LASER PLASMA DEPOSITION OF THE THIN ALUMINIUM FILMS IN VACUUM.

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Introduction One of the modern ways of engineering industry products updatings and instrument production is a geometrical sizes reduction of their elements. Many products include thin-film. Characteristics of these coverings can be changed if to vary their thickness. Such coverings are practically connected with all physics sections: the mechanics, electricity, magnetism, optics on functionality. Materials for coverings are almost all of elements of Periodic table. Products are covered thin metal films and alloys to make surfaces with other physical-chemical and mechanical properties which are differ from properties of metallic (initial) material. Metallization apply to protection products from corrosion, deteriorations, erosion, in decorative and etc. purposes.

The modern requirements to microelectronics products are necessity of a working frequencies increase of products and an elements accommodation density increase. It brings to reduction of track width of internal connections. Aluminium is often used in technological process of the track production. Therefore the thin aluminium homogeneous films production is an urgent task.

Pulse laser deposition allows producing extremely thin continuous films (less than 10 nm). The pulse laser deposition method provides preservation of a target initial structure at multicomponent substances deposition. The laser deposition is manufacturable very much as allows using targets of any size and forms. The exact monitoring of a film thickness is the basic advantages of the laser deposition if to compare with other methods. Besides, the deposition in vacuum provides a cleanliness of the technological process.

Q-factor solid-state lasers with the modulated good quality are used the widest in the thin films deposition.

The determination of plasma parameters (power spectrum of ions, electronic temperature and density), their dependence on laser pulse energy, the spatial evolution and angular dependence is of interest at the deposition of thin metal films using pulse laser.

The experimental equipment. For the films deposition the LOTIS-TII pulsed YAG:Nd^{3+} laser with a wavelength λ = 1064 nm and a pulse duration τ = 20 ns (full width at half maximum FWHM) was used. The pulse repetition rate was kept at 10 Hz. The deposition time was 1 hour. The target was mounted at 45° with a respect to the laser beam. Silicon plates were used as substrates.

The deposition was carried out in vacuum at the residual gases pressure ~ 10^{-3}Pa. The substrates were placed in parallel with laser target surfaces. The distance between the substrate and target was 10 sm. The target was rotated with a velocity 2 rev/min to prevent a deep crater formation on a target surface. Liquid drops of the target material (1÷10 μm) enter the erosion flame due to the hydrodynamical mechanism when a crater forms /2/.

The targets were made tough-pitch aluminium. Films thicknesses were measured using Talystep (USA) profiler, a crater width on a target surface with an employment of the microscope MKTF-1.

Discussion of results. The films have been deposited at the same energy of the laser radiation 230 mJ at the acting on an aluminium target. The laser beam had got different spots: 1 mm, 2 mm, 3 mm. Average intensity of the laser radiation was $q=1.63\times10^{8}$ W/sm^{2}÷ 1.46×10^{9} W/cm^{2}. The maximal intensity is ~(4.89×10^{8} W/cm^{2}÷ 4.38×10^{9} W/cm^{2}) when it is considered that the beam have gauss distribution of the energy (fig.1).

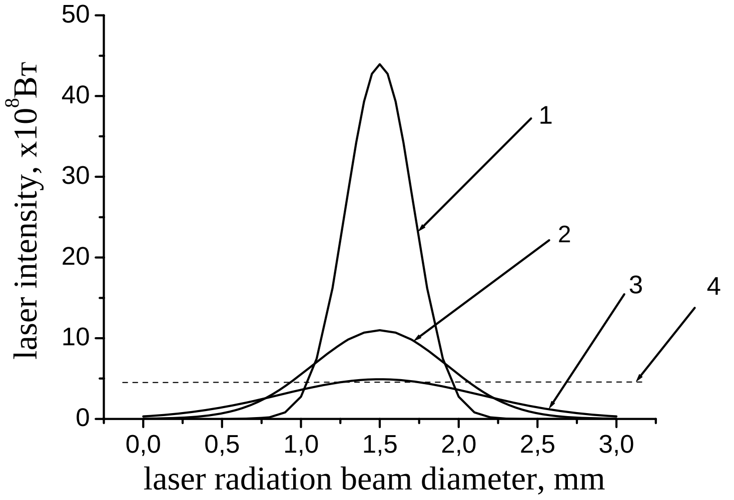

Fig. 1. Laser radiation intensity distribution at the different diameters of the spot irradiation: 1- 1 mm, 2- 2 mm, 3 - 3mm. 4 - threshold of evaporation

