

Investigation of microwave sintering as a potential fabrication method of Additive Manufacturing technologies for an extra-terrestrial construction processes

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Aim: to develop an underpinning theory and practice of microwave sintering method as a potential fabrication method of Additive Manufacturing (also known as 3D Printing) technologies in extra-terrestrial environments, including the Moon and Mars, which academics and practitioners in the field of Built Environment and Space Engineering can readily refer to and translate into practice.

Objectives:

- To investigate the strengths and weaknesses of microwave sintering and compare with other methods, including solar and laser sintering.
- To understand the phenomenon of microwave sintering with lunar regolith and simulant under lunar surface environment conditions.
- To develop an optimal fabrication method of AM technologies as part of a potential construction process on the Moon.
- To evaluate the developed fabrication method by measuring the mechanical properties of sintered specimens.

Description: The Open University is initiating a ground-breaking research area – Space Architecture, which addresses important challenges of construction processes in extra-terrestrial environments and investigates alternative construction processes and materials, particularly with a relevance to the Moon where multiple agencies consider plans for extended facilities in the foreseeable future. As part of the effort, the proposed research will explore the link between the fields of the Built Environment (architecture and construction) and Planetary/Space Sciences by further extending the ongoing research, which explores the phenomenon of microwave sintering with lunar simulant JSC-1A. The key research questions that will be addressed through this research are:

- Which microwave frequencies could provide optimal performance of sintering for lunar regolith?
- How best to fabricate materials using microwave sintering in order to maximise the mechanical properties?
- What is the best way to cure the printed materials in a lunar (vacuum) environment?

The proposed research is topical and timely in light of the upsurge in global efforts in lunar science and exploration. This project will provide an excellent opportunity for the student to work as a part of a lunar team at the Open University with training in the handling and analysis of lunar samples and simulants, and will seek for potential collaboration opportunities with industry such as Industrial Microwave Systems Ltd (IMS) in order to develop a bespoke microwave sintering system. Interested candidates should first discuss their research proposal with Dr Lim (sungwoo.lim@open.ac.uk).

References:

- 1) Mueller, R., et al., (2016), "Automated Additive Construction (AAC) for Earth and Space Using In-situ Resources", Proceedings of the *Fifteenth Biennial ASCE Aerospace Division International Conference on Engineering, Science, Construction, and Operations in Challenging Environments* (Earth & Space 2016), Orlando, Florida, USA, 11-15 Apr 2016. Reston, Virginia, USA: American Society of Civil Engineers.
- 2) Srivastava, V., **Lim, S.**, Anand, M., (2016), "Microwave processing of lunar soil for supporting longer-term surface exploration on the Moon", Special Issues, Space Policy Journal, Vol 37, Issue 2, pp. 92-96;
- 3) Lim, S., Buswell, R.A., Le, T.T., Austin, S.A., Gibb, A.G.T. and Thorpe, A., (2012), "Development in construction-scale additive manufacturing processes", Automation in Construction, Vol. 21, Issue 1, pp. 262-268

Qualifications required: Applicants should have a first class or upper second-class MSc degree or equivalent (or BSc degree with some industrial experiences) in a relevant discipline, which may include Engineering, Construction or planetary science. Any previous experience in using lunar simulant, 3D Printing and CNC/robotic programming would be an advantage.