

# PhD subject / sujet de thèse (2023)

**Title:** Selected laser sintering for lunar dust simulants

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**Host Unit/ Unité d'accueil :** ICube Laboratory (D-ESSP Department)

IPP team (Photonics Instrumentation and Processes)

**Affiliate institution:** University of Strasbourg / INSA of Strasbourg/ Icam site de Strasbourg-Europe

**Collaboration(s) (if applicable):** ISU, Mines d'Albi – Institut Clément Ader

**Attachment to a program (if applicable):**

## Summary:

Nations with space capabilities are now in a race to build the first base on the Moon as launch pad to go to Mars. The European Space Agency is currently recruiting the next generation of astronauts that will go back to the moon on the *Artemis* project. Additive manufacturing using regolith, the main Lunar in-situ material resource, is offering a solution for long duration stay on the Moon or Mars. Applying Selective Laser Sintering (SLS) technology to build infrastructures or tools will reduce the space transportation efforts from Earth and lower the cost of the space missions. Furthermore, additive manufacturing will be a precious asset for companies looking into settlements for space mining of various resources such as water and helium 3.

However, many challenges still lie ahead to optimize the SLS process. First of all, the regolith composition is region dependent. Various simulant thus must be tested and their respective adequate experimental conditions for correct sintering compared. Furthermore, the mechanical integrity of the manufactured samples must match the requirements depending on the diverse applications.

Our research team has developed a powder bed SLS prototype using a 100 W 1090 nm CW laser and a galvo head for high speed and accuracy. The height and compression of the added layers can be controlled thanks to a Z-stage, a roller and a blade. Various lunar dust simulants were characterized by XRD and used (JSC-2A, LHS, LMS, and EAC-1). Specific care is taken when manipulating the nano-size powders. The experimental process is monitored by a pyrometer. The process conditions are optimized thanks to a numerical model developed on COMSOL Multiphysics. Nonetheless, the processing conditions do not currently reflect those that will be met in space such as gravity or atmosphere. In order to recreate some of the conditions, a vacuum chamber with  $10^{-2}$  mbar capacity is currently being refurbished. This chamber will host X/Y/Z/rotation stages. The outside will be adapted to fit the laser and galvo head to stir the beam. The PhD student will have to finish the instrumentation of the vacuum chamber.

The thermomechanical characterization of the samples will be made by the CGE team at ICube, Strasbourg, and the ICA, Albi.

The PhD candidate will work on three axes:

- The optimization of the process in the experimental powder bed SLS machine for various simulants ;
- The optimization of the process in the low atmospheric conditions ;
- The optimization of the numerical model.

The PhD candidate will work on three sites, Icam site de Strasbourg-Europe in Schiltigheim, and ICube and ISU at Illkirch.

## References:

- Stupar, D., Chabrol, G., Razak, A., Lecler, S., Tessier, A. et al., 2022, Feasibility of additive manufacturing processes for lunar soil simulants. *Advanced Technologies & Materials* , 47 (1), pp.39-43. <https://doi.org/10.24867/ATM-2022-1-007>
- Farries, K.W., Visintin, P., Smith, S.T. and van Eyk, P., 2021. Sintered or melted regolith for lunar construction: state-of-the-art review and future research directions. *Construction and Building Materials*, 296. <https://doi.org/10.1016/j.conbuildmat.2021.123627>.
- Fateri, M., 2013. Experimental investigation of selective laser melting of lunar regolith for in-situ applications. In: *ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE)*. American Society of Mechanical Engineers (ASME). <https://doi.org/10.1115/IMECE2013-64334>.
- Grossin, D., Montón, A., Navarrete-Segado, P., Özmen, E., Urruth, G., Maury, F., Maury, D., Frances, C., Tourbin, M. and Lenormand, P., 2021. A review of additive manufacturing of ceramics by powder bed selective laser processing (sintering / melting): Calcium phosphate, silicon carbide, zirconia, alumina, and their composites <https://doi.org/10.1016/j.oceram.2021.100073i>.
- Grossman, K., 2004. *Regolith-Based Construction Materials for Lunar and Martian Colonies*. [online] Available at: <<https://stars.library.ucf.edu/etd/6165>>
- Hon, K.K.B. and Gill, T.J., 2003. *Selective Laser Sintering of SiC/Polyamide Composites*. [https://doi.org/10.1016/S0007-8506\(07\)60558-7](https://doi.org/10.1016/S0007-8506(07)60558-7)
- Zheng, Y., Zhang, K., Liu, T.T., Liao, W.H., Zhang, C.D. and Shao, H., 2019. *Cracks of alumina ceramics by selective laser melting* <https://doi.org/10.1016/j.ceramint.2018.09.149>
- Song, S., Gao, Z., Lu, B., Bao, C., Zheng, B. and Wang, L., 2020. *Performance optimization of complicated structural SiC/Si composite ceramics prepared by selective laser sintering*. <https://doi.org/10.1016/j.ceramint.2019.09.004>
- Duke, M.B., Blair, B.R. and Diaz, J., 2003. Lunar resource utilization: Implications for commerce and exploration. *Advances in Space Research*, 31(11), pp.2413–2419. [https://doi.org/10.1016/S0273-1177\(03\)00550-7](https://doi.org/10.1016/S0273-1177(03)00550-7)
- Prof. Dan Britt, Dr. Zoe Landsman and et al., 2019. *ExoLith Lab*. [online] Available at: <<https://exolithsimulants.com/>> [Accessed 21 February 2022]
- D. Urbina, H. Madakashira, J. Salini, S. Govindaraj, R.B., J. Gancet, M. Sperl, A. Meurisse, M. Fateri and B. Imhof, 2017. *Robotic prototypes for the solar sintering of regolith on the lunar surface developed within the Regolith project*. Adelaide, South Australia.