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LASER MARKING ON THE POLYAMIDES WITH GLASS FILLED (PA6 GF50) IN AUTOMOTIVE INDUSTRY

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Abstract:

The automotive industry requires reliable, flexible and high-quality marking. Laser marking, which uses light beams to create permanent designs on various materials such as metal and polymers is already an established solution. The process is fast, highly efficient and easily integrated into any production cycle. The non-contact method of laser marking on polymers is widely used in the automotive industry. Laser machines have been used for years by automotive parts manufacturers due to their ability to create tamper-resistant and easily recognizable markings. This publication examines the marking process for automotive electrical switches made of polyamide (PA6) with a glass percentage of GF50. The publication aims to investigate the influences of the orientation of the glass fibers after the molding process and also the shape and dimensions of the glass filler on the laser marking process. Samples were used to determine the quantitative ratios of organic (matrix), inorganic (fillers) and the phase composition of the fillers with which the influence of the components making up the polymer was studied.

1. INTRODUCTION

Polyamides are polymers whose molecular structure contains amide bonds (CONH- or CONR-, where R is a substituent). These materials are characterized by high thermomechanical properties, including high softening point, high thermal resistance and high mechanical modulus, which make them highly suitable for various engineering applications [1]. Many companies offer polyamides with added glass fibers or other fillers to meet the specific requirements of different industries. However, materials reinforced with glass fibers or other fillers can have an increased abrasive effect, leading to rapid wear in friction applications.

Fig. 1 Automotive electrical switch module made of PA6 GF 50%. The marking of the symbols was performed on a Scorpion laser printer.

2. THEORETICAL BASIS

A laser is a device for amplifying light by stimulated emission of radiation. It is a source of monochromatic, coherent, directional light that emits a light beam with a constant wavelength, constant phase and high brightness.

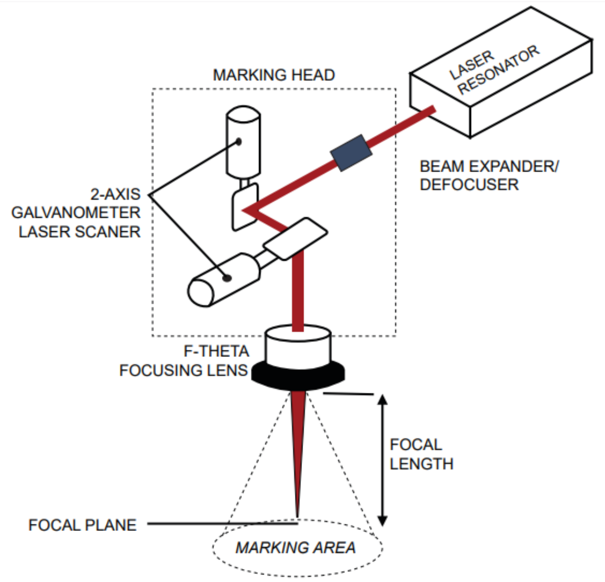

Fig. 2 Schematic diagram of a laser marking system [2].

The laser consists of three main components: an active medium, an external energy source and a resonator. It consists of two mirrors, one of which has a reflection coefficient close to 100 %, and the second mirror – lower than 100 % (semi-transmissive) – the so-called Fabry-Pérot system [3]. The process of printing on plastic with a laser is called laser marking or laser engraving and uses the energy of the laser to modify the surface of the material (in this case plastic). The task of the laser is to create a permanent mark (image) that is distinct on the surface of the marked element.

Problems that engineers and designers have to solve when implementing laser machines in the automotive industry, in particular when marking glass-filled polymers, are related to:

1. The type of material and the percentage of impurities used in the polymer.
2. The surface profile of the marked product.
3. The colors of the products and the final results on the marked elements.
4. Selection of the power of the marking unit (laser).
5. The speed of the laser marking.
6. The focal length of the selected configuration.
7. The industry in which the machine will be used.
8. The requirements for the emitted radiation.
9. The customer requirements for color, size, shape, etc.

