Using the laser radiation at hard deposits on steels to improve

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Laser are being used as a controlled intense source of heat for many metallurgical application. The main advantages of laser for materials processing are: very high accuracy in the final processed product than can be obtained without the need for polishing. The paper describes the process of obtaining hard layers resistant to wear, deposited by pulsed laser irradiation. The experimental tests were performed on samples made by two types of non-alloyed steels improvement (1.0503 and 1.0601) and two allied (1.6582 and 1.7035). They were initially subjected to heat treatment for improving, characteristic hardness and structure being obtained. The deposition of thin films it was made in a vacuum system (vacuum booster pump and a turbo molecular high vacuum pump) using a special gas device for working in nitrogen atmosphere. The purpose of this research was to obtain a deposited layers made of hard and adherent silicon carbide; the substrate which is not affected while laser deposition remains tough, shock resistant. It is pointed out the influence of some factors of the working parameters (the target –substrate distance, the substrate temperature and the working pressure) on the deposition of thin films using lasers.

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1. Introduction

One of the major advantages of the laser as a tool for material processing is the ability to precisely control where in the material and at what rate energy is deposited. This control is exercised through the proper selection of laser processing parameters to achieve the desired material modification [1].

In pulsed laser deposition (PLD), the laser radiation is directed on a target located in a vacuum chamber. The impact of the laser radiation on the target surface results in various complicated processes including removal, melting, evaporation of material and / or plasma generation due to excitation and ionisation of the species ejected from the target by the laser photons [2, 3].

All these processes are triggered by a conversion into thermal, chemical, and mechanical energy. The material ejected from the target is deposited on a substrate generally positioned opposite the target [4-6].

The deposition of thin films by laser irradiation it is realized by laser beam action on the filler material (target), its vaporization and the obtained jet is projected onto the part (substrate). The schematic diagram of pulsed laser deposition is presented in figure 1.

The focused laser radiation falls at an angle of 45° on the target. The steam plasma that is formed with the angular distribution, is directed according to the normal [7]. Where the focused laser radiation fall is formed a crater. If the successive impulses would radiate the same place, it would be formed a deep crater, which would prevent the development of the long-distance steam plasma (the order of centimeters).

To avoid this, the target is placed on a platform which is rotated by a engine [8]. The system also allows the realization of heterostructures by using multiple targets that can each in turn be brought in "beating" the laser beam.

The deposition of thin films can be made in vacuum or in a work place containing nitrogen at the pressure of 5 · 10^{-2} ... 1mbar [9, 10]. The installation has a vacuum system (vacuum booster pump and a turbomolecular high vacuum pump) and a special gas device for working in nitrogen atmosphere [11, 12].
2. Materials and methods

2.1. Materials

The experimental tests were performed on samples made by two types of non-alloyed steels improvement (1.0503 and 1.0601) and two allied (1.6582 and 1.7035). They were initially subjected to heat treatment for improving, characteristic hardness and structure being obtained.

Further were effectuated depositions of silicon carbide (SiC) films by using pulsed laser radiation. The laser has worked at the parameters indicated in table 1, for all samples.

Table 1. The parameters for the laser

<table>
<thead>
<tr>
<th>Target</th>
<th>( P ) [mbar]</th>
<th>( P_{N2} ) [mbar]</th>
<th>( D ) [cm]</th>
<th>( Pulses ) ([n])</th>
<th>( A ) [nm]</th>
<th>( Energy) density [J/cm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiC</td>
<td>( 10^{-2} )</td>
<td>0.05</td>
<td>4</td>
<td>6000</td>
<td>193</td>
<td>3</td>
</tr>
</tbody>
</table>

2.2. Parameters of pulsed laser deposition

Upon the results regarding the deposition of thin films using lasers, there are several parameters that influence them, such as:

- Target-substrate distance

The average particle size and the roughness of deposited films are significantly influenced by the target-substrate distance; if this distance is small, the deposition presents embossed portions and the layer roughness is high; if the distance increases, the deposition is more uniform, the number of the embossed particles decreases and the layer roughness is lower. In figure 2 are illustrated these differences, depending on the target substrate distance [9].

Fig.2. AFM images for two films deposited on two different target-substrate distance: a) 3 cm, b) 2 cm.

