3D printing of microscale graded shape memory components for in-vivo actuated medical devices

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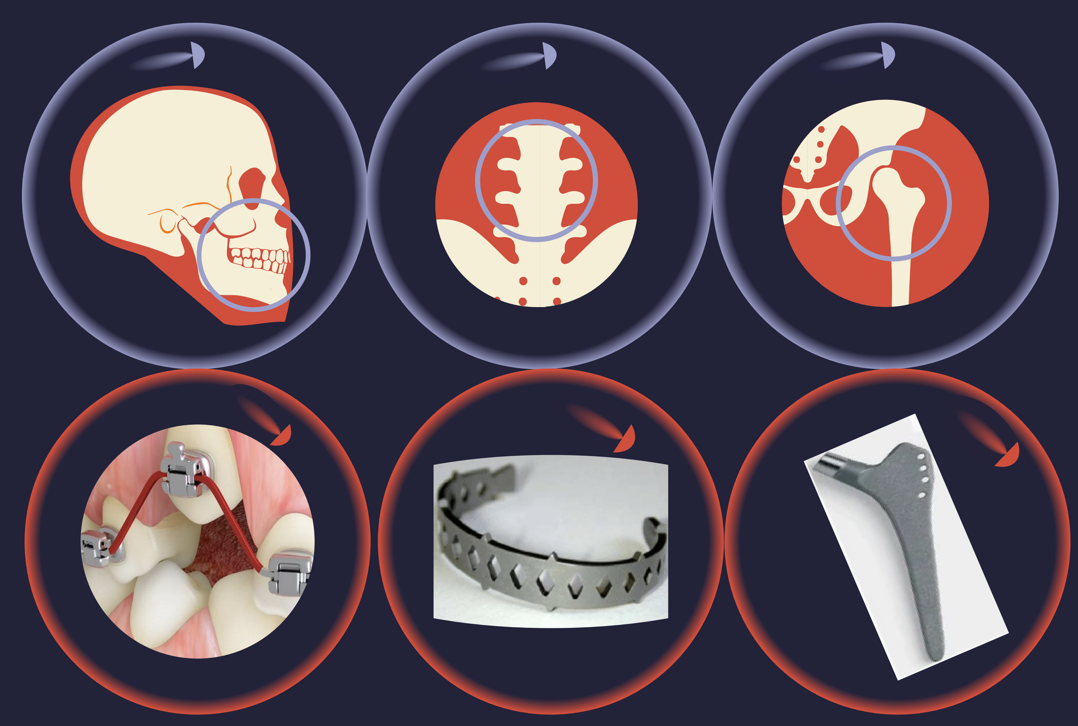
1. Project description

*Laser material processing is becoming increasingly popular in the biomedical industry owing to its high precision to fabricate complex structures, improved quality and low cost. **Nickel-titanium (NiTi)** alloy is an active material that can deform at low temperatures and return to its original shape when heated. The ability of NiTi is called the shape memory effect. This paves the way for the use of these materials as actuators inside the body to perform specific tasks. The idea of the project is to use a laser-driven process called **laser-induced forward transfer (LIFT)** to fabricate a **shape memory alloy (SMA)** component in the scale of 10's of microns by depositing sub-voxels (3D pixels) of material layer by layer in order to obtain a fully functional microscale graded actuator.*



Schematic of biomedical implants such as orthodontic archwires, spinal cages and hip replacement joints [1-3].

2. Industry challenge

- *The project builds on strengths of the UK in industrial lasers and their application to laser driver manufacturing processes.*
- *It aligns with both the Productivitiy and Health priorities of EPSRC; the functional grading LIFT process will be disruptive by providing a route to functional grading of materials at the microscale, and key initial applications being in medical devices.*
- *This project helps to address the 21st Century Products priority, in that it will enable the manufacture of miniturised medical devices with functionalities that are currently not possible at such scale. As an inherently digitally-controlled process, it also aligns with the Digital Manufacturing priority.*