3. DATA

3. 1. ANALYSIS OF THE PRODUCT AND CUSTOMER REQUIREMENTS.

Fig. 3

Fig. 4

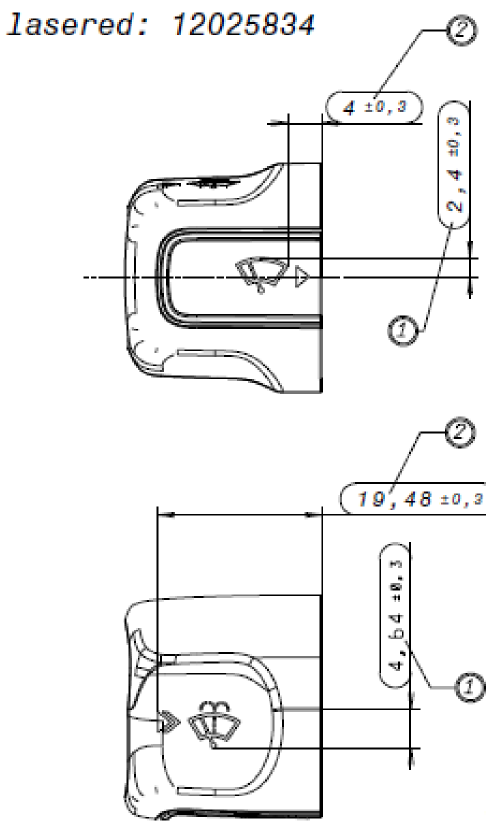

Fig. 5 Drawing with data on the location of the marking on the marked detail

Fig. 3 and **Fig. 4** show 3D models of the marked parts.

The complexity of the marked parts depends on the customer's requirement for marked areas from the provided model. The main problem is also the alignment of the part with the laser head. The color of the marked elements depends on the laser setting and the chemical composition of the polymer used. Pale color, darkening or unfilled markings are the main reasons for readjusting the marking machine and stopping the production process.

Fig. 5 shows a drawing with data on the location of the marking on the marked detail.

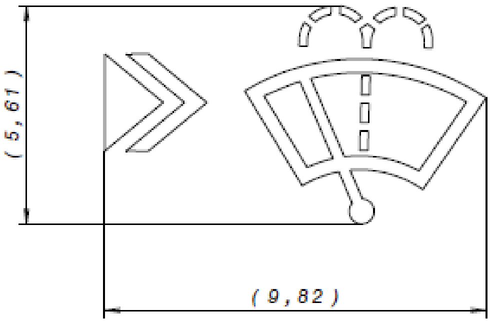

Fig. 6

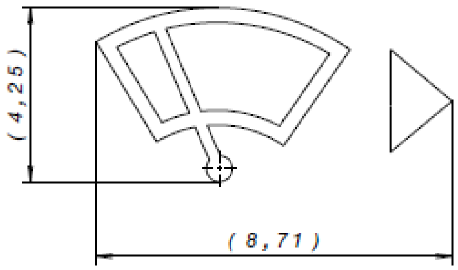

Fig. 7

Fig. 6 and **Fig. 7** show the requirements for the size and shape of the seal.

TABLE 1 Chemical composition of the polymer used Badamid PA6-GF50.

Component	Percentage content
PA6	47%
GF-Fiber	50%
Further additives	2%
Carbon black	1%

3. 2. CHOOSING A MARKING LASER

Fig. 8 SCORPION Laser.

The laser parameters were selected after a thorough analysis of the area to be served by the machine and the chemical composition of the polymer.

