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Mobile – Selective Laser Melting (M-SLM) for Construction on the Moon

Executive Summary

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When setting up a lunar station, technologies for the use of locally available materials are crucial. Such technologies drastically reduce the need for transportation from Earth. This project idea aims to provide proof of a key technology, namely Mobile – Selective Laser Melting (M-SLM) for building large structures on the Moon. A mobile high power laser beam is directed on lunar regolith leading to its melting and after cooling to solid structures as illustrated in Figure 1. The main experimental configuration was based on parameters derived from the previously developed MOONRISE payload engineering model. A laboratory setup was upgraded with a galvanometer scanner, which made it possible to deflect the laser beam without the need for an external motion system (e.g. a robotic arm) as required for the MOONRISE payload.

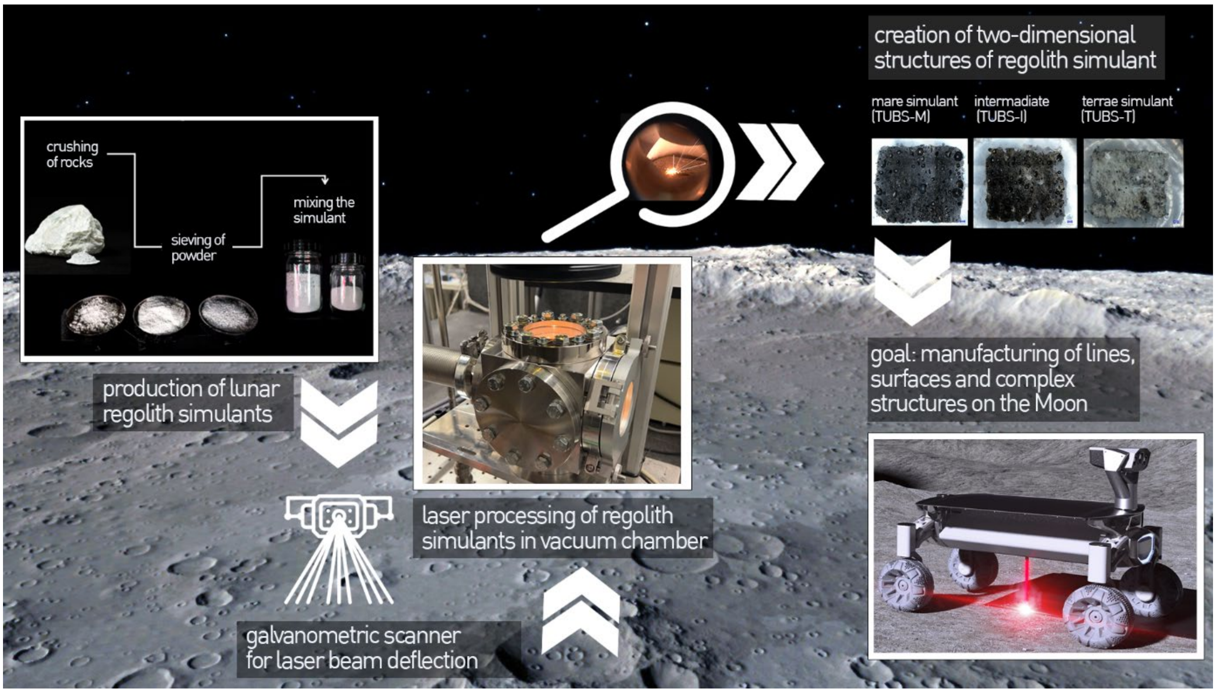

Figure 1. Illustration of the M-SLM process for construction on the Moon.

The Laser Zentrum Hannover e.V. (LZH) carried out laser tests in a vacuum chamber with lunar regolith simulants from TU Berlin (TUB). Multiple process parameter variations for the generation of 1D and 2D regolith structures were tested by LZH and analysed by TUB.

Furthermore, this study investigated state-of-the-art laser beam deflection technologies and their potential use in space. For this study, a galvanometer scanner was chosen after an assessment of available scanning technologies, demonstrated TRL, and commercial availability. However, micro-opto-electromechanical systems (MOEMS) have also demonstrated suitable technical specifications. For a future flight model development, for both technologies, highly customized systems will have to be developed and qualified for the specific use case.

The investigations in this study showed that laser melting of lunar regolith simulants under vacuum in a powder bed without substrate material is possible. The low heat conductivity, caused by manufacturing directly in the powder bed and the vacuum, is one of the major challenges. The laser scanning speed must be very slow (slower than 5 mm/s for this configuration) to keep the melt pool size in a suitable range and avoid balling effects due to surface tension. Cooling times must be applied to avoid overheating of the material. Taking these phenomena into account, the manufacturing of closed, stable two-dimensional structures as shown in Figure 2 is feasible.

