A fast and flexible method for manufacturing 3D molded interconnect devices by the use of a rapid prototyping technology

Amend, P.¹*, Pscherer, C.⁴, Rechtenwald, T.⁴, Frick, T.⁴, Schmidt, M.⁴b

¹Bayerisches Laserzentrum GmbH, Erlangen, Germany
²University of Erlangen-Nuremberg, Chair of Photonic Technologies, Erlangen, Germany

Abstract

This paper presents experimental results of manufacturing MID-prototypes by means of SLS, laser structuring and metallization. Therefore common SLS powder (PA12) doped with laser structuring additives is used. First of all the influence of the additives on the characteristic temperatures of melting and crystallization is analyzed by means of DSC. Afterwards the sintering process is carried out and optimized by experiments. Finally the generated components are qualified regarding their density, mechanical properties and surface roughness. Especially the surface quality is important for the metallization process. Therefore surface finishing techniques are investigated.

Keywords: molded interconnect device (MID); rapid prototyping (RP); selective laser sintering (SLS); laser structuring and metallization

1. Introduction

A 3D molded interconnect device (MID) is typically an injection-molded plastic part with integrated metallic circuit traces that combines electrical and mechanical functionalities in a single assembly [1]. The MID process chain can roughly be separated into the injection molding of the interconnect device and the fabrication of the circuit traces. The main MID-manufacturing methods for circuit traces are 2-shot injection molding, hot stamping, mask-lighting process, film back injection molding and laser structuring and metallization. Thereby laser structuring and metallization is the most flexible method of manufacturing circuit traces by which frequent changes of the layout can be realized during the conception [2]. The functional and geometrical requirements for 3D-MIDs for industrial applications have been increased during the last years [3] so that functional MID-prototypes are essential for an economic and efficient product engineering for first experiments during the conception stage [4]. However using current MID-technologies is highly time-consuming and expensive for manufacturing of geometrical complex prototypes because cost intensive injection molds are necessary [2].

An innovative and rational approach for a fast and flexible production of complex 3D-MID can be achieved by the use of rapid prototyping (RP) technologies. Characteristic of RP techniques is that products can be directly manufactured based on CAD datas without any shape forming tools. Well-established and industrially relevant RP
techniques are fused deposition modelling (FDM), selective laser sintering (SLS) and stereolithography (SLA) [5]. However the electrical functionality of RP prototypes which is a central component of MID products is insufficiently considered by common RP techniques. Therefore the raw materials used for the RP techniques have to be functionalized by enactable additives for the laser structuring process. For this purpose the known findings for the laser structuring of injection molded parts have to be transferred to RP techniques. For manufacturing complex 3D prototypes FDM and SLS seem to be particularly more suitable than SLA because of the fact that for FDM and SLS MID relevant thermoplastic raw material (FDM: e.g. ABS, PC; SLS: e.g. PA12, PC) as used for injection molding is available whereas the SLA process is based on UV-curable resins (acrylic- and epoxy resins). Due to the higher accuracy in contrast to FDM SLS allows the fabrication of filigree structures and has the advantage of fabricating multiple prototypes at the same time. Therefore SLS seems to be the best technique for manufacturing functional 3D-MID prototypes.

1.1. The SLS Process

Selective laser sintering is a modern layer-based manufacturing process in which the part is directly built up based upon digital computer data. During the SLS process preheated polymer powder particles are melted by a laser that scans the part contour. Each time a layer is finished the building platform is lowered on a defined height (100-200 μm) and a new powder layer is applied on the top of the previous one by a spreading knife. In this way the part is build in multiple steps layer by layer (see Fig. 1). After the fabrication process and the cooling phase the part can be removed from the part cake and cleaned from remnants of the powder [6, 7].

In consequence of the layer by layer sintering process the surface quality is limited by the stair-step effect and the particle size of the polymer powder. For an improvement of the rough surface of SLS parts finishing techniques can be used [6].

