

Wojciech NAPADLEK<sup>1</sup>  
Izabela KALMAN<sup>1</sup>

## **ABLATIVE LASER CLEANING OF LACQUER COATING**

The paper presents the selected results of tests on ablational laser removal of polymer lacquer coating with metallic filler (aluminium plates). The fibre laser with the Galvo head of the following parameters: the radiation wavelength  $\lambda = 1064\text{nm}$ , the exposition time of the laser impulse  $\tau = 25\text{ns}$ , and the repetition frequency 30-500kHz was used. By changing the power thickness, repetition frequency, and scanning speed various effects of varnish, coating removal were obtained. The melting of the colourless lacquer coat was observed when small power thickness was applied. Multiple scanning with the laser beam of higher power thickness resulted in sequential removal of several to tens of micrometers of the lacquer coating. This technology brings very good perspectives for the renovation of lacquer coating systems in present vehicles (bodies, frames).

### **1. INTRODUCTION**

The surface of the elements of the bodies of motor vehicles is covered with a lacquer coating system built from many coats whose thickness varies between several to tens of micrometers (Fig. 1). The whole coating system is supposed to protect the body from external factors, e.g. mechanical abrasion or chemical and atmospheric factors, and it should also be decorative. Each of the coats in the lacquer system fulfils a separate function, for example, the phosphate and cataphoretic coats protect the elements of the body from corrosion, and the base lacquer and colourless lacquer protect from mechanical damage, and fulfil the decorative function. Unfortunately, the lacquer-coating system does not always fulfil its role. It is exposed to atmospheric factors (e.g. water, salt, temperature, solar radiation), as well as chemical and mechanical ones. Its damages are often too deep to protect the body from, for example, corrosion. In this case, removing the damaged section of the lacquer coat together with corrosion products is often the only solution. Usually, grinding with abrasive papers of various granulation and shape is used. However, grinding may cause side effects, e.g. environment pollution. Besides, the process is difficult to control, because it is impossible to remove the layer of the lacquer coat with exactitude to several micrometers. It is important to control the process with this exactitude, because of the following:

---

<sup>1</sup> Military University of Technology, Mechanical Faculty, 00-908 Warszawa, ul. Gen. S. Kaliskiego 2, Poland.  
tel. (0-22) 683-73-57, e-mail: [wnapadlek@wat.edu.pl](mailto:wnapadlek@wat.edu.pl), [i.kalman@wat.edu.pl](mailto:i.kalman@wat.edu.pl)

- the productive lacquer coat is 95-135 $\mu\text{m}$  (Fig. 1), or even 165 $\mu\text{m}$  thick, e.g. in Ferrari cars,
- it is not often necessary to remove all the layers of the lacquer coating (e.g. when only some of the coats were damaged or when we want only to improve decorative values),
- the material of the base should not become damaged in the process of removing the lacquer coat.

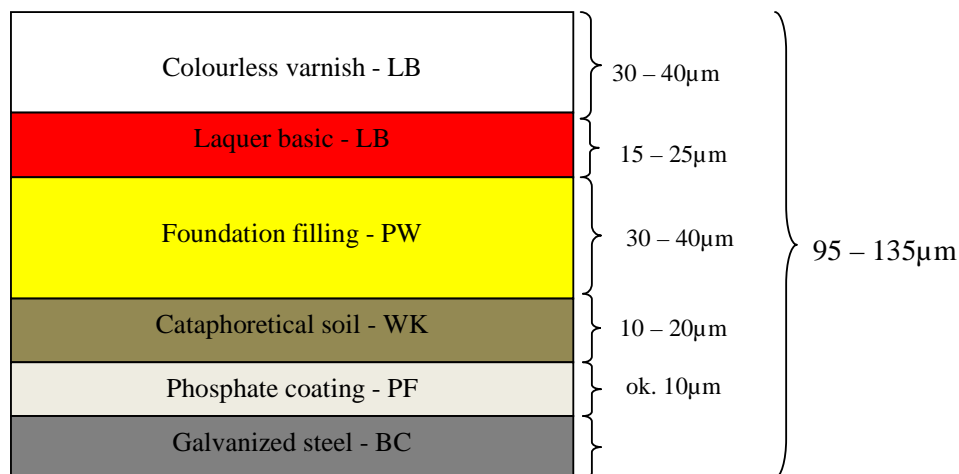


Fig. 1. The structure of productive lacquer coating system applied in the bodies of passenger cars

The renovation of the lacquer coat involves the removal of the damaged coating system or single coats, the proper preparation of the surface and spraying a new coat, thereby restoring decorative and protective values [1-3].