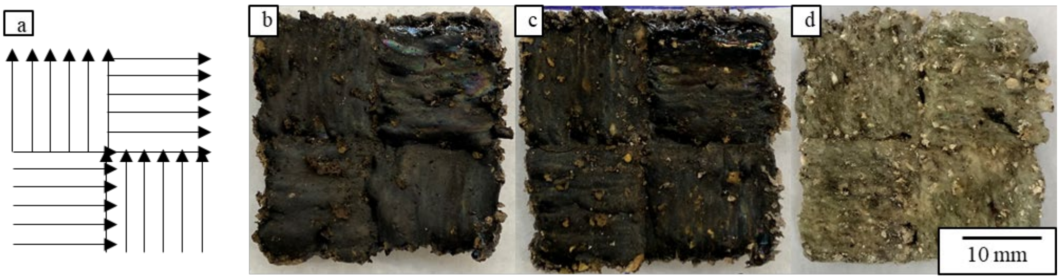

Figure 2. Scaled two-dimensional surfaces; a) Schematic illustration of scanning path, b-d) surfaces manufactured out of TUBS-M, TUBS-I and TUBS-T lunar regolith simulants.

Evaporation is noticeable during the laser melting process in an increase of pressure and a high number of pores within the manufactured samples. The resulting porosity for all samples is approx. 70% and can be seen in Figure 3.

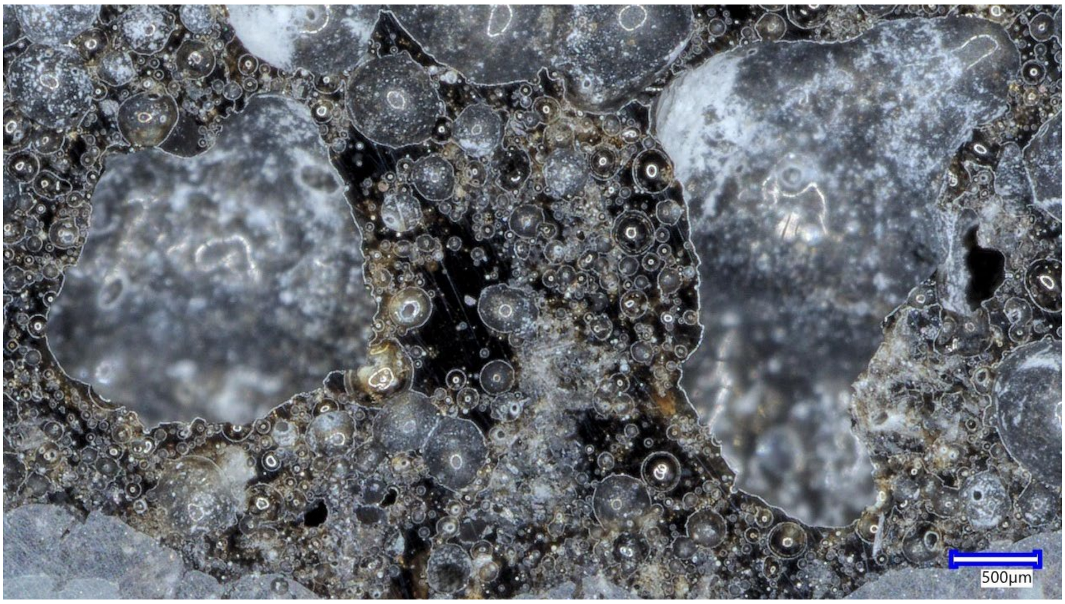

Figure 3. Pores in TUBS-M with sizes ranging from ≈10 µm to ≈2 mm.

Regarding surface defects, roughness, and waviness of the samples, it can be concluded that low scanning speeds and small hatch distances lead to less visible defects and a smooth surface.

Due to the glass-like material structure and high number of pores, the material characteristics are showing a low tensile breaking stress. If the process can be adapted to produce more compacted material with less pores, it will be possible to achieve higher breaking stresses.

Since the process uses slow scanning speeds and long cool down times, an approach to increase the manufacturing speed could be the use of a laser diode array instead of increasing the laser power. To create three-dimensional structures, a possibility to deposit regolith powder in a controlled manner must be integrated.

In summary, this study showed that it is possible to produce 1D and 2D samples under vacuum atmosphere from different lunar regolith simulants using scanner guided laser radiation. Mobile Selective Laser Melting can be a key technology to build infrastructure for an outpost on the Moon.