![Fig. 1. Typical system components of a laser sintering machine](image-url)

The major build parameter of the SLS process is the supplied energy density \( E_D \) [J/mm\(^2\)] which is defined as [8]:

\[
E_D = \frac{P_L}{v_s \cdot h_s}
\]  

(1)

In Equ. 1 the parameters are laser power \( P_L \) [W], scan velocity \( v_s \) [mm/s] and hatch distance \( h_s \) [mm]. Hatch distance is the distance of two laser lines by filling a contour. Furthermore part build orientation, part bed temperature, layer thickness, powder consistency and material type influence the sintering process [8].

1.2. Fabrication of the circuit traces by means of laser structuring and metallization

For the laser structuring process an enactable material is used which can be activated for the chemical metallization by laser. Therefore two similar techniques exist which are named LPKF-LDS and ADDIMID technology.

For the LPKF-LDS process a special laser enactable additive which is based on a metalorganic complex is
compounded with the polymer matrix. By laser activation the polymer matrix is ablated and a physical-chemical reaction is triggered whereby the complex bonds in the polymer matrix are cracked and the metal atoms are separated from the organic ligands. These metal atoms are used as germinal for the metallization. The micro surface roughness gained by the laser process strengths the anchoring of metal deposition [9].

For the ADDIMID technology which is used in this paper microencapsulated metal fine powder (e.g. Cu, Ni, Al) is used for activation (see Fig. 2). The metal particles absorb the laser and heat the polymer matrix up to its evaporation. This physical thermal reaction effects that the surface gets activated for the following metallization process by the metal fine powder [10].

Fig. 2. Principle of ADDIMID technology

1.3. Objectives

The present work is focused on manufacturing MID-components by means of SLS which get their electrical function in a following process step based on laser structuring and additive metallization. Therefore the SLS-powder has to be doped with ADDIMID additives. Due to the addition of laser enactable additives to the raw material a new material systems is generated that has not yet been qualified for SLS. Therefore the influence of the additives on the powder properties, the sintering process and part properties are discussed in this paper. Firstly the particle distribution of the doped material and the effect of the metallic additives on thermal properties of the basic SLS powder have to be analyzed to conclude first adaptations of the sintering process. Afterwards the sintering process for the doped material is carried out and compared to the sintering process of the undoped material. Finally the generated components are characterized regarding their density, mechanical properties and surface roughness in contrast to the raw material. Especially the surface quality is important for a selective metallization by a laser process. Because of the fact that SLS parts normally have a rough surface finishing techniques are investigated to improve the following process steps of laser-induced activation and metallization. In the end the results of laser-induced activation and the subsequent selective metallization are qualified.

2. Experimental

2.1. Used Material and material processing

The experiments shown in this paper were carried out using semicrystalline PA12-powder with an average particle size of 58 μm sold under the brand name PA2200 (EOS GmbH). As activator system for the adaptation of the raw material for laser activation and additive metallization fine aluminum powder was used. The used aluminum particles that are sold under the brand name Aluminiumfeingrieß AS MEP 027 (ECKA Granulate GmbH & Co. KG) have a spattered, irregular shape and an average particle size of 1.2 μm. Unintentional metal deposition on the surface of SLS parts was tried to be avoided by encapsulation of the aluminum particles in a sol-gel coating process with passivating SiO₂. For the material functionalization for the additive metallization 5 wt.% SiO₂ encapsulated aluminum and dried raw material were blended 45 minutes in a tumbling mixer.
2.2. Characterization of material

For a stable sintering process and effective laser activation a homogenous distribution of the activators is preferred. Therefore the raw material and doped powder were analyzed by scanning electron microscopy (SEM). The processability of the SLS powder is determined by its melting and crystallization behavior. These significant thermal process parameters were analyzed by means of differential scanning calorimetry (DSC). Therefore material samples have to be heated and cooled under defined conditions (here: heating /cooling rate = 10 °C/min) meanwhile temperature and heat flow associated with thermal transitions in the material are measured [11]. In this paper the measured DSC curves for the raw material and the doped powder were analyzed by the characteristic temperatures of melting $T_m$ and crystallization $T_c$.