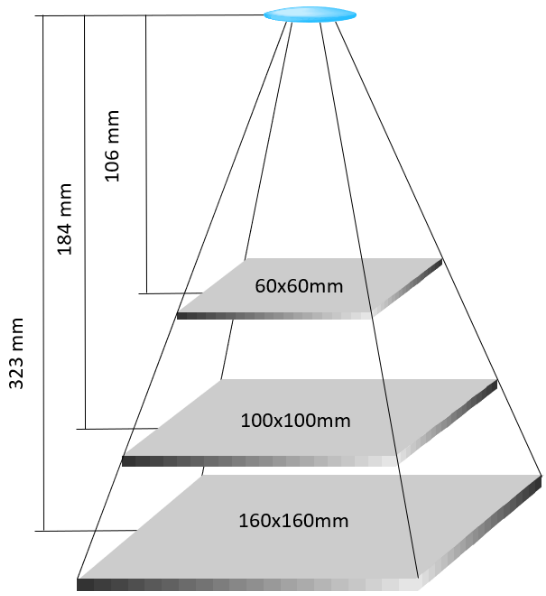

Fig. 9

Fig. 9 and **Table 2** show how the focal length parameters affect the marking field, contact spot size and working distance. The maximum speed and working distance depend on the power of the laser diode and the type of laser. The size of the laser beam is selected according to the specification (**Fig. 5** and **Fig. 6** and **Fig. 7**). Also, the focal length must be consistent with the profile of the part to be marked. In our case, the shape of the part is complex and the marking needs to be done in several positions of the marked element.

TABLE 2 [4]

Flat field focal length (mm)	Max. Square marking field (mm)	Max. Marking diameter (mm)	Working distance (mm)	Spot size (µm)
100	60	85	106	30
163	100	140	184	50
254	160	220	323	80
350	220	310	423	110
410	250	350	512	130

The basing will be done with the help of a robot.

Fig.10 and **Fig. 11** show a 3D model of the laser installation in two views.

The implementation of a robot, which will be used to base the part during marking, requires calculating the machine's operating cycle and calculating the machine time from the laser marking and the robot's movements. The simulations on Emulator 3D allow us to calculate the approximate time for one cycle of the workstation.

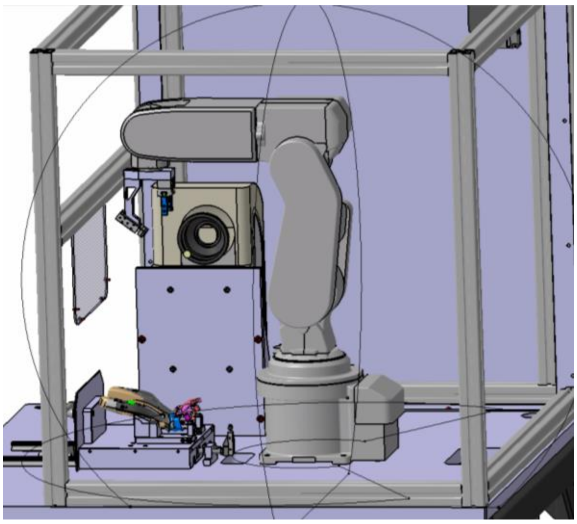

Fig. 10

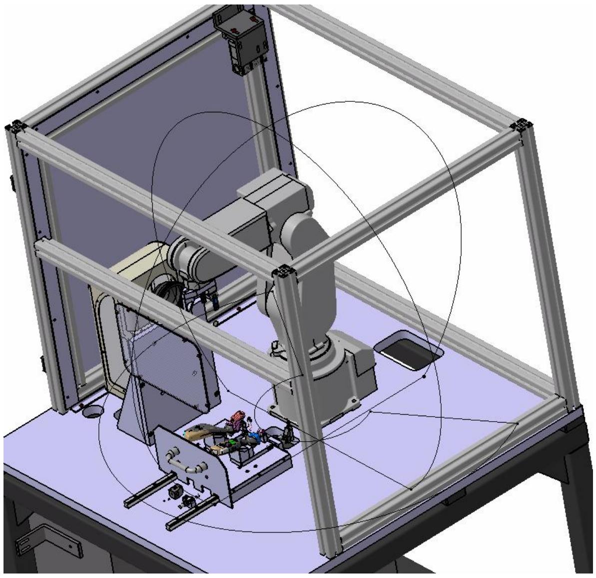

Fig. 11

4. EXPERIMENTAL RESULTS

Research on print quality in laser marking and analysis of the influence of the glass-containing component.

