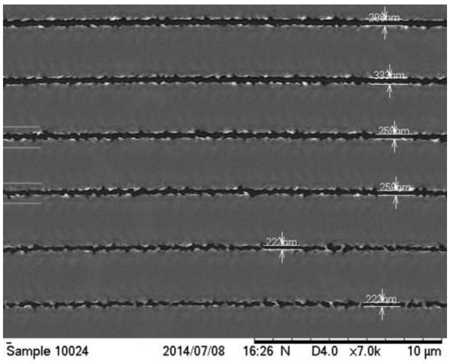
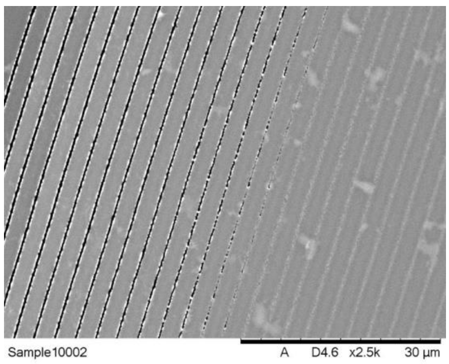


Fig. 2. – The SEM picture of the surface nanostructures on film of molybdenum with a thickness of 35 nm



a)



b)

Fig. 3. – The SEM picture of the surface nanostructures on film of molybdenum with a thickness of 17 nm: the shape and the characteristic sizes of tracks (a) General view (b)

Conclusion

The study of microstructures of metallic patterns of the DOE showed that the best spatial resolution and minimum defects in the figure of the mask is achieved at a film thickness of molybdenum 17 nm.

Minimum attainable period of record limit width trace of the laser spot and is in our case 0.8 μm. Spatial resolution will be limited to this value and can be increased by reducing the wavelength and, correspondingly, the diameter of the laser spot.

Given the fact that the selectivity of the plasma etching films of molybdenum relative to quartz can reach several hundred, the result opens the way for the creation of structures with submicron resolution, in particular, short-focus of the DOE, and also allows you to create patterns with a minimum number of manufacturing operations. In addition, as described in the article, the research is also relevant for the development of certain laser technology [20 – 22].

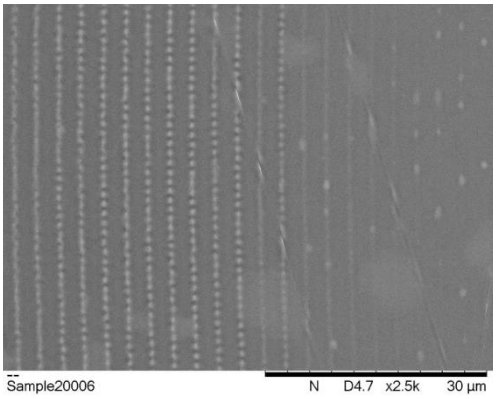


Fig. 4. – The SEM picture of the surface nanostructures on film of molybdenum with a thickness of 70 nm

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