Apart from control, another essential issue in the process of renovation and, in particular, in the process of base preparation, is spraying the next layer of the coating and producing a suitable profile of roughness on its surface. It is particularly important to ensure suitable adhesion. This also affects the quality of the lacquer coat.

In the technological processes of cleaning and removing the lacquer coating system from the elements of car bodies and frames, one aims to obtain the right roughness of the surface, high cleanness, and meet the required ecological standards. Nowadays, coatings are usually removed mechanically, mainly by grinding (e.g. with oscillation grinders or by hand with water and sandpaper).

The specific properties of the laser radiation give good possibilities for ablational cleaning and removing subsequent coats of the lacquer system with very large precision and high efficiency. By applying the suitable length of the laser radiation (e.g. 1064nm, 532nm, 355nm, 256nm), short (nano- and pico-second) laser impulses, the right power thickness, repetition frequency, beam shape (mod - TEM) and precise actions on coatings, surprisingly positive effects can be obtained. Because these coatings are often polymer, they can be cleaned and removed with lasers, e.g. continuous and pulse lasers, CO<sub>2</sub>, Nd:YAG, excimer lasers, or short exposition (e.g. nano- and pico-second) lasers. Using lasers, one can avoid the damages of the base and conduct a selective process of coating removal.

Laser ablation involves removing the surface layer of the material as a result of the absorption of laser radiation in a very short time (between single microseconds to femto-seconds), quick heating and vaporisation of the selectively chosen surface layer. In some cases, laser radiation is irreplaceable, particularly when small or hard to access zones need cleaning.

The effect of laser ablation is absorption and dissipation of laser radiation during which the material is ejected in the form of liquid and vapour [4-8].

The concept of the ablation process is presented in Fig. 2.

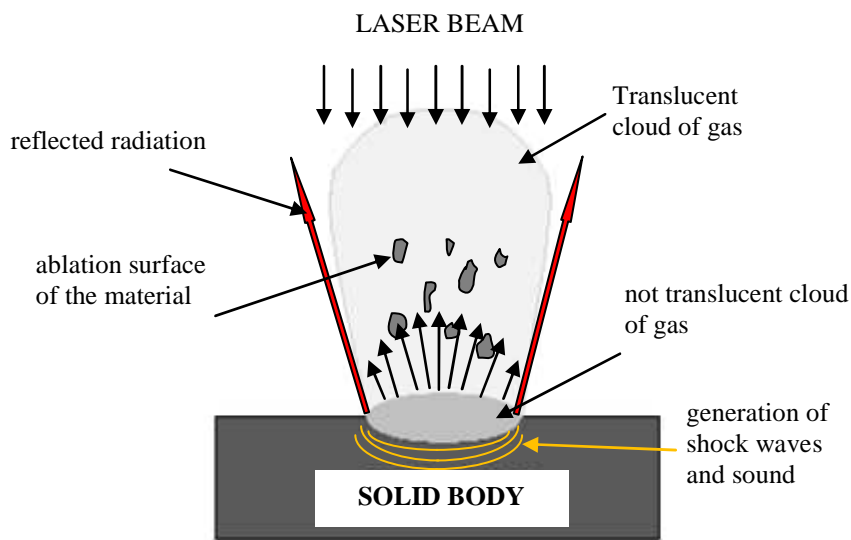


Fig. 2. The idea of ablation

In Fig. 3 there are presented the mechanism of removing lacquer coats with the beam of a Nd:YAG laser, which causes partial vaporisation of the lacquer coating under the influence of temperature, and also ejecting the remaining particles under the influence of the pressure wave, which leads to the exposure of the base.

