# THE INVESTIGATION OF LASER INDUCED CHANGES IN THIN Ti FILMS

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## INTRODUCTION

The interest in investigation of laser induced damages on the solid surface appeared as a consequence of a very frequent use of lasers in industry. The interaction between the laser beam and the surface includes many physical processes and results in creation of damage on the surface, which depends on the beam characteristics and the parameters of the material /1/.

In this work, the effects of the interaction of the laser beam with thin Ti films deposited on glass substrate were investigated. The subjects of investigation were the damage character and morphological changes on the surface. In respect to this, the damage threshold, the shape and the dimensions of the damage were investigated and evaluated. SEM analysis and the profilometer were used and the obtained results compared.

## EXPERIMENTAL

The realisation of thin Ti film-glass substrate system, the investigation of its parameters and the characterization of changes induced by the laser beam were performed by means of techniques which enabled a good defining of the thin filmsubstrate parameters as well as the phenomena occuring during the interaction process.

Thin Ti films were deposited by rf sputtering technique on glass substrates with the deposition rate of 0.1 nm/s-0.2 nm/s. The obtained thicknesses in the range 22 nm to 2200 nm were finally controlled by the profilometer (Talystep). The damage on the investigated films was induced by a point-focused YAG:Nd laser radiation in the energy density range of $2x10^3 W/cm^2 - 9.1x10^4 W/cm^2$.

For investigation and characterisation of changes which occur on the film surface SEM analysis and profilometer were used, which enabled the investigation and evaluation of the damage threshold, surface changes in the damaged zone, the size, the shape and the profile of the induced damage /2/.

## RESULTS AND DISCUSSION

The investigation of changes induced during the interaction of laser radiation with the thin Ti film have shown their strongly dependence on the applied energy density and the parameters which define the film (thickness, substrate). The lowest energy, which creates a detectable damage on the surface, defined as the damage threshold was evaluated for all the investigated thicknesses. The results given in Table 1 show that the damage threshold is a linear function of thickness /3/.

Table 1. The damage threshold for Ti films deposited on glass a function of the film thickness ($d_f$).

| $d_f$(nm) | $E_t$ ($W/cm^2$) |
|---|---|
| 110 | $3.236x10^3$ |
| 700 | $3.292x10^3$ |
| 2200 | $3.347x10^3$ |

For energies above the threshold, due to the matterial melting and its retreating toward the periphery of the damaged area, the damage becomes noticably, as shown in Fig. 1. Very regular in shape, the damage has a form of a crater surronded by ringlike swells originated by the molten material and gathered on the rim.

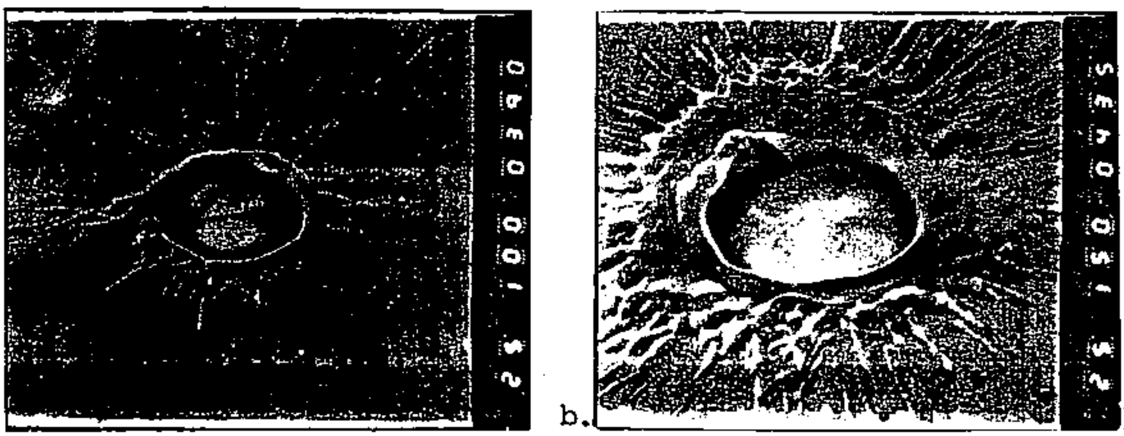
a. 