2.3. Manufacturing of specimens

All specimens were manufactured on an EOSINT P380 laser sintering machine. The set up contains a CO$_2$ laser with gaussian beam distribution (focus diameter at working surface 0.35 mm). It offers a building volume of $340 \times 340 \times 620 \text{ mm}^3$, a maximum scan velocity of 5 m/s and a lateral resolution of 0.1 mm. For the experiments the building platform was lowered 150 μm layer by layer and before the manufacturing process started the process chamber was preheated more than 12 hours on 167 °C.

The optimal part bed temperature for the doped material was derived by experiments. Therefore thin single layers were build while the part bed temperature was increased step-by-step until no more curling effect (shrinkage induced by residual stress) could be observed. It has been proven that the optimal part bed temperature for PA2200 + 5 wt.% SiO$_2$ encapsulated aluminum is 174 °C. In order to guarantee comparable specimens the part bed temperature of pure PA2200 was also fixed at 174 °C.

As specimens tensile bars according to DIN EN ISO 3167 (see Fig. 3 a) and cuboid test specimens for surface analysis were manufactured (see Fig. 3 b). The influence of laser parameters on the part properties especially density and tensile strength of the fabricated tensile bars were investigated using the parameters shown in Table 1.

All tensile bars were build with applying scale factors for compensation of inherent shrinkage during cooling. The scale factors ($x$, $y = 3.1 \%$, $z = 1.8 \%$) were chosen for all tensile bars according to the product data sheet of PA2200. After the fabrication process the samples were removed from the part cake and cleaned from remnants of the powder. Therefore pressurised air and 10 minutes stay in an ultrasonic water bath were applied to the samples. Afterwards the samples were dried for 4 h with a temperature of 50 °C.

Table 1. Fabrication parameters of tensile bars

| Parameter                  | Parameter set 1 | Parameter set 2 |
|----------------------------|-----------------|-----------------|
| Laser power $P_L$ [W]      | 53.1            | 12.3            |
| Scan velocity $v_s$ [mm/s]  | 4.5             | 1.0             |
| Hatch distance $h_s$ [mm]   | 0.3             | 0.3             |

Fig. 3. (a) Tensile bar according to DIN EN ISO 3167 including measuring points for volume calculation ($l_1 = 170 \text{ mm}$, $w_1 = 10 \text{ mm}$, $t = 4 \text{ mm}$); (b) Build dependant cuboid test specimens for surface analysis ($l = 30 \text{ mm}$, $w = 20 \text{ mm}$, $t = 20 \text{ mm}$)
Furthermore the influence of the part orientation during the sintering process and its consequences on the surface quality and following metallization process were analyzed by cuboid test specimens (Fig. 3 b). The specimens were rotated respectively in an angle of 15° by the x-axis so that build dependant surfaces were fabricated under the following angles: 0°, 15°, 30°, 45°, 60°, 75° and 90°. These specimens were manufactured with parameter set 1 (see Table 1).

Because of the fact that SLS parts typically have a rough surface after-treatment techniques were investigated to reduce the steplike structure which is dedicated by the sintering process. The surface quality can be improved by abrasive techniques like grinding, polishing and blasting whereupon only the last one is appropriate for processing complex parts like 3D-MID prototypes [12]. Therefore the specimens were blasted with glass bead and corundum on a SMG 45 K-P machine (MHG Strahlanlagen GmbH) at Fraunhofer IPA. The used fabrication parameters are listed in Table 2.

Table 2. Blasting parameters

|                          | Glass bead blasting | Corundum blasting |
|--------------------------|---------------------|-------------------|
| Particle size [μm]       | 70 - 100            | 106 - 150         |
| Nozzle diameter [mm]     | 7                   | 7                 |
| Angle of impact [°]      | ca. 90              | ca. 90            |
| Blasting time per part [min] | ca. 3              | ca. 3             |
| Blasting pressure [bar]  | 2.5                 | 4                 |

Another technique used for improving the surface quality and preventing unintentional metal deposition was the infiltration of the SLS parts with protective paint. Therefore a paint which is sold under the brand name Wepelan-Abdecklack SD 2154E (Lackwerke Peters GmbH + Co KG) was used. This infiltration paint is a special air-drying galvano-resist paint which can be used for electronics.