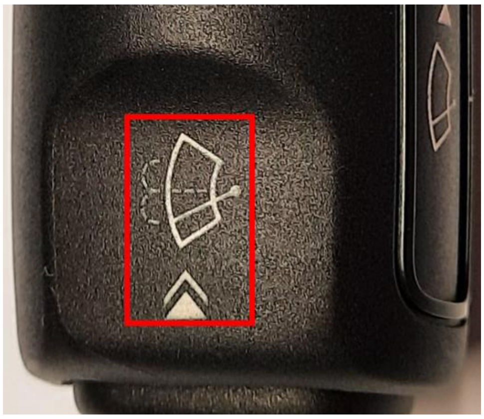

Fig. 12

Fig. 12 shows a detail of PA6 GF50 material, printed with a laser printer.

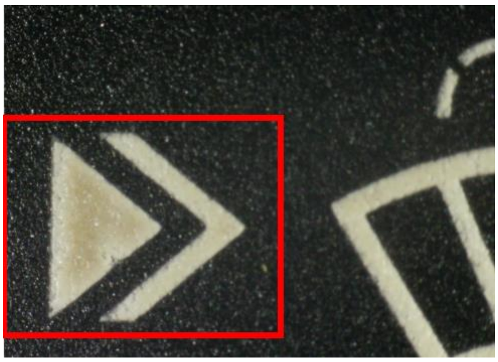

Fig. 13

Fig. 13 shows a photo of poor quality printing after marking with a laser printer.

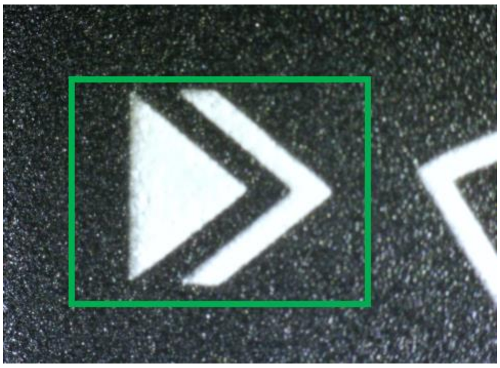

Fig. 14

Fig. 14 shows a photo of a quality print after laser marking.

A deviation from the quality of the printed details is the visible darkening and change in the color of the print in the central area. The problem in the marking process is expressed in a change in the color of the marking, which was performed with identical laser parameters. In changing the laser power, the quality of the poor print is corrected, but this requires constant adjustments to the laser machine and stopping the production process. The second problem that appears is related to the impossibility of checking the poor details and their sorting. The quality assessment is visual, which requires the detail to be marked, and subsequent actions for secondary marking are not possible.

4. 1. INFLUENCE OF THE ORIENTATION OF THE GLASS FIBERS ON LASER PRINTING

Fig. 15 depicts a three-layer pattern of glass fiber orientation of PA6 GF30 during injection molding [6].