The experiments have shown, that at the same energy of a pulse laser radiation equal 230 mJ at an irradiation spot 1 mm (intensity $q=4.38\times10^{9}$ W/cm^{2}) the crater had diameter 0.99 mm, at an irradiation spot 2 mm (intensity $q=1.1\times10^{9}$ W/cm^{2}) – diameter – 1.17 mm, at an irradiation spot 3 mm (intensity $q=4.89\times10^{8}$ W/cm^{2}) – diameter 0.45 mm (fig. 1). The observable results are connected with the intensity laser radiation change from a laser diameter spot. The laser radiation intensity $q=4.89\times10^{8}$ W/cm^{2} on the irradiation beam edge is not enough for a beginning of the evaporation of the target material. Local laser intensity grows up to 10 times when $q=4.38\times10^{9}$ W/cm^{2} and spot diameter is 1 mm. It is enough for a beginning of the effective evaporation from a peripheral irradiation beam part.

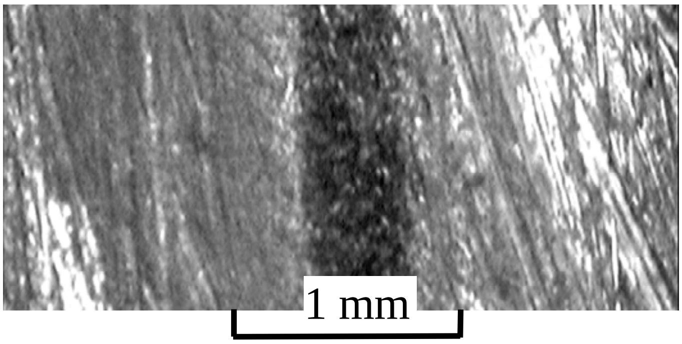

Fig. 2. – The image of erosion crater aluminium target: d - 3 mm, E = 230 mJ (q=4,89×10^8 W/cm^2). Dark region is an erosion crater

It is important to know the laser radiation intensity threshold when evaporation target material begins to determine an efficiency of the metallic films deposition. It can be used above described results on erosive crater investigations. If compare irradiation diameter spot (3 mm), gauss distribution energy in a spot (fig.1), a crater size (fig.2) we can conclude that the threshold laser radiation intensity for aluminium is 4.5×10^8 W/cm^2. The laser intensity absorption is ≈8·10^6 W/cm^2 in our case /1/.

The films thickness is determined in this work (the intensity laser radiation q=4.89×10^8 W/cm^2 - thickness 33.7 nm, q=1.1×10^9 W/cm^2 - thickness 43.6, q=4.38×10^9 W/cm^2 - thickness 83.3 nm. The films thickness has linear dependence from laser radiation intensity (fig.3).

The probing measurement in aluminium plasma were made. The signals from electronic and ionic components on a probe in the aluminium plasma (less than zero - electronic component, more zero - ions component) were fixed depending the time from a beginning of the laser pulse acting on a target (fig. 4). The power electronic component is formed at laser intensity radiation q=4.38×10^9 W/cm^2. Its speed is maximal if to compare with laser intensity 4.89×10^8 W/cm^2, where electronic component level is insignificant. The ion speed component also depends on laser radiation intensity (fig. 4). It is connected with higher temperatures, pressure and multiple ionization of the target material are realized