All experiments for laser structuring were made on a Trumpf VMC3 Nd:YAG laser ($\lambda = 1064$ nm, $P_{\text{max}} = 11$ W, $f = 0 - 60$ kHz) with a focus diameter at working surface of 30 - 40 μm. For the fabrication of the circuit traces the metallization bath Enthone Cu 9070 was used. In the process specimens were kept 30 minutes in the 47 °C tempered bath.

2.4. Characterization of specimens

First of all the particle distribution and the porosity of the tensile bars were observed by micrographs. Secondly, the density of the tensile bars was investigated. Therefore dried tensile bars were weighted and dimensions were obtained using callipers. Each measuring point shown in Fig. 3 a was taken three times and an average of these values was used to calculate the volume of the part by scale factors using the CAD program Solid Works. The part density was found by dividing weight $m$ of parts by volume $v$, which is given by the external dimensions.

Despite the density the mechanical properties of the manufactured parts were investigated by tensile tests according to ISO 527. For the tests five tensile bars per material and per parameter were tested and interpreted by the measured tensile strength. The cross-sectional area of the tensile bars which has to be known for stress calculation was developed from the averaged part thickness $t$ and the averaged width $w_1$ (see Fig. 3 a).

Besides the density and mechanical properties the surface roughness of the generated specimens (see Fig. 3 b) was investigated. For this purpose the surface quality of the specimens was qualitatively investigated by micrographs and SEM pictures. The quantitative characterization of the specimens according to DIN 4768 was done by means of the contact profilometer MarTalk. A profilometer is a measuring instrument that moves a diamond stylus vertically in contact with a sample and measures the surface profile as a function of position. For all samples the surface texture was measured three times under the conditions shown in Table 3.

The target parameter of the surface quality analysis in this paper is the surface roughness depth $R_z$ (see Equ. 2) which is defined as mean of five $R_{z(2)}$-values from five sampling lengths $l_i$ over the total measured length $l_n$ (see Fig. 4).
Each $R_z$-value represents the sum from the height of the highest profile peak and the depth of the lowest profile valley with the sampling length $l_i$.

$$R_z = \frac{1}{5}(R_{z1} + R_{z2} + R_{z3} + R_{z4} + R_{z5})$$ (1)

Fig. 4. Calculation of the surface roughness depth $R_z$ according to DIN EN ISO 4287 [13]

Table 3. Measurement conditions for roughness measurements

| Roughness measurement parameter          | Value   |
|-----------------------------------------|---------|
| Stylus tip radius [$\mu$m]              | 2       |
| Traverse speed $v_t$ [mm/s]              | 0.5     |
| Single measured length $l_s$ [mm]       | 2.5     |
| Total measured length $l_n$ [mm]        | 12.5    |
| Traversed length (measured length plus start-up and trailing length) $l_t$ [mm] | 17.5    |

3. Experimental results and discussion

3.1. Material properties

For the laser sintering and laser activation process a homogenous particle distribution is important. Fig. 5a shows a SEM micrograph of the pure fine powder PA2200. The particles of PA2200 have a spherical form and a average particle size of about 60 $\mu$m. In relation to the pure raw material Fig. 5 b presents the SEM micrograph of SLS powder doped with laser structuring additives. The SiO$_2$ encapsulated aluminum particles with an average size of 1.2 $\mu$m which are used for laser activation and additive metallization stick to the about 50-fold larger PA2200 particles and allocate a large area of the raw material. This behavior shown in Fig. 5 b allows drawing the conclusion that the activator particles are regular arranged in the fine powder with a maximal distance of the PA2200 particle size. Agglomerations of activator particles were hardly observed so that the doped powder can be contemplated as homogenously mixed.

