Advancements in Laser Micro Sintering

P. Regenfuß, A. Streek, L. Hartwig, S. Klötzer, A. Maaz, R. Ebert, H. Exner
Laserinstitut Mittelsachsen e.V. / Hochschule Mittweida; Technikumplatz 17
D-09648 Mittweida, Germany, email: exner@htwm.de

Abstract

Until recently, the technique of laser micro sintering was employed preferentially for the realization of structural features ranging down to 30µm from sub-micrometer grained powders.

Lately, however, it has been increasingly applied to process coarser powders with grain sizes in the dimension of 10µm. Although a reduction of the resolution has to be taken into account - minimal structures are around 60µm – the variety of available feedstock is considerably higher, allowing for the choice of more economic and industrially interesting materials.

Additional advantages are: accelerated performance and improved solidity of the products. Sinter results with a nickel-chromium alloy and a stainless steel powder are presented.

Keywords: freeform generation, laser micro sintering, nickel-chromium, selective laser sintering

1 Introduction

In early 2003 Laserinstitut Mittelsachsen e.V. announced a newly developed modification of SLS – mean-while referred to as "laser micro sintering" - that shifted the resolution of selective laser sintering below the limits commercial SLS devices had been confined to [1,2]. The concomitantly developed sintering reactor was based on an earlier developed scheme [3].

The obtained structures show a resolution of less than 30µm for structural details, of 20µm for ligaments and of 10µm for notches at aspect ratios of 12 and above and presently a minimal roughness Ra of 1.5µm.

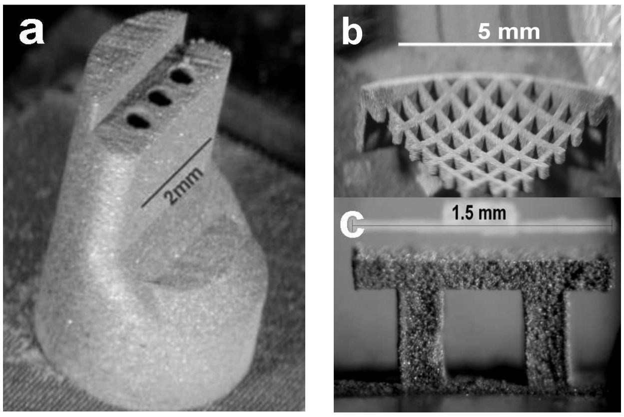

***Fig. 1a:** laser micro sintered grip bit. **b,c:** micro sintered parts with high resolution and 90° undercut angles.*

The technique has been commercially applied for the production of grip bits of micro manipulators **[Fig. 1a]**; a test mold generated from a blend of aluminium and tungsten proved stable enough to withstand shear and drag forces during injection molding of poly(oxymethylene) [4].

Despite the high and constantly improved performance **[Fig. 1b,c]**, however, in quite a number of cases, industrial implementation is still hampered by the restriction of the material due to limited availability of sub micrometer grained powders.

Powders with grain sizes around 10µm are available for a considerably larger number of materials. Additionally, the increased thickness (10µm) of the applied powder layers speeds up the process noticeably, compared to the process times when 1µm layers are employed.

In the following, laser micro sinter results are presented from powders with an average grain size of 10µm.

2 Experimental

2.1 General technique and equipment

The sintering was performed with the techniques and equipment described earlier [4-7]. After a special coating strategy the powder layer is sintered by stochastically distributed Q-switched pulses.

2.2 Alterations regarding materials

Whereas for the earlier applications grain sizes were restricted to 1µm and below, the recent processes employ powders with average particle sizes of 10µm. The examples presented below were generated from powders of steel 1.4404 and an 80Ni20Cr-alloy.

2.3 Alterations regarding the process

Under consideration of the larger grain size the sinter layer thickness was correspondingly increased to 10µm. As larger grained powders are assumed to be less reactive the emphasis was placed on assays under normal atmosphere.