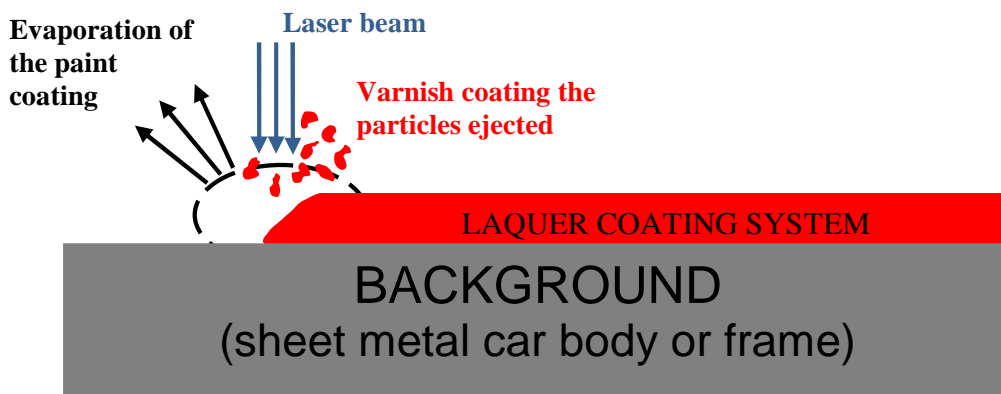


Fig. 3. The diagram of laser ablation applied to remove the lacquer coating system

## 2. SELECTED RESEARCH RESULTS OF LACQUER COATING ABLATIONAL REMOVAL

The pulsed Nd:YAG laser was used in preliminary laboratory investigations (max. 10Hz) with maximum impulse energy of 500mJ - Fig. 4.

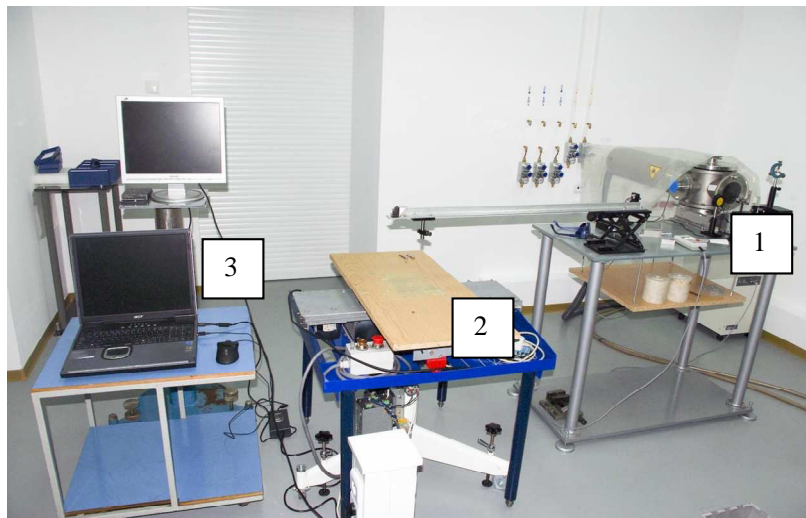


Fig. 4. The laser cleaning stand: 1 - Nd:YAG laser, 2 - measuring table, 3 - computer stand to steer the laser and measuring table

The time of the radiation exposition did not exceed 25ns. The lacquer coating was removed as a result of ablation caused by a large power thickness in a short time (a dozen seconds) under the influence of a single impulse of the laser beam (Fig. 5a). Single impulses and uneven distribution of power thickness in the beam made it impossible to control the process, because one cannot foresee precisely the area on which the laser beam will operate (unless the technological mask is used). Another problem was to remove the exact thickness of lacquer coating needed. Moreover, there were uneven edges of the remaining coating after the selected area was removed (Figs. 5b, c), and zones of the lacquer coating system of various degrees of cleanness formed after using the laser beam, whose distribution was similar to a Gaussian distribution. The best distribution of a laser beam in the cleaning process is a rectangular one. Then, the whole zone where the laser beam operates is evenly cleaned.

In the next stage, a sample of the body of a Fiat Panda, covered with a lacquer coating system with metallic filler (aluminium plates) was examined.

The coating was cleaned with the beam of the Yb:YAG fibre laser with a Galvo head of the following parameters: the length of the radiation wave  $\lambda = 1064\text{nm}$ , exposition time 25ns, and repetition frequency  $3\div 500\text{kHz}$  (Fig. 6). Sixteen various parameters of the beam operation were applied. By regulating the power thickness of the laser beam, the repetition frequency, and the head scanning speed (Fig. 7), various cleaning effects of the coating were obtained.