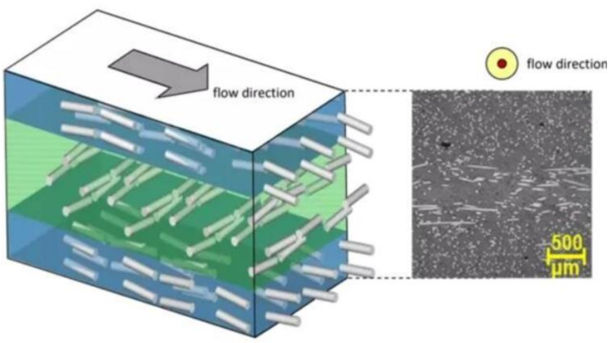

Fig. 15

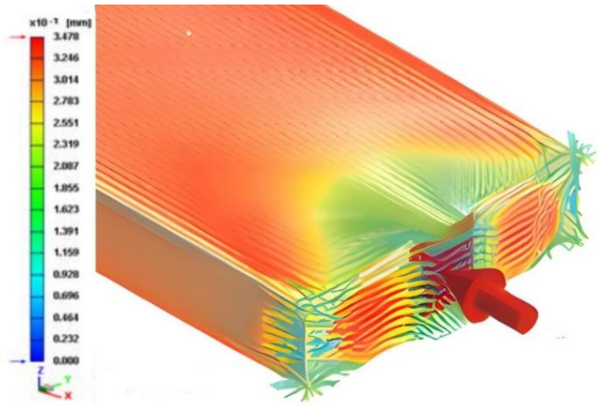

Fig. 16 [5].

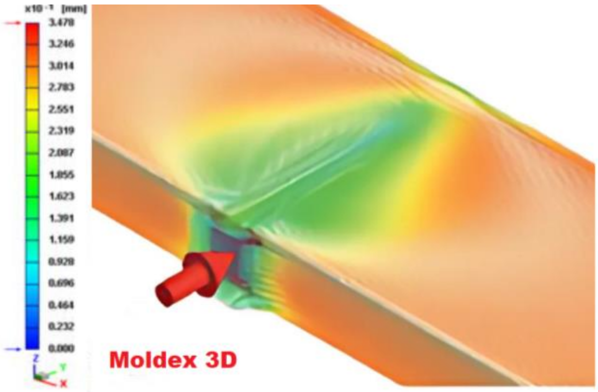

Fig. 17

The orientation of the glass fibers at different positions of the incoming flow is shown in **Fig. 16** and **Fig. 17** [5].

4. 2 WEIGHT ANALYSIS OF THE MARKED DETAILS

A study was conducted on 4 plastic samples to determine the quantitative ratios of organics (matrix), inorganics (fillers), and the phase composition of the fillers.

Equipment used:

X-ray diffractometer Philips generator PW1830 and goniometer PW 1050; (The X-ray diffractometer is widely used for studying the crystal structure and diagnostics of various types of materials).

METAM-P1 optical microscope and Zeiss Epignost equipped with a digital camera for the Bresser MikrOkular Full HD eyepiece.

TABLE 3

Components	HR1	HR2	HR3	HR4
P1	10.1266	10.1076	10.1489	10.0458
Foil	0.9155	1.3138	1.0536	0.9635
P1-i	6.0766	6.4526	6.1933	6.0526
P1%	50.97	50.84	50.64	50.66
Fiber%	50 %	49 %	50 %	49 %
Result LP	OK	OK	NOK	NOK

Table 3 shows the results of the weight analysis of 4 samples.

P1 - measured sample for analysis.

Foil - the weight of the foil in which the sample for combustion is placed, then the weight of the foil is subtracted from the measured sample P1-i.

P1% - percentage of the residue, which is calculated (P1-i/P1)*100. Fiber% - the percentage of fiber content. The results show the percentage of glass fibers in the polymer and the result of the laser print quality.

4. 3 OPTICAL MICROSCOPY

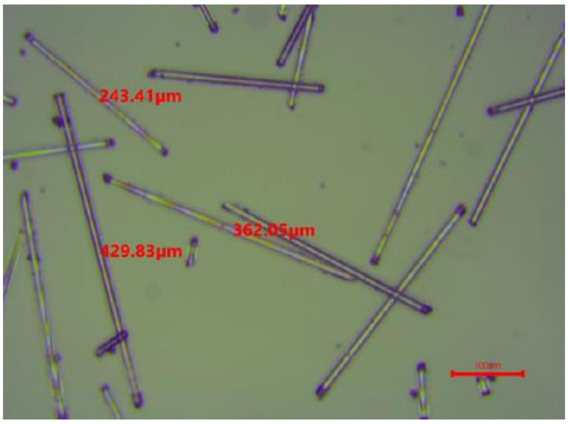

Fig. 18 Sample HR1 OK.