3 Results

3.1 Assays with stainless steel 1.4404

Fig. 2 shows two interlocked gear wheels with outer diameters of 8.65 and 4.52 mm respectively. The sample has been generated under normal atmosphere. The gear is rotatable and held by two solid axels generated in the same process.

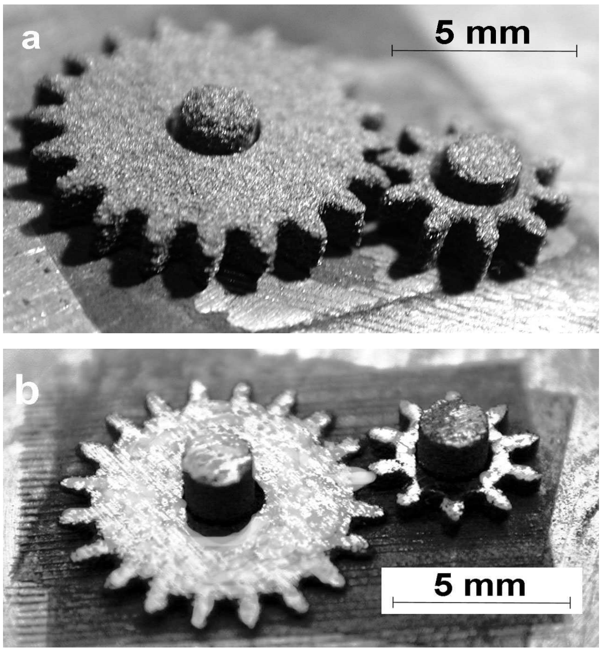

Fig. 2a: *laser micro sintered gear wheels (steel 1.4404, normal atmosphere). b: gear after finishing.*

The inside of the square prism presented in **Fig. 3a,** with a base size of 10mm x 10mm, is partitioned by vertical walls resulting in parallel channels with an aspect ratio of 15. The separating walls have a thickness of 180µm as shown in **Fig. 3b**. 150µm was about the smallest thickness of walls that were generated with this material under normal atmosphere. Ligaments with a gauge down to 60µm can be generated from this material in oxygen free environment.

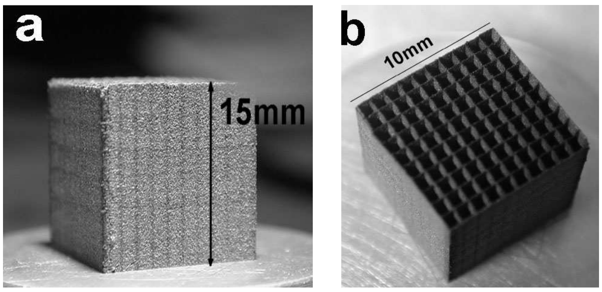

Fig. 3: *Hollow square prism (steel 1.4404, normal atmosphere.* ***a:*** *side view,* ***b:*** *top view, showing the grid-like arrangement of the separating walls*

A single, double and a triple helical coil are presented in **Figs. 4a-c.** The outer helical diameter is 5mm, the vertical and horizontal strand thickness is 0.5mm and 1mm respectively. The heights of the specimens are 15mm for the single and triple helix and 10mm for the double stranded coil. The generation of the triple helix afforded 30min. All samples were processed under normal atmosphere.