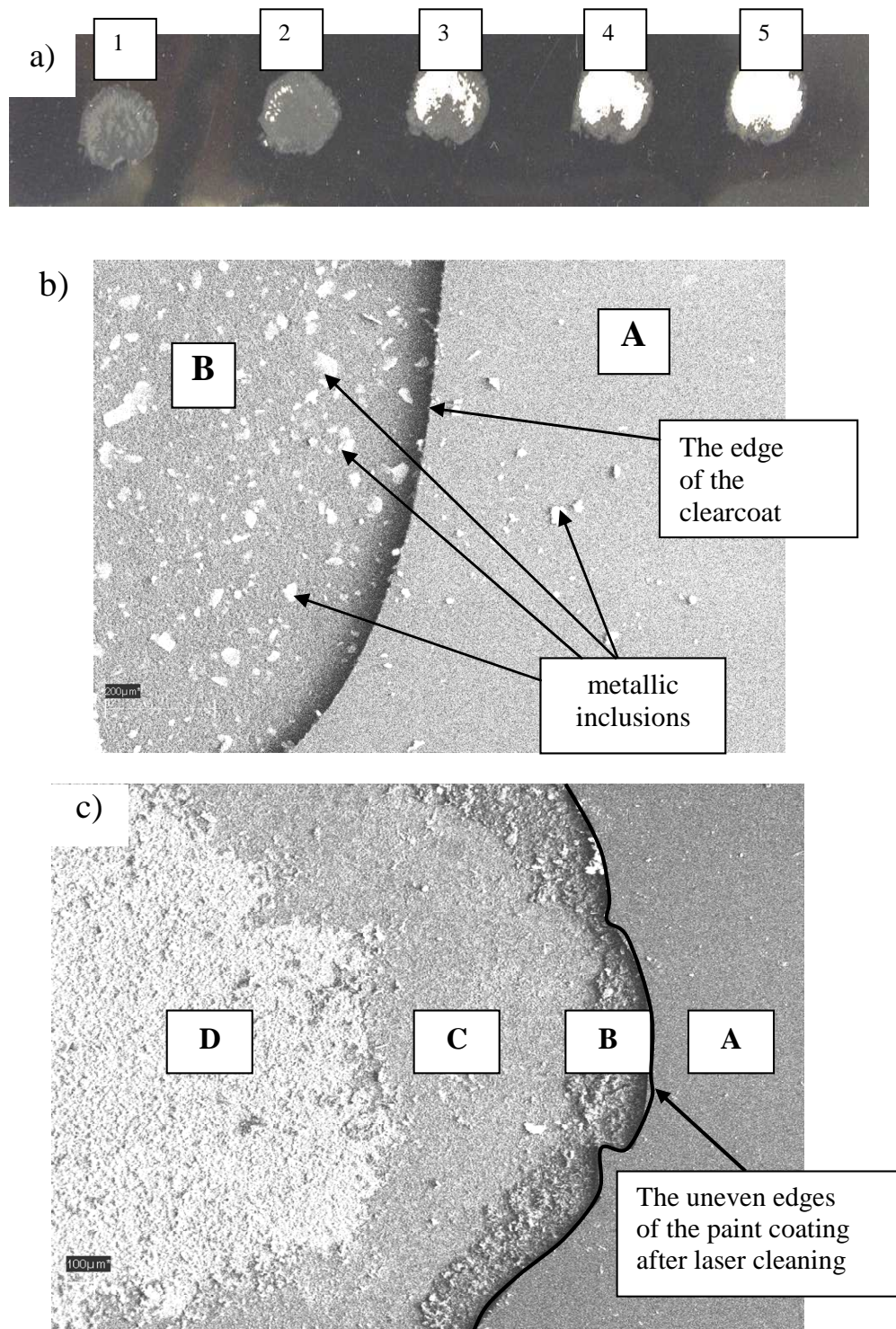


Fig. 5. The results of the experiment with the use of the Nd:YAG laser without the Galvo head – the removal of lacquer coating system under the influence of single impulses of the laser beam of the distribution similar to the Gaussian distribution; a) various variants of laser cleaning (1-5), b) lacquer coating system with the layer of colourless lacquer removed (Variant 2), c) lacquer coating system with uncovered various layers of the lacquer coat (Variant 4) - visible large non-homogeneity of the removal resulting from the distribution of the thickness of the laser beam power; A - colourless lacquer, B - base lacquer with metallic filler (aluminium plates), C -filling foundation, D - cataphoretic ground coat