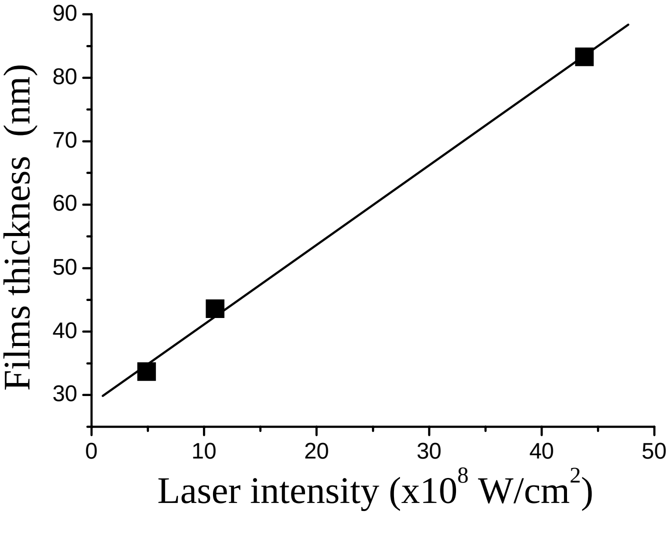

Fig. 3 – thickness dependence of the deposition aluminium films vs laser radiation intensity

in an irradiation zone at laser intensity 4.38 $\times 10^9$ W/cm^2. So the electron concentration is considerably increased. The pressure increase a particles speed. The electron concentration and pressure in an erosive flame near a target and the charged particles speed decreases at the decrease of the laser intensity 4.89×10^8 W/cm^2.

The films surface structure substrate is determined at different laser radiation intensity. The experiments have shown that a film forms with particles on its surface from 1 up to 10 microns at the acting laser radiation intensity $q=4.38\times10^9$ W/cm^2 on the aluminium target. The film is formed without particles of liquid drop phase on its surface at the laser radiation acting on an aluminium target with intensity 4.89×10^8 W/cm^2.

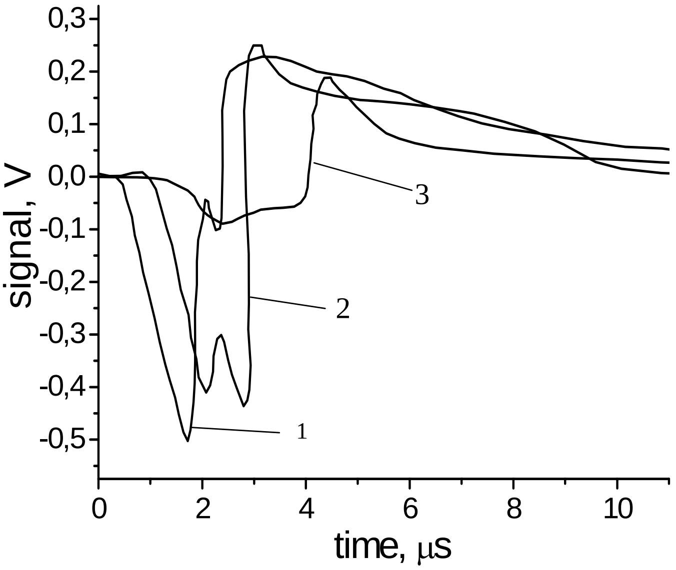

Fig.4 – Probe signal vs acting beginning of the laser radiation for different intensity: 1 – $4,38\times10^9$ W/cm^2, 2 – $1,1\times10^9$ W/cm^2, 3 - $4,89\times10^8$ W/cm^2

Conclusion

The threshold of the aluminium target destruction has experimentally been determined. It is 8×10^6 W/cm^2 in our conditions. The irradiation regime of the aluminium target has been found when in erosive laser plasma contains minimal number of the liquid drop phase particles of the target material formed by the hydrodynamical mechanism. The deposition regime of aluminium films is found, on which surface there are no liquid drop phase particles of the target material $q=4.89\times10^8$ W/cm^2.

References

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