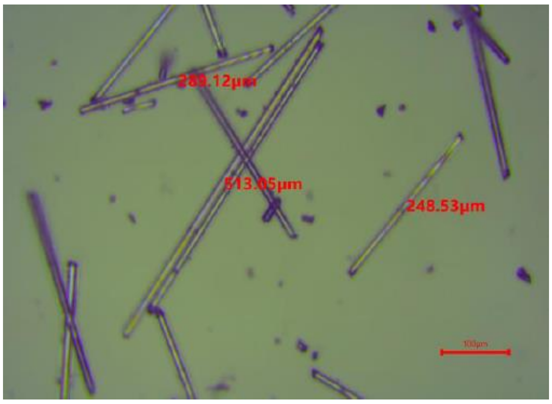

Fig. 19 |Sample HR2 OK

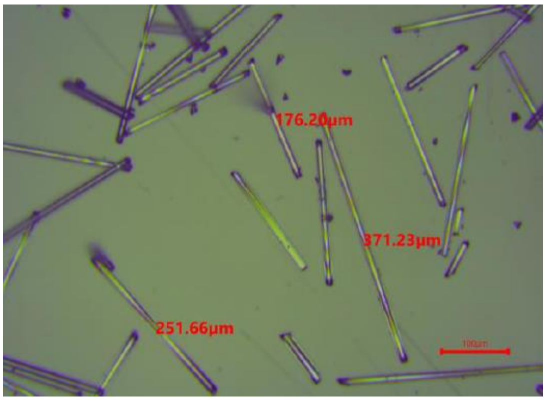

Fig. 20 Sample HR3 NOK.

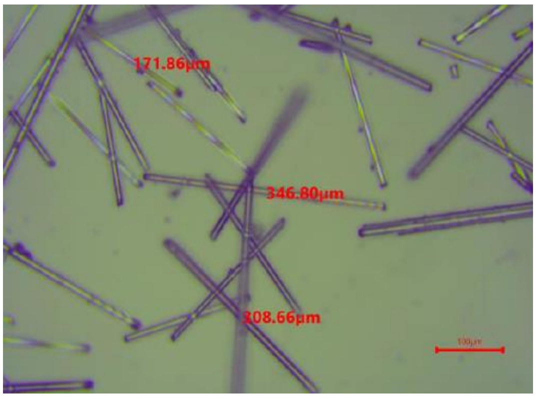

Fig. 21 Sample HR3 NOK

After the optical microscopy analysis **Fig. 18-21**, differences are found in the individual samples:

1 – Differences in the lengths of the fibers.

2 – Difference in the shape of the fibers.