Fig. 1.
The melting effects and the characteristic shape of the damage
a. $d_f$ = 700 nm, b. $d_f$ = 2200 nm; E = $9.1x10^4$ $W/cm^2$

The craterlike damages are formed at energies about $E \geqslant 3.6x10^3$ $W/cm^2$. The with of the damaged zone, the width of the craters as well as the width of the ringlike swells on the periphery depend on the laser energy density and the film thickness, too /3/. The quantitative value, obtained by SEM are given as functions of the energy density and the thickness in Table 2 and show a linear dependence on the both parameters.

Table 2. The width of the damaged zone (D), the diameter of craters (d), and the swells with (1) as functions of the beam energy density and the film thickness ($d_f$).

| $d_f$(nm) | E(W/cm²) | D(μm) | d(μm) | 1(μm) |
|---|---|---|---|---|
| 2200 | $9.1x10^4$ | 59.09 | 25.3 | 15.15 |
| | $4.5x10^4$ | 34.84 | 19.4 | 7.5 |
| | $3.7x10^3$ | 18.6 | 9.9 | 4.5 |
| 700 | $9.1x10^4$ | 34.8 | 26.51 | 4.5 |
| | $4.5x10^4$ | 27.27 | 18.18 | 3.0 |
| | $2.1x10^4$ | 24.2 | 12.12 | 1.8 |
| 110 | $4.5x10^4$ | 27.27 | 23.2 | – |
| | $3.7x10^3$ | 22.2 | 18.68 | – |

By retreating of the molten material, the glass substrate becomes exposed to the beam. The damage on glass apears at energies $E = 3.45x10^3 W/cm^2$, which can be taken as the threshold value. Microcracks and an induced microrelief on the glass surface becomes visible.

The comparison of measurements of the investigated parameters performed by SEM and the profilometer is shown in Table 3.

Table 3. The comparison of the results obtained by SEM and the profilometer. The notation is the same as in Table 2.

| | | SEM | | Profilometer | |
|---|---|---|---|---|---|
| E(W/cm²) | $d_f$(nm) | D(μm) | d(μm) | D(μm) | d(μm) |
| $9.1x10^4$ | 2200 | 59.09 | 25.03 | 55.0 | 20,0 |
| | 700 | 34.8 | 26.51 | 41.0 | 23.0 |
| $5.6x10^4$ | 2200 | 39.3 | 24.2 | – | – |
| | 700 | – | – | 34.0 | 22.0 |
| $4.5x10^4$ | 2200 | 34.84 | 19.4 | 42.5 | 17.0 |
| | 700 | 27.27 | 18.18 | 35.5 | 23.5 |
| $2.1x10^4$ | 2200 | 20.75 | 15.5 | 27.0 | 10.0 |
| | 700 | 24.2 | 12.12 | 31.5 | 19.5 |
| $3.7x10^3$ | 2200 | 18.6 | 9.9 | 25.0 | 5.5 |
| | 700 | – | – | 25.0 | 5.0 |

The quantitative values obtained by the profilometer are in good agreement with the results evaluated from the micrographs.

## CONCLUSION

The investigation of the development of the damage induced by the laser beam on thin Ti films deposited on glass led us to following conclusions:

1. Thin film thickness and the applied laser beam energy density are the two very important parameters which influence the degree of damaging.

2. The damage threshold is dependent on the film thickness and this dependence is linear.

3. At higher energies the melting process is very expresed, the molten material expanded towards the periphery of the damaged zone forming ringlike swells which surround the affected area. The shape of the damage is very regular and gated film thicknesses. The size of the damaged zone, the diameters of the craters and the widths of the swell regions are linear functions of the film thickness and the laser energy.

4. The comparison of quantitative values of the examinated parameters obtained by SEM and the profilometer show a good agreement of those both results.

## REFERENCES: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