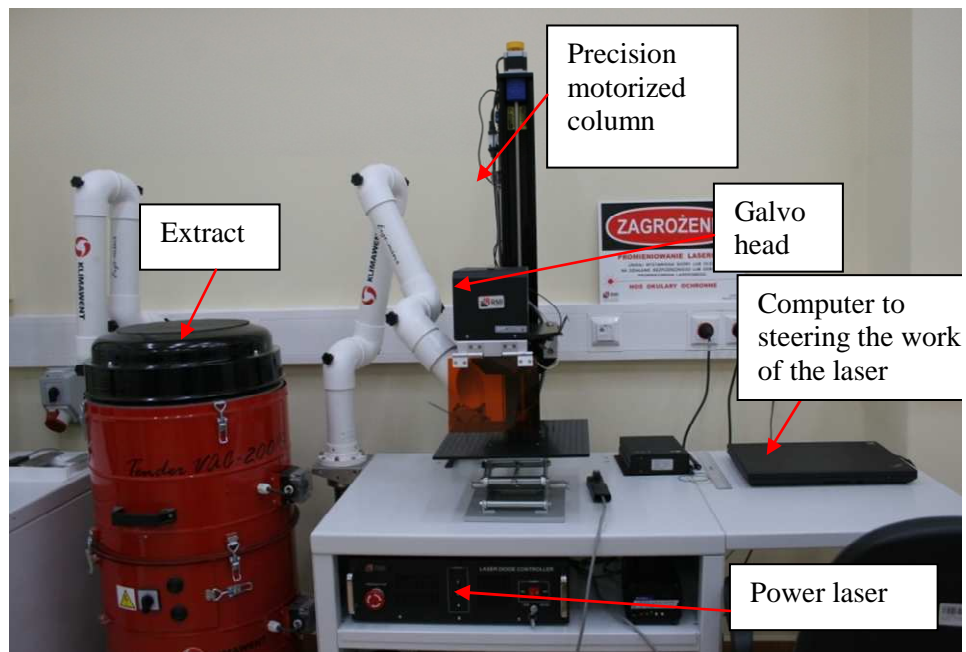


Fig. 6. The laser micro tooling stand consisting of a fibre laser, Galvo head, electrically steered precision column, ventilating fan, and a computer with specialist software to steer the work of the laser

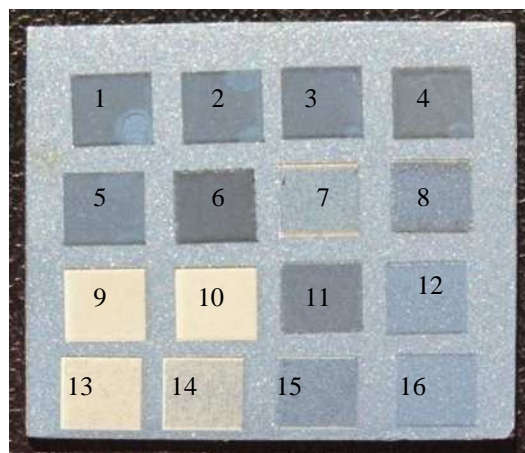


Fig. 7. The sample taken from the passenger car body with the lacquer coating system with metallic filler, subjected to 16 variants of laser micro tooling (1-16)

Two variants of cleaning the lacquer coating were presented in the article (Variants 11 and 13 – Fig. 7). In order to illustrate the effects of the lacquer coat removal, Figs. 8÷10 show the topography of the surface and the profile of characteristic zones.

The first analysed variant of the laser cleaning is the removal of several micrometers (approx.  $7\mu\text{m}$ ) of the colourless lacquer, that is the upper layer of the lacquer coating (Fig. 8). Such removal of the lacquer is very necessary in the case of small scratching or fogging of the lacquer coat, that is the damage of the coat that frequently occurs during the

exploitation of the vehicle. In order to remove several micrometers of the surface layer, a larger thickness of the radiation power and much larger scanning speed of the laser beam than in the previous variant were applied. Due to the increased scanning speed, the material was not overheated, so its volume did not increase.