4. 4. X-RAY PHASE ANALYSIS

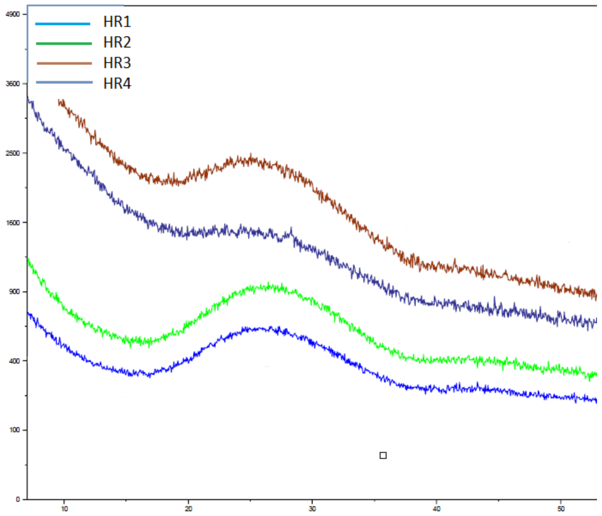

Fig. 22

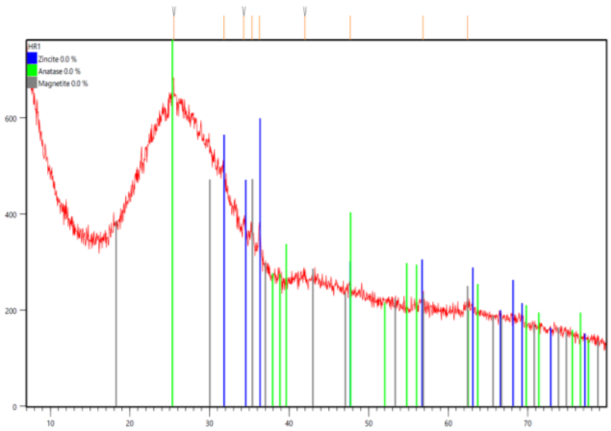

Fig. 23

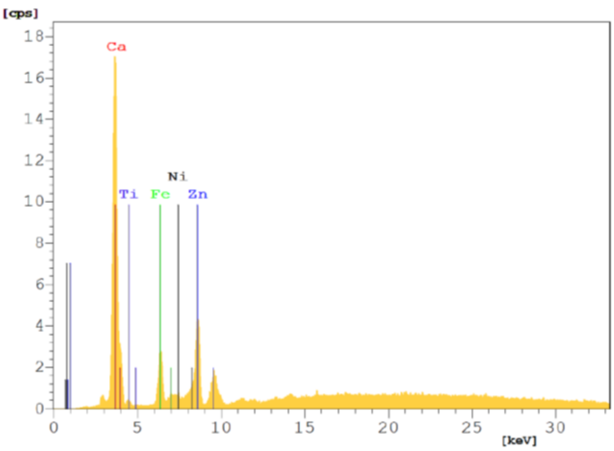

Fig. 24

In general, distinct diffraction peaks are observed – the samples are over 99 % amorphous **Fig. 22**. The presence of free iron oxide **Fig. 23** may explain the pink color of the residue of these two samples if it has oxidized to hematite Fe_2O_3, which is red in color, **Table 4**.

TABLE 4 Additional elements found in the melt.

Ref. Code	Component name	Chemical Formula
98-006-5119	Zincite	ZnO
98-008-2080	Anatase	TiO_2
98-008-2440	Magnetite	Fe_3O_4

However, this method cannot determine the amount of carbon, which is usually added in the form of soot, because it also burns together with the matrix (polymer). The research method cannot track differences in the polymer. The present metal elements from K (Potassium) to Bi (Bismuth) and the content of Ca/Ti/Fe/Ni/Zn **Fig. 24**, which is a possible reason for a change in the color of the laser marking, but further studies are needed to prove it.

5. COMMENTS AND CONCLUSIONS

1. The optical microscopy analysis proves that the shape and length of the glass fibers in this case do not affect the quality of the laser printing.

2. The reading of the percentage content of the glass fibers (**Table 2**) of the samples shows:

- Same percentage content of glass (**Table 1**) are the results OK/NOK reported after marking.

3. After the optical microscopy analysis, differences are found in the individual samples:

- Differences in the lengths of the fibers.

- Difference in the shape of the fibers (the difference in the shape of the fibers may be a consequence of crushing the glass fibers after the molding process or added fibers of different shape and length), which has not been proven and additional tests must be made.

The differences found in the shape and size of the glass fibers do not prove their influence on the quality of the laser print, this is proven by the tests that were made with the same laser parameters.

4. The presence of free iron oxide **Fig. 22** can explain the pink color of the sample, if it has oxidized to hematite Fe_2O_3, which is red. However, this method cannot determine the amount of carbon, which is usually added in the form of carbon black,

because it also burns together with the matrix (polymer).

5. X-ray phase analysis shows the content of Ca/Ti/Fe/Ni/Zn **Fig. 23**, which is a possible cause of the change in the color of the laser marking.

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