Fig. 5. (a) SEM micrograph of pure PA2200 powder; (b) SEM micrograph of PA2200 powder + 5 wt.% SiO$_2$ encapsulated aluminum
Besides the particle distribution the thermal melting and crystallization behavior of the SLS powder defines the processability. The DSC curves for pure PA2200 and raw material with 5 wt.% SiO₂ encapsulated aluminum particles are shown in Fig. 6.

![Characteristic DSC curves of pure PA2200 and PA2200 + 5 wt.% SiO₂ encapsulated aluminum (heat/cooling rate = 10 °C/min)](image)

The DSC curves pictured in Fig. 6 show that the characteristic temperatures \( T_m \) and \( T_c \) for the raw material and the doped powder are nearly identical. For PA2200 the melting temperature \( T_m \) is 187.6 °C and for the doped material \( T_m \) is 188.2 °C. The ascertained crystallization temperature \( T_c \) varies between 149.2 °C for PA2200 and 149.5 °C for the doped material. Besides the two characteristic temperatures also the enthalpies for melting and crystallization which are defined by the amount of the heat during the thermal transmission can almost be regarded as equal. The experimental results let draw the conclusion that the additives do not significantly influence the thermal behavior of the SLS powder so that the processability of the doped powder should be possible.

3.2. Specimens properties

As shown in chapter 3.1 the SLS powder properties of doped material and the raw material are approximately the same. In the following the properties of the fabricated parts subject to the used materials are compared.

3.2.1. Particle distribution and porosity

The particle distribution and the porosity in a fabricated tensile bar made from PA2200 + 5 wt.% SiO₂ encapsulated aluminum is illustrated in Fig. 7. The micrographs show that the inner structure of the part is dense even if there are isolated pores. The aluminum particles are homogeneously distributed and there is hardly none agglomeration. The distance between the aluminum particles equates in a rough first approximation to the particle diameter of PA2200 (see Fig. 7 b). For a more detailed statement about the porosity of the fabricated parts the density and the tensile strength of the tensile bars are investigated in the following chapter.

![Micrograph of a tensile bar made from PA2200 + 5 wt.% SiO₂ encapsulated aluminum shows particle distribution and pores; (b) Enlarged detail of (a)](image)
3.2.2. Density and tensile strength

The ascertained densities of all fabricated parts are in the range of the manufacturer’s data for PA2200 (see Fig. 8 a). Tensile bars of the raw material reach densities of 0.94 g/cm³ to 0.96 g/cm³. Specimens made from doped material have ascertained densities in the range of 0.93 g/cm³ to 0.95 g/cm³. In consequence the laser structuring additives reduce the density of the sintered parts a little bit compared to specimens made from pure PA2200. The density is furthermore conditioned by the used laser parameters. For an almost equal energy density $E_D$ high laser power $P_L$ and high laser velocity $v_s$ ($P_L = 53.1 \text{ W}$, $v_s = 4.5 \text{ m/s}$) lead to lower densities for both materials than the parameter set of low laser power $P_L$ and low laser velocity $v_s$ ($P_L = 12.3 \text{ W}$, $v_s = 1.0 \text{ m/s}$). This shows that a better fusion of the polymer particles can be reached by a longer and less powerful application of energy.

The density of the sintered parts is additionally an indicator for the mechanical part properties. The ascended densities correspond with the tensile strength shown in Fig. 8 b. For pure PA2200 the values vary between 46 MPa and 47 MPa depending on the used laser parameter set. The tensile strength of the doped material is clearly lower than for PA2200 and reaches values between 41 MPa and 45 MPa. Despite the lower tensile strength even the doped material has a tensile strength that is close to the manufacturer’s data for PA2200 so that the laser structuring additives have only a minor influence on the mechanical part properties.

![Fig. 8. Diagrams show the ascertained densities (a) and the tensile strength (b) of tensile bars made from PA2200 and PA2200 + 5 wt.% SiO₂ encapsulated aluminum depending on laser power $P_L$ and scan velocity $v_s$.](image)

3.2.3. Surface quality and metallization

Beside the density and the tensile strength of the SLS parts the surface quality was investigated. In Fig. 9 micrographs of cuboid test specimens (see Fig. 3 b) made from doped material and different part orientations during the sintering process are shown. Besides the characteristic build dependant angles and the layer thickness of the SLS parts (dashed lines) are illustrated.

