# EVALUATION OF DYNAMIC HARDNESS AND ADHESION OF THIN LAYER USING NANOSECOND LASER PULSE

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## 1. Introduction

Properties of materials under conditions of dynamic deformation significantly differ from those in static conditions. Sensitivity to the strain rate of most metals and alloys significantly increases at strain rates above 10 $s^{-1}$. The study of processes occurring in materials at very high speed of deformation is possible using nanosecond laser pulses. A shock wave is generated for this purpose. Nanosecond high power pulses and carefully selected absorption layer as well as inertial layers, allow obtaining a wave pressure from a few to several GPa [1]. The strain rate during the process is from $10^7$ to $10^9$ $s^{-1}$ [2]. The plastic deformation of the material generated by the single nanosecond laser pulse can be basis for evaluation of the hardness of the material under the ultra-high strain rate. Tensile stresses at the interface of the material/layer, which caused separation of the layer from the substrate can be used for estimation adhesive strength for thin layer [3].

## 2. Experimental method

Nd:YAG laser with a wavelength of 1.064 μm and pulse time of 10 ns was applied in the test. The diagram of the measurement system is shown in Fig.1. Laser beam falls through the transparent inert layer (1) on the absorption layer (2), where it is absorbed and creates high pressure plasma, which in turn induces a shock wave. Propagation of the shock wave causes plastic deformations of samples (3) and delamination of layer (4). Piezoelectric PVDF sensor (5) creates a charge which is proportional to the transient value of pressure in the piezoelectric sensor. Measurements of shock wave pressures have been performed using piezoelectric, polymer PVDF sensors [4]. Typical pressure profile on back side of sample shows Fig. 1b. The study of plastic deformation induced by a nanosecond laser pulse was carried out for typical commercial metals and alloys: aluminium, copper, stainless steel.

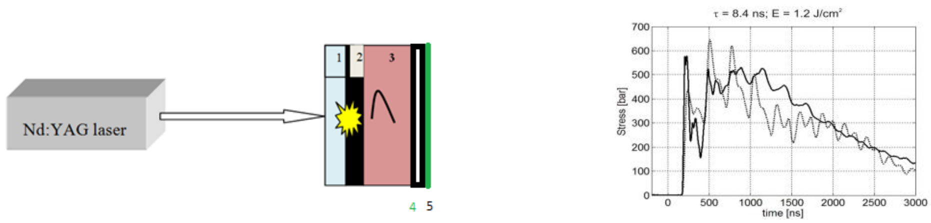


Fig. 1. A- Experimental scheme for testing dynamic hardness and adhesion of thin films. B- Comparison of calculated (- -) and experimental (--) profile of pressure of shock wave.

## 3. Results

The study showed that single laser pulses with energy of 0.35 - 1.22 J allow to get required levels of pressure and reproducible conditions necessary to obtain the size of plastically zone deformed necessary to assess the dynamic materials hardness HDL. For steel and materials with high hardness, a pulse energy greater than 1 J is needed. In all cases, the plastic deformation had a circular shape, exemplary surface deformation generated by a single laser pulse with the energy of 1 J is shown in Fig. 2. The dynamic hardness was expressed as a function of the deformation work of material by impact perpendicular to surface; thus as the value of dynamic hardness, the specific work is adopted:

*(1)* $HD = L_{wl} = L/V$

*(2)* $L = \int_0^h F \, dh$

$V$ - volume of imprint [$mm^3$]

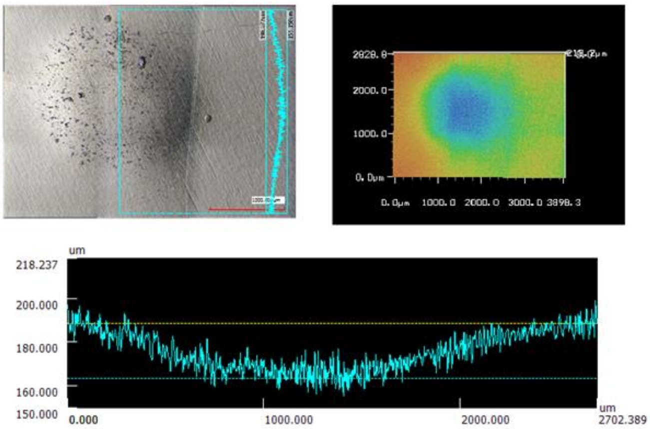


Fig. 2. Exemplary image of deformation zone of the steel 304 at the, contour map and profile.

Generation of shock waves by the laser pulse was also applied to determine adhesion of thin films. A very short pressure pulse underwent propagation in the tested composite steel 304/Ti layer 1 μm thickness. At the material-layer interface the tensile stresses were stated. They caused separation of the layer from a substrate. An adhesion of the layer was determined.

## 4. Conclusions

The proposed measurement system allows obtaining the proper level of pressure and reproducible measurement conditions necessary to apply for testing mechanical properties materials and films under conditions of ultra-high stain rate, of the order of $10^7$ $s^{-1}$. The laser pulses can be used to evaluate the dynamic hardness of the materials and can be used to estimate the adhesion of thin films.

## 5. References


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