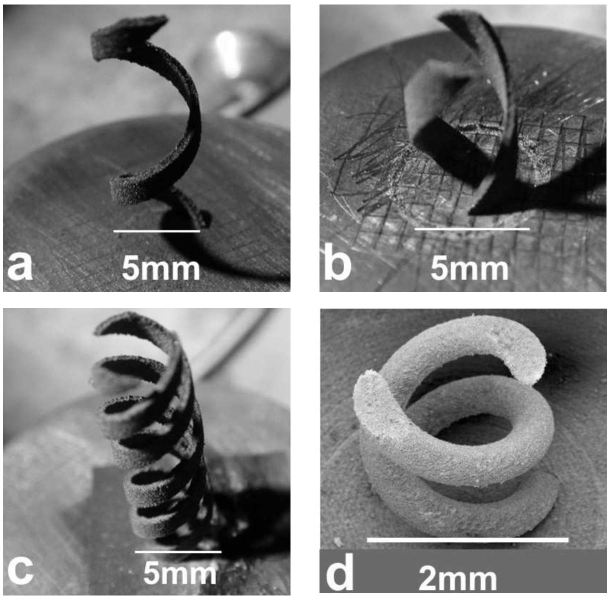

Fig. 4a,b,c*: single, double and triple helices (steel 1.4404, normal atmosphere) with respective heights of 15mm, 10mm and 15mm.* ***d:*** *double helix from tungsten nanopowder.*

As a comparison the SEM view of a double stranded helix [4,6] is shown in **Fig. 4d**. This helix had to be generated in an oxygen free environment and required a process time of 4 hours and 30 minutes.

3.2 Assays with 80Ni20Cr-alloy

As in the case of steel 1.4404 the alloy 80Ni20Cr with an average grain size of 10µm can also be processed under normal atmosphere by the Q-switched pulses typical for laser micro sintering. The already mentioned effect of the environment on the resolution of the technique can also be observed with 80Ni20Cr. Whereas under oxygen free shield gas ligaments of a minimal width of 55µm are feasible, 125µm is the resolution that can be achieved under normal atmosphere. **Fig. 5a, c** shows a circular ligament, generated under shield gas; the probe in **Fig. 5b** was sintered under normal atmosphere.

Fig. 5d is an SEM-view of a coiled tungsten ligament [4,6] generated under shield gas from tungsten powder (grain size <1µm).

Another impression regarding the deterioration of the surface and structural details, by switching from laser micro sintering of nano-powder to “normal-atmosphere-sintering” of 10µm-sized 80Ni20Cr, can be obtained from **Fig 6**. Although the tool in **Fig. 6a** is principally still employable for the designed purpose, it is much coarser than the one in **Fig. 6b** that was generated in steps of 1µm-layers [1]. On the other hand the

80Ni20Cr-tool required a process time of 90 minutes whereas the generation of the high resolution tungsten tool took 45 hours.

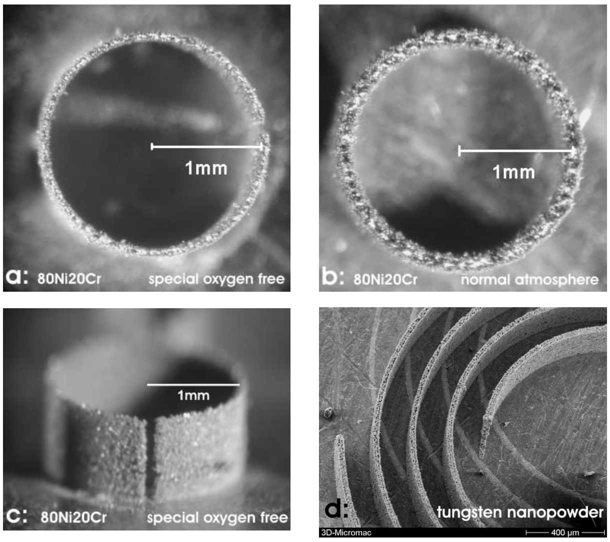

Fig. 5a,c: *Cylindrical wall generated from 80Ni20Cr in an oxygen free environment with a wall thickness of approximately 60µm.* ***b:*** *cylinder from 80Ni20Cr generated under normal atmosphere (wall thickness: 125µm).* ***d:*** *coiled tungsten ligament from nanopowder (gauge: 40µm).*

Fig. 6a*: A fiber positioning tool produced from 80Ni20Cr in normal atmosphere within 90min.*

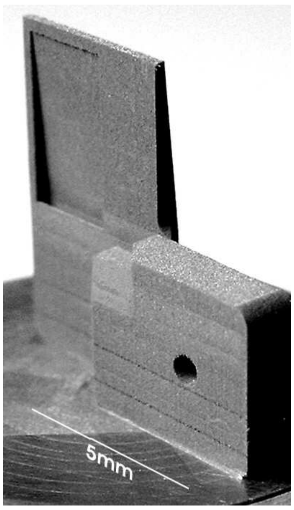

Fig. 6b: *The same tool produced from nanopowder in 1µm steps in a 20h process*

3.3 Features of laser micro sintering of 10µm grains

The performance characteristics of laser micro sintering with 10µm grained powders are listed in **Tab. 1** along with the corresponding data for the process with nanopowders.