![Fig. 9. Micrographs show the build dependant surface quality of cuboid test specimens with surfaces made under an angle of: (a) 45°; (b) 30°, 60°; (c) 15°, 75°; (d) 0°, 90°](image)
In Fig. 9 it can be seen clearly that the surface quality of SLS parts depend on the part orientation during the building process. The best surface quality was achieved for an angle of 0° and 90° (see Fig. 9 d). These surfaces seem to be relatively even with sporadic adhesion of particles from the solid powder bed. Instead of surfaces that are fabricated parallel and perpendicular to the building direction surfaces made under an angle of 15° till 75° have a highly rough surface texture with broad undercuts (see Fig. 9 a-c). The distinct profile of heights and depths is due to the layer based manufacturing process and the surface roughness depending on the powder particle size. Already the qualitative characterization of the surfaces shows that the fabricated parts have a rough surface which is unfavorable for the metallization process. In order to enforce the results of the qualitative surface characterization the measured surface roughness depth $R_z$ of the raw and doped material are shown in Fig. 10 a.

As a result of the interpretation of Fig. 10 a the surface roughness for both materials can be regarded as equal and the influence of the metal particles is negligible. The surface measurements also attest that the surface quality parallel ($R_z = 115.5-124.9 \mu m$) and perpendicular ($R_z = 79.6-81.6 \mu m$) to the building orientation is the best. Surfaces that are not fabricated parallel or perpendicular to the building orientation have higher $R_z$-values. For the surface made under an angle of 15° the surface roughness depth $R_z$ reaches its maximum of more than 200 \mu m. Because of the fact that for a high quality metallization a good surface quality is recommended, the fabricated parts were improved by surface finishing techniques (glass bead and corundum blasting, see Table 2). As a consequence of the after-treatment the surface roughness could be reduced because the abrasive particles ablate the roughness peaks. Thereby the use of corundum blasting was much more efficient than glass bead blasting (see Fig. 10 b). By means of corundum blasting and glass bead blasting a minimum surface roughness depth $R_z$ of 26.5 \mu m respectively 36.7 \mu m can be reached for a surface fabricated under an angle of 0°. In the following SEM-micrographs (see Fig. 11 a-c) the influence of the after treatment-techniques on the surface texture is illustrated.

The untreated surface (see Fig. 11 a) consists of a fusion of particles that can be clearly detected. In contrast to that the sintered surfaces treated by abrasive techniques seem to be even and no more particles can be seen. Besides
the SEM-micrographs Fig. 11 b and 11 c show that by corundum blasting a uniform level of the surface can be realized whereas by glass bead blasting in fact a smooth surface can be made but the profile depths still remains.

For a better understanding of the influence of the surface roughness on the metallization process untreated as well as surface finished parts made form doped material were kept 30 minutes in a metallization bath. In Fig. 12 b-d the metallization results for the surface (0°) of a cuboid test specimens PA2200 + 5 wt.% SiO₂ encapsulated aluminum are shown.

Untreated and surface finished parts have a totally metallized surface what means that on the one side the rough surface activates unintentional metal deposition (see Fig. 12 b) and on the other hand that the encapsulation of the aluminum particles seems not to work appropriate so that metal particles can act as germinal for the metallization (see Fig. 12 a). The damage of the encapsulation can be caused during the laser sintering process or the after-treatment process. The exact failure analysis is an element of current research. However Fig 12 b-c show that the quality of the metallization depends on the surface roughness. The untreated part shows a metallized surface with defects (see Fig. 12 b) whereas glass bead blasting makes a holohedral and complete metallization possible (see Fig. 12 c). The surface with the lowest Rₙ-value which was treated by corundum blasting also achieves a nearly homogenous metallization.