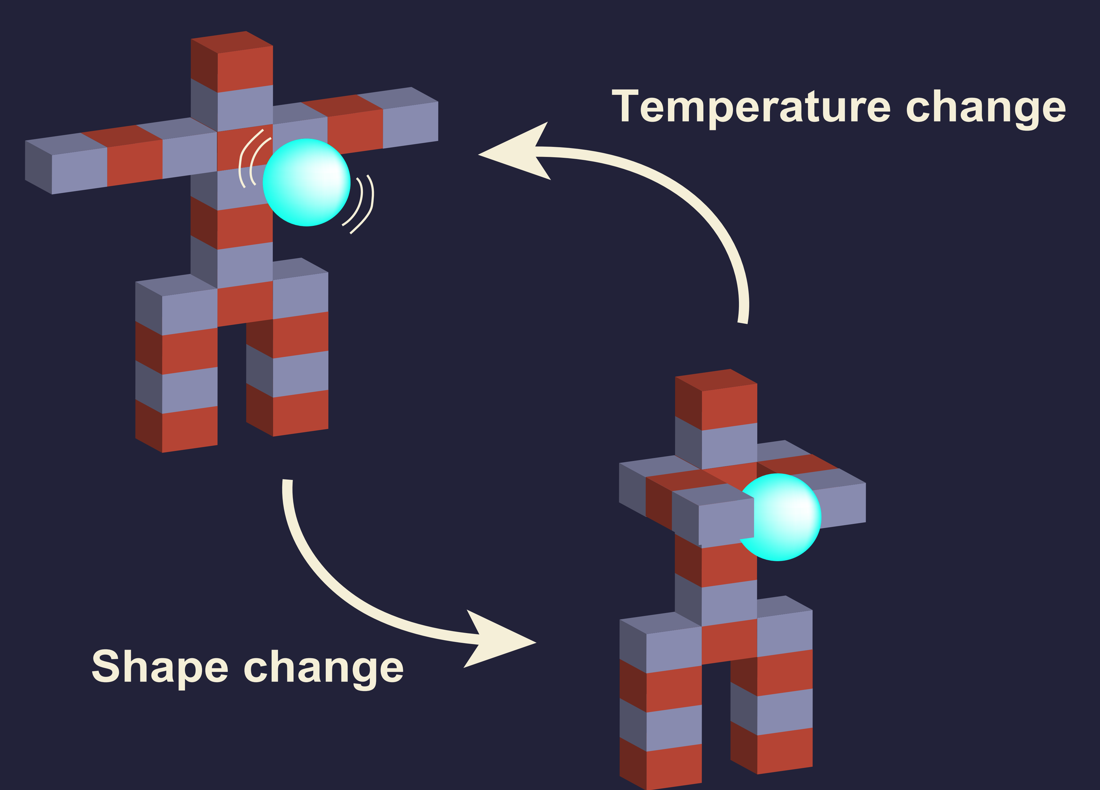
Amplitude

EPSRC
Engineering and Physical Sciences Research Council

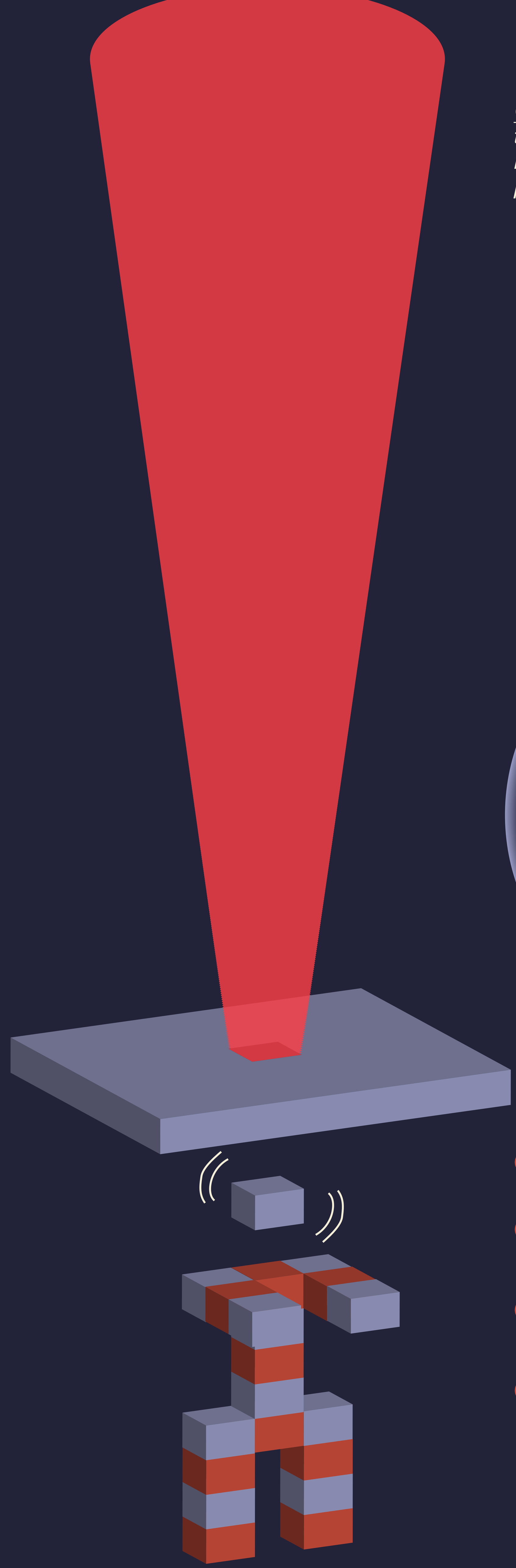
3. Proposed research

Laser 3D printing: *Depositing metals layer by layer from a donor thin film using a focused laser beam to fabricate an actuator.*

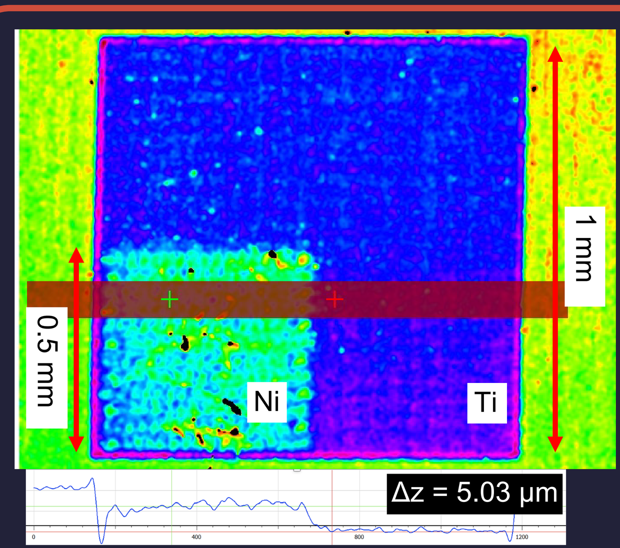
Shape memory effect: *The built structure can be deformed to any shape. Once heat is applied, its brought back to its original shape. Here is a conceptual robot acting like a micro-gripper to pick and place components in a specific part of the body. It is made out of Nickel-Titanium alloys that are biocompatible and have high corrosion resistance and fatigue strength.*



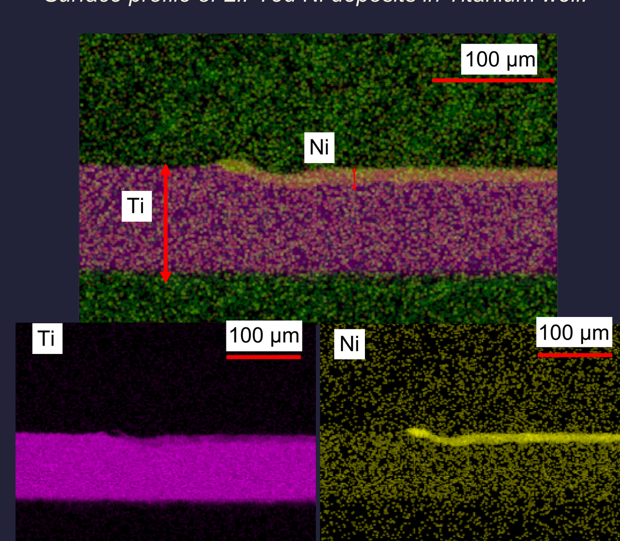
Shape memory effect. At low temperature, stress is applied and the object comes back to its original shape when heated at the transition temperature.



Schematic of LIFT of nickel and titanium voxels.



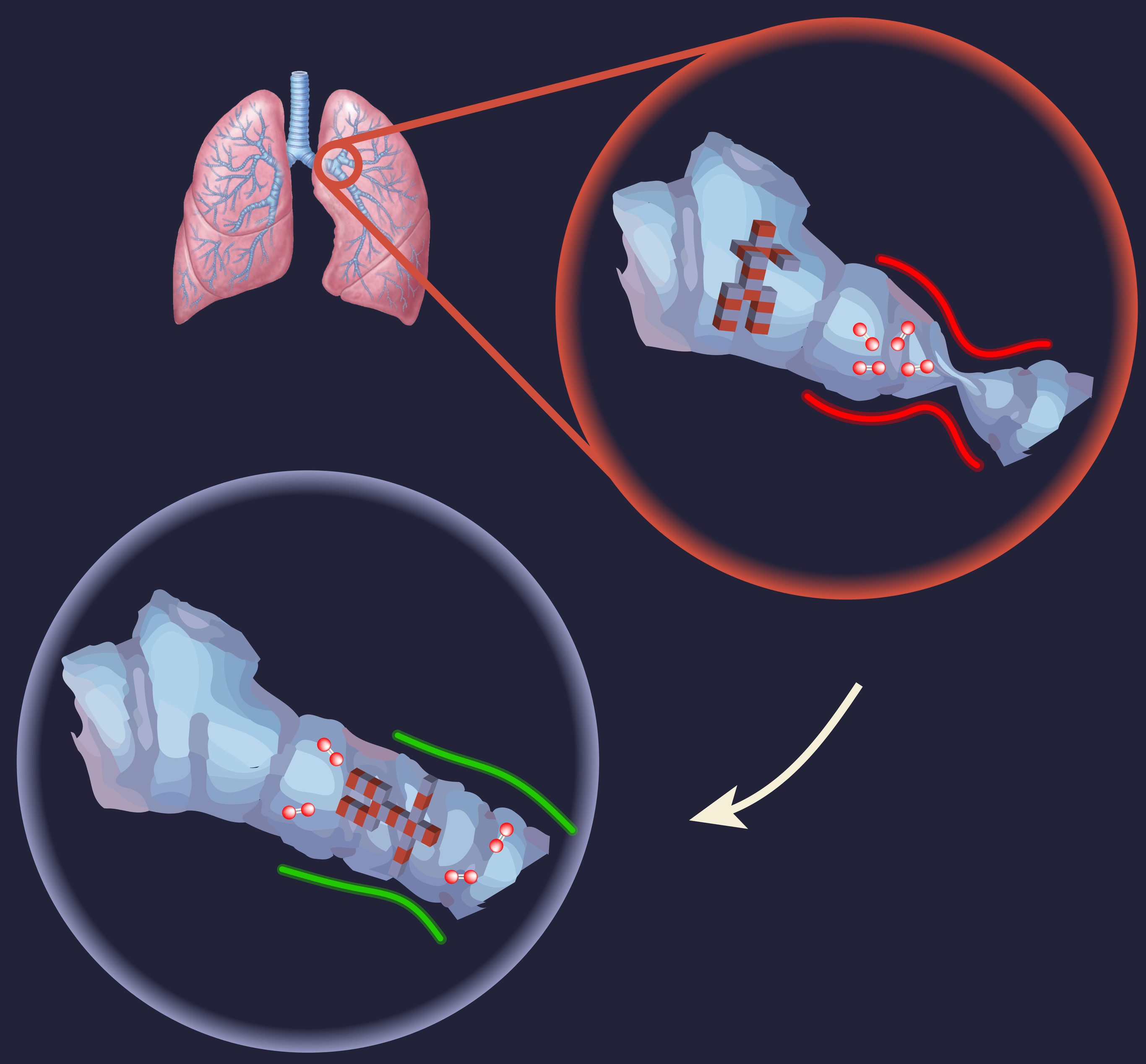
Surface profile of LIFTed Ni deposits in Titanium well.



SEM-EDX image of cross-sectional distribution of Ni and Ti

3. Proposed research II

Conceptual working principle of an in-vivo actuator device: *A patient is having trouble breathing due to the inelasticity of lung tissues. Once the robot is deployed inside the lung tract, when heat is applied, the micro-robot holds the surrounding pathways to help restore oxygen levels in airways.*



Working principle of shape memory alloy based actuator.

- ***Heriot-Watt** provides access to technology that allows us to use different types of lasers and characterisation facilities.*
- *Industrial links like **Oxford lasers** provide valuable input about Laser induced forward transfer based on their previous experiences.*
- ***Renishaw**, one of our main collaborators is interested in manufacturing medical devices. They provide the much needed potential pathways for industrial exploitation.*
- *We are also currently collaborating with **University of Barcelona** to fabricate carbon-based resistors for actuating shape memory alloys.*

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4. Desired outcomes

- *We aim to exploit the controllability offered by laser driven approaches to fabricate functional devices.*
- *Our manufacturing solution will be transformative in the field of micro-additive 3D printing to fabricate bio-medical actuators.*
- *We have successfully demonstrated Laser induced forward transfer of our primary metals and Nickel-Titanium shape memory alloys [4].*
- *Laser induced forward of phase intact NiTi voxels is the short-term technical target.*
- *Publications based on the laser heat treatment of alloys are planned for the coming months.*

5. References

[1] *Foerster, A., Cantu, L. R., Wildman, R., & Tuck, C. (2019). Current market for biomedical implants. In Polymer-Based Additive Manufacturing (pp. 97-119). Springer, Cham*

[2] *https://nanografi.com/blog/shape-memory-alloys/*

[3] *https://www.mdpi.com/2079-4991/10/6/1244/html*

[4] *Muniraj, Logaheswari, et al. "Laser induced forward transfer of NiTi deposits for functionally graded SMA components." Laser Applications in Microelectronic and Optoelectronic Manufacturing (LAMOM) XXVII. Vol. 11988. SPIE, 2022.*

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