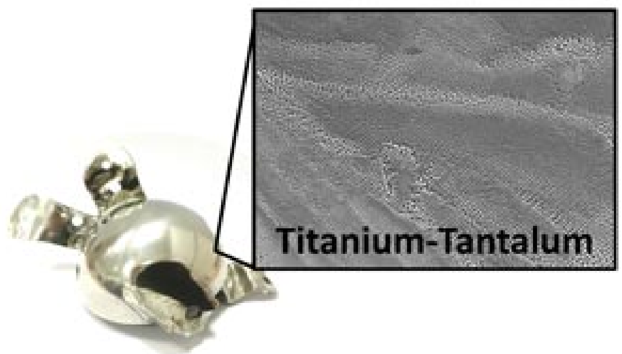
Biocompatible bone replacements using three-dimensional additive manufacturing

May 6 2016



An innovative titanium-tantalum alloy can be printed into 3D shapes by selective laser melting for biomedical applications. Credit: A*STAR Singapore Institute of Manufacturing Technology

Titanium alloys are a primary choice for orthopedic devices such as knee and hip implants because they have excellent mechanical attributes and resist infection. An A*STAR team has now found a way to produce customized, patient-specific implants with improved stress absorption using a titanium-tantalum powder with intriguing properties1.

Selective laser melting (SLM) is one of many emerging three-dimensional (3D) printing technologies that promise to revolutionize small-scale manufacturing. SLM uses high-powered lasers to fuse powdered metals into computer-designed shapes, layer-by-layer. So far, researchers have had success creating biomedical prototypes using titanium-aluminum-based powders. However, concern over aluminum's long-term effects on human neurology has prompted a search for alternatives.

Florencia Edith Wiria from A*STAR's Singapore Institute of Manufacturing Technology (SIMTech) and Wai Yee Yeong from the Singapore Centre for 3D Printing (SC3DP) at Nanyang Technological University initiated a collaboration that aims to manufacture better titanium alloy biomedical products via SLM by creating innovative metal blends.

Alloys with titanium and tantalum are desirable because they are biocompatible and mechanically superior to titanium alone. However, tantalum's incredibly high melting point (over 3,000 degrees Celsius) means it is not viable economically to turn into finely dispersed microspheres which flow smoothly for SLM printing. Commercial tantalum powders are usually made of rough, elongated microparticles that are formed via gas atomization.

To overcome this problem, the team blended the jagged tantalum powder with another readily available powder