To avoid a complete and to realize a selective metallization by ADDIMID technology the SLS parts have to be infiltrated by a protective paint which can be ablated by laser structuring. In Fig. 13 a and 13 b the metallization results for laser structured surfaces with and without protective paint are shown.

Fig. 13 a confirms the theory that a selective metallization without protective paint is not possible and furthermore it can be shown that the metal deposition in the laser structured areas is higher than in the unstructured. The used protective paint nearly eliminates unwanted metal depositions and enables a selective fabrication of circuit traces on SLS parts (see Fig. 13 b).
4. Conclusion and outlook

As an alternative to the current MID-technology which is highly time-consuming and expensive because of the need of shape forming tools the use of rapid prototyping can be a fast and flexible method for fabricating complex 3D prototypes and for improving the MID product engineering during concept stage. In this paper the use of selective laser sintering and ADDIMID technology is shown as a suitable solution for this challenge. Therefore SLS powder (PA2200) was doped with ADDIMID particles (5 wt. % SiO₂ encapsulated aluminum) for the laser structuring process.

By the characterization of the doped material it could be shown that the ADDIMID particles were homogeneously distributed in SLS powder and the thermal behavior of pure PA2200 and the doped material can almost be regarded as equal so that important demands for a stable sintering process and effective laser activation are fulfilled (see Chapter 3.1).

As specimens tensile bars and cuboid test specimens for surface analysis made from PA2200 and doped material were manufactured. The ascertained density and tensile strength of all fabricated parts were in the range of manufacturer’s data for PA2200 so one can conclude that the ADDIMID additives have a minor influence on the part building and the resulting part properties. Besides it can be shown that higher part density and tensile strength can be realized with low laser power \( P_L \) and low laser velocity \( v_L \), than with high laser power \( P_L \) and high laser velocity \( v_L \), for an comparable energy density \( E_D \) because of a better fusion of the polymer particles by a longer and less powerful application of energy (see Chapter 3.2.2).

Furthermore in this paper the high influence of the orientation of the specimens during the sintering process on the surface quality of the SLS parts are presented. For the surface roughness of untreated SLS parts measurements by means of a contact profilometer surface roughness depths \( R_{\text{a}} \) between 80 μm (Minimum, 0°) and 200 μm (Maximum, 15°) depending on the angle between surface and building direction were investigated. However it can be said that the use of ADDIMID particles is negligible for the surface roughness. For a high quality metallization a low surface roughness, e.g. which is given by injection molding parts, is recommended. Therefore in this paper the surface finishing techniques glass bead blasting and corundum blasting were used to reduce the roughness peaks by ablation with abrasive particles. Thereby the use of corundum blasting (\( R_{\text{a}} = 26.5 \) μm, 0°) was much more efficient than glass bead blasting (\( R_{\text{a}} = 36.7 \) μm, 0°). Besides the influence of surface roughness of untreated as well as surface finished parts made from doped material on the metallization process were investigated. Therefore it could be shown that after 30 minutes in a metallization bath untreated and blasted SLS parts have a totally metallized surface what leads to the conclusion that besides the rough surface a defect of the encapsulation of some aluminum particles which are located on the surface must be responsible for the metallization. The exact failure analysis of the encapsulation is a part of current research. However it could be shown that for a improved surface quality which can be realized by blasting a holoheadral and complete metallization can be fabricated whereas untreated parts show defects in the metallized surface. One solution to avoid a complete metallization and to fabricate circuit traces for MID-components by SLS and ADDIMID technology is the use of an infiltration paint which improves the surface quality and acts as a protection layer for the ADDIMID particles like the skin of an injection-molded plastic part which cools down really quickly in the tempered mold. Through the use of this protective paint a selective metallization could be realized and there was none unintentional metal deposition (see Chapter 3.2.3).

The ablation process of the used protective paint and the influence of the surface roughness which has to be smoothed by infiltration on the ablation and the following metallization process are focuses of current scientific investigations.

All in all in this paper SLS and ADDIMID technology could be proven as a possible solution to manufacturing MID-prototypes even if there are still unsolved problems like the best handling of the protective paint and the encapsulation of the ADDIMID particles.

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