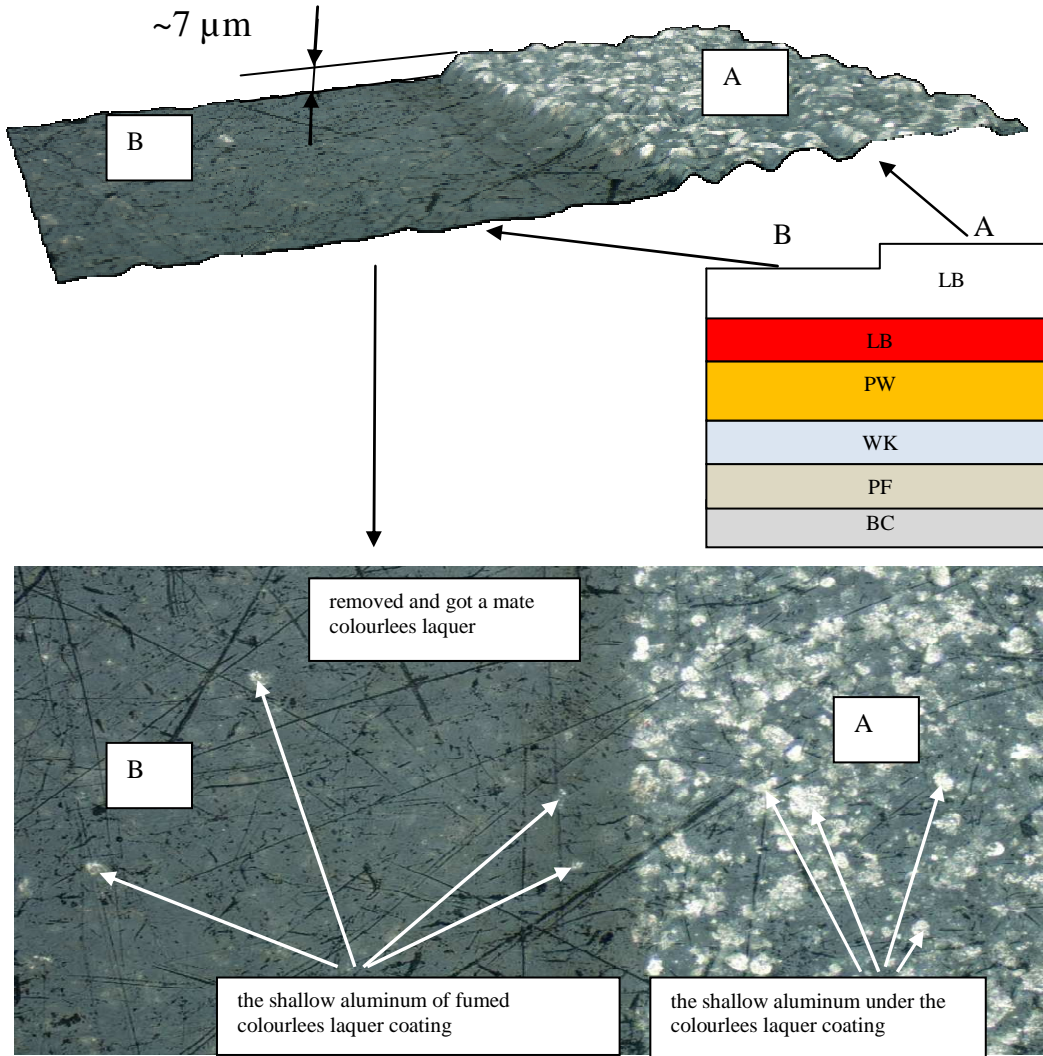


Fig. 8. The topography of the surface of the sample with the lacquer coating system taken from the car body after the laser beam operated on it; A - the zone before the laser beam operated on it, B - the zone after the laser beam operated on it - Variant 11 of laser micro-tooling from Fig. 4

In the other variant, the effects of cleaning two layers of the lacquer coating, that is the colourless lacquer and foundation lacquer with metallic filler (aluminium plates) are presented. As a result of pulsed laser radiation, the filling foundation was uncovered. This effect was obtained after scanning the surface with the laser beam five times with the same parameters as in the previous variant. Due to multiple scanning, approx. 70μm of the lacquer coating was removed (Figs. 9, 10).