The gain in build-up rate by a factor between eight and ten is still at the expense of a discernable increase in surface roughness. The reduction of this effect is being worked on.

On the other hand, tensile and shear strength of the sintered material is in the order of magnitude of the bulk material, though standard material data have not been acquired yet. Hardness of the sintered material seems to be higher than the bulk. 80Ni20Cr products also feature detectable elasticity.

Tab. 1: *Features of Laser micro sintering with sub-µm and 10µm grained powders*

Grain size [µm]		≤ 1	10
Sinter layer thickness [µm]		1	10
min. roughness [µm]	normal atmosphere	--	8.5-10
	special oxygen free	1.5-2.5	5.5-8.5
ligament gauge [µm]	normal atmosphere	--	125-150
	special oxygen free	20	55-60
Process time for 1000mm^3 [hrs:mns]	present equipment	65:00	08:00
	upgraded equipment	35:30	02:50

4 Summary

The technique of laser micro sintering has been successfully adapted to the processing of 10µm grained metals applying 10µm thick sinter layers in the freeform process. This closes the technological gap between the commercial lower limit of 20µm and heretofore laser micro sintering material of ≤1µm.

Depending on the material, the processing of 10µm metal powder is feasible under normal atmosphere.

Bibliography

[1] Regenfuss, P.; Hartwig, L.; Klötzer, S; Ebert, R.; H. Exner, H.: Microparts by a Novel Modification of Selective Laser Sintering. Conference Paper; Rapid Prototyping and Manufacturing Conference, May 12– 15, 2003, Chicago (IL), USA

[2] Regenfuss, P.; Hartwig, L.; Klötzer, S.; Ebert, R.; Exner, H.: Microparts by a Novel Modification of Selective Laser Sintering. *SME Technical paper TP04PUB185*

[3] Ebert, R.; Exner, H.: Vorrichtung und Verwendung von Vakuum und/oder einer zusätzlichen Wärmequelle zur direkten Herstellung von Körpern im Schichtaufbau aus pulverförmigen Stoffen. Patent, date of application 01.11.1999; ref. no. DE 199 52 998

[4] Regenfuss, P.; Hartwig, L.; Klötzer, S.; Ebert, R.; Brabant, Th.; Petsch, T.; Exner, H.: Industrial freeform generation of microtools by laser micro sintering. Rapid Prototyping Journal, Jan. 2005, Vol. 11, no. 1, 18-25(8)

[5] R. Ebert, P. Regenfuss, L. Hartwig, S. Klötzer, H. Exner: *Process Assembly for µm-Scale SLS, Reaction Sintering, and CVD*. LPM 2003, 4th International Symposium on Laser Precision Microfabrication, Proceedings of SPI, June 21-24, 2003, Munich, Germany, Vol. 5063, 183-188.

[6] Exner, H.; Regenfuß, P.; Hartwig, L.; Klötzer, S.; Ebert, R.: Selective Laser Micro Sintering with a Novel Process. LPM 2003, 4th International Symposium on Laser Precision Microfabrication, Proceedings of SPI, June 21-24, 2003, Munich, Germany, Vol. 5063, 145-151

[7] Regenfuß, P.; Ebert, R.; Klötzer, S.; Hartwig, L.; Exner, H.; Brabant, Th.; Petsch, T.: Industrial laser micro sintering, Proceedings of the 4th LANE 2004, Erlangen, Sept. 22.-24 2004, 413-424