Comparison of laser polishing effects for different materials

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Integrated optical components are becoming more relevant for complex and miniaturized systems. For this application, the necessary freeform objects can only be machined with increased effort when using conventional finishing processes. Therefore, an adjustable finishing process, such as laser polishing, which is a non-contact and low-ablation process, is needed.

1 Motivation

Multi-material and integrated optical components become more and more relevant for small, highly functional systems due to the different properties of material classes. In the case of additive manufactured components, the post treatment of the surface is still necessary to the requirements for e.g. surface roughness. Especially for multi material components and their different optical behavior the questions arises, if multiple post treatment processes, and therefore an increased finishing effort, are needed in order to ensure the optical quality.

In order to reduce process steps for the post treatment, investigations on the feasibility of laser polishing as a non-mechanical post treatment with one laser source on multiple materials are performed. There are many studies on laser polishing in the literature, but they are focused on single materials [1] [2] [3]. Also for laser polishing of additively manufactured components first works are available [4].

In this article, the uniform post-processing of different material classes by laser polishing is investigated. The laser polishing is performed with the same laser source (here CO_2-laser) on mono-material components to investigate the effectiveness of laser polishing without changing the laser source for fewer process steps.

2 Process and Materials

The used experimental set-up consists of a CO_2 laser beam source (with a wavelength of 10.6 µm), a scanner system and a sample table. The scanner allows to adapt the geometry of the field being polished to the shape of the component. As the process is performed in a defocused way, with a small divergence, low height variations can be handled.

During the experiments, three materials are used: AlSi10Mg for samples using Selective Laser Melting (SLM), PLA for Fused Deposition Modelling (FDM) samples and fused silica slices. Each of the materials is used to manufacture additively manufactured optical components like lenses or mounts. With the use of this materials selection, preliminary tests are carried out for laser-based polishing using the most important material classes for optics manufacturing.

3 Results

First, the surfaces of the samples produced in the SLM process are compared before and after polishing (Fig. 1). For optical quality, the roughness values must be in the two-digit nanometer range. The surface roughness of the aluminum samples in particular has been degreased, but surfaces defects are still clearly visible. After polishing, the roughness values S_a are still in the range of 14 µm (initial state 40 µm, Tab. 1). Therefore, further parameter studies must be carried out using the laser system for the aluminum components, even if an improvement has been achieved.

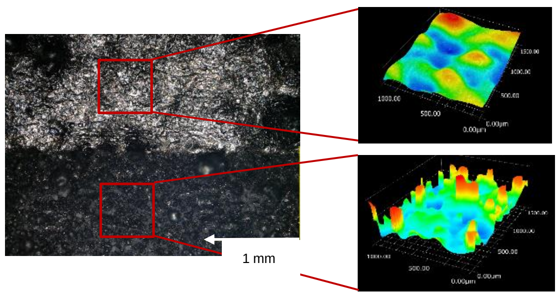

Fig. 1 *Comparison of the roughness from the surface of a printed SLM part (bottom) and the surface after the polishing process (top).*

For the glass samples, surface roughness values under 30 nm could be achieved. The absorption of glass at 10.6 µm is very high compared to aluminum, which allows a more efficient processing (Fig. 2).

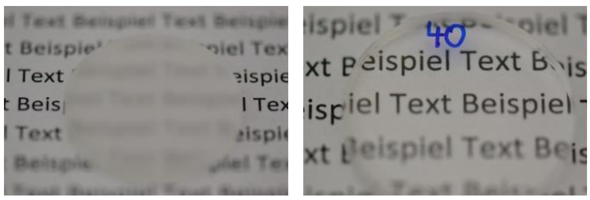

Fig. 2 *Left: Fused silica slice before the polishing process; Right: Fused silica slice after laser polishing.*

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Literature values for the surface roughness of optical lenses is in the range of λ/10 [5]. This range is already achieved looking at the surface, but there is still a waviness. Internal stresses, which can influence the light propagation and image quality of the optical components as a result of a stress birefringence were induced by the laser-polishing (Fig. 3).

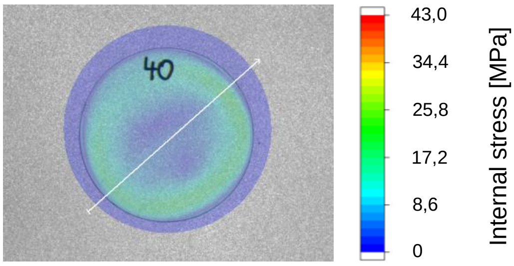

Fig. 3 *Internal stress of a laser polished fused silica slice.*

The PLA also shows a significant improvement of the surface roughness after polishing. The characteristic layer lines created in the FDM process are nearly entirely removed (Fig. 4).

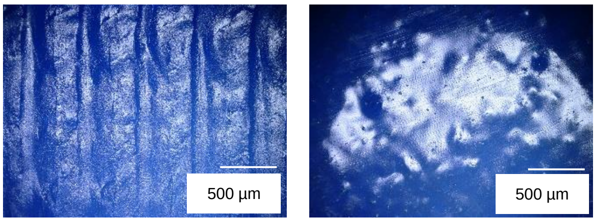

Fig. 4 *Left: Printed PLA component from the FDM process without a post process; Right: PLA part after the laser based polishing.*

Remarkable, however, is the bubble formation in the processed samples, which is probably caused by outgassing of the plastic. This effect and the composition of the material have to be further investigated for a more detailed understanding.

Material	Non-polished		Polished	
	S_q [µm]	S_a [µm]	S_q [µm]	S_a [µm]
AlSi10Mg	45.957	39.036	16.598	13.983
SiO_2	2.531	1.885	0.028	0.022

Tab. 1 *Comparison of the area roughness values of the unpolished and polished surfaces of the aluminum and glass material.*

Overall, significant improvements of the surface roughness were achieved with all materials compared with the original condition.

4 Discussion

This work shows that multi-material processing with only one laser beam source is feasible but not with the required quality. A significant challenge with the used experimental set-up are the different absorption coefficients of the materials. For each component, individual parameter sets must be adapted to the respective material properties. Depending on the used material, different effects like the outgassing with PLA have to be kept in mind when processing the surfaces and therefore the post-process might need additional considerations regarding process parameters and environmental conditions. The causes for the inclusions and defects on the surface created in the process must be identified and reduced.

5 Outlook

The laser polishing for metals, glass and polymer with a single laser system is feasible although different processing efficiencies have an impact on the surface quality. Further parameter studies for the polishing of polymers from a FDM process and metals from a SLM are necessary in order to get results with a lower surface roughness. This prerequisite is indispensable for applications in optical setups.

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