2.3. The substrate temperature

An important role in the pulsed laser deposition is the substrate temperature; the lower substrate temperature, the higher level of roughness of the deposited layers. This is illustrated also by the images obtained by the atomic force microscopy (fig. 3) [9].
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2.4. The working pressure

The enclosure pressure strongly influences the deposition appearance; increasing the pressure significantly finishes the deposited particle size. Keeping known the substrate temperature, the fluency, the energy and the laser frequency, different working pressures lead to the situation presented in figure 4 [9].

In table 2 are indicated the microhardness obtained in the deposited layers for different target-substrate distance.

### Table 2. The microhardness obtained in the deposited layers

<table>
<thead>
<tr>
<th>Steel brand</th>
<th>Substrate thermic treatment</th>
<th>Superficial treatment</th>
<th>Distance [mm]</th>
<th>Hardness [HV 0.005]</th>
</tr>
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<tbody>
<tr>
<td>1.0503</td>
<td>Improvement</td>
<td>PLD</td>
<td>1.5</td>
<td>634</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>670</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.5</td>
<td>1106</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>905</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.5</td>
<td>571</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>541</td>
</tr>
</tbody>
</table>

Increasing the target-substrate distance is favorable in terms of layer hardness up to about 4.5 cm; higher than this value is registered the decrease of the surface hardness on the samples of 1.0503 steel, with SiC deposition. The deposited layers microstructure was studied on the samples surface and also on the cross-section by optical, electronic [11], scanning (SEM) microscopy, X-ray diffraction, as illustrated in the following figure 5 and 6.
In figure 7 it is shown the image of the surface of the SiC film deposited on 1.0503 unalloyed improvement steel, achieved with the SEM + EDAX scanning electronic microscope [11].

It is observed that here, as from the images obtained by the optical microscope, an oriented structure, with irregular appearance.

In the figure 8 it is observed both silicon carbide layer, and the thermic influenced areal; the last one is very narrow, micron range, which confirms that the sensitive layer does not change after the pulsed laser deposition [11].

Fig. 7. SiC film deposited on improved 1.0503 steel.

![Image](image1)

Fig. 8. Cross-sectional microstructures of the silicon carbide layer. 200:1 a) 1.0503 steel b) 1.0503 steel core, c) 1.0601 steel d) 1.6582 steel.

![Image](image2)

Note that the initial heat treatment of hardened and tempered high had a special influence on this material, namely: hardening involved starting epitaxial growth of an amorphous layer which is formed on the surface of evidence and their mass base consist in a crystalline structure.

By using laser radiation subsequently SiC film deposition, we aimed to obtain a coating with superior properties of hardness, wear, all this is due to the structure composed mainly of fine martensite and carbides, with an average uniformity surface.

After using laser radiation SiC film deposition, relatively uniform layer properties are superior due to the structure consists of martensite and fine carbide hardness and thus favorably influencing the resistance to wear.
The figure 9 are made using the SEM + EDAX scanning electronic microscope on the SiC layer deposited with PLD; there are also presented the graphic of the elements identified in its composition (O, Cr, Si, C and N) and their distribution in micro zones interest [11].

The analysis of data presented in figures 5-9, it is noted that the surface structure of the material is made of SiC (partial) and steel, and in the center, the structure is specific to the base material.

3. Conclusions

The main results are summarized as follows:

(a) The initial heat treatment of hardened and tempered high had a special influence on this material, namely: hardening involved starting epitaxial growth of an amorphous layer which is formed on the surface of evidence and their mass base consist in a crystalline structure.

(b) Following the experimental research can be concluded that pulsed laser deposition method (PLD) on alloyed and unalloyed improvement steels is advantageous because through the heat source strictly localized the surface hardening is achieved only in the interest areas, so that the deformations are practically insignificant.

(c) It is also remarkable the obtaining of high hardness film.

(d) The silicon carbide, being a hard material, by forming a tough substrate of this film it can counted on a considerable improvement of the wear resistance.

(e) For small pieces, the process becomes applicable and also profitable due to the very short time of surface treatment.

(f) The advantages of laser hardening are short duration compared to the classic process, yielding high quality crystalline structure in both surface and base material.

References


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