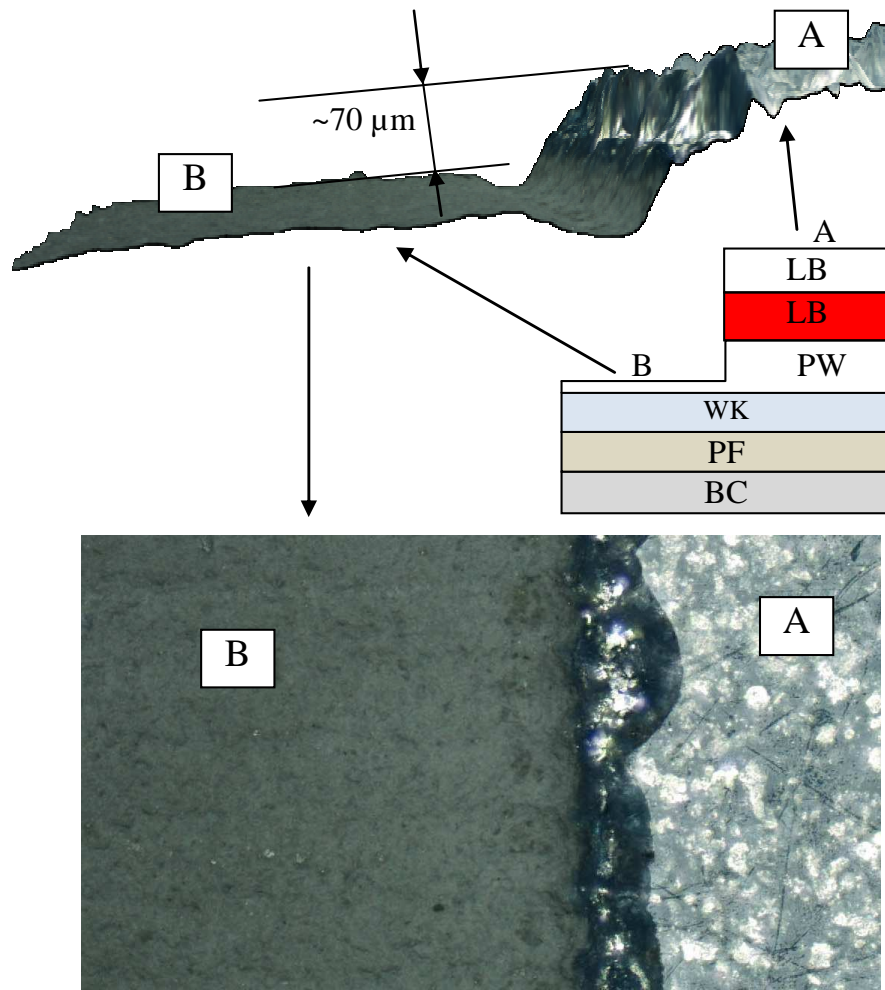


Fig. 9. The surface topography of the sample taken from the passenger car body with the lacquer coating system after the laser beam operated on it and approx. 70µm of the coat was removed- Variant 13 of laser micro-tooling from Fig. 4

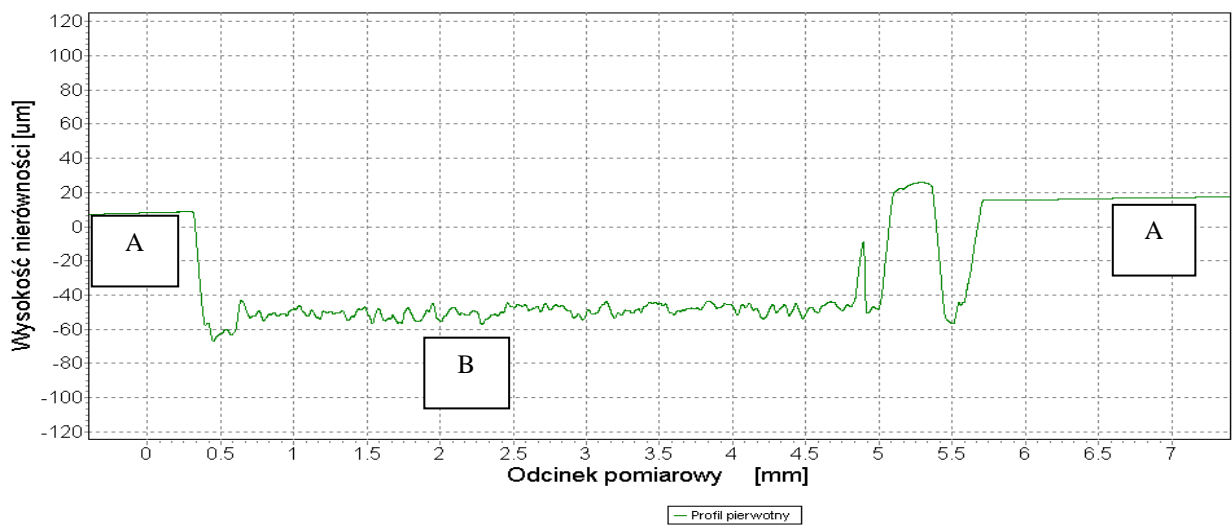


Fig. 10. The profilogram of the sample surface taken from the passenger car body with the lacquer coating after the laser beam operated on it and approx. 70µm of the coat was removed - Variant 13 of laser micro tooling (Fig. 4)



### 3. CONCLUSIONS

The tests proved that, by applying ablational laser micro-tooling, it is possible to clean elements of the car body and selectively remove the component elements of the lacquer coating system in a very precise way. Following the preliminary laboratory tests, the following conclusions were drawn:

1. In order to remove lacquer coats properly, one must know the basic parameters of the laser beam (e.g. the length of the radiation wave, power thickness, impulse duration time, repetition frequency, scanning speed, coat absorptivity, etc.). It is recommended that large power thickness, short (nano- and picoseconds) impulses of laser radiation and the large scanning speed of the laser beam (e.g. larger than 1000 mm/s) are applied.
2. An important feature of the laser cleaning of lacquer coating systems is the possibility of selective removal of individual lacquer coats. These coats can be removed one by one, with the exactitude of even several micrometers, which will create great technological possibilities in the future.
3. By applying a larger scanning speed and larger power thickness of the laser radiation, a very favourable technological effect was obtained – ablational removal of several micrometers of the colourless lacquer.
4. By scanning the same surface of the lacquer coat with the laser radiation of the same power thickness a few times, a dozen or even tens of micrometers of the lacquer coating were removed. This suggests that it is possible to remove several layers of the lacquer coating during one scanning, or one can even remove the whole lacquer coating system without damaging the base material.

### REFERENCES

- [1] PN-EN ISO 4618: 2007, *Paints and varnishes, Terms and definitions*, (in Polish).
- [2] SOBIERAJSKA G., NEUMAN N., 2006, *Varnishing car*, SIMP – ZORPOT Ośrodek Rzeczoznawstwa, Szczecin, (in Polish).
- [3] SZARAMA Ł., 2008, *Varnisher's hand-book part 1, Service guide 2*, (in Polish).
- [4] ZIĘTEK B., 2009, *Lasers*. Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, Toruń, (in Polish).
- [5] JÓŻWICKI R., 2009, *Laser technology and applications*, Oficyna wydawnicza Politechniki Warszawskiej, (in Polish).
- [6] MARCZAK J., NAPADŁEK W., SARZYŃSKI A., 2005, Modification of features of top layer of aluminium by laser striking wave, *Inżynieria Materiałowa*, 5/147, 622- 624, (in Polish).
- [7] BURAKOWSKI T., MARCZAK J., NAPADŁEK W., 2006, Essence of ablation laser cleaning of materials, *Prace Instytutu Elektrotechniki*, LIII, 228, 125 – 135, (in Polish).
- [8] BURAKOWSKI T., NAPADŁEK W., MARCZAK J., 2006, Laser ablation micro machining in areology, *Inżynieria Materiałowa*, 5/153, 882 – 889, (in Polish).
- [9] BURAKOWSKI T., KUBICKI J., MARCZAK J., NAPADŁEK W., 2006, Technological possibilities of use of laser ablation cleaning of materials. *Prace Instytutu Elektrotechniki*, LIII, 228, 137 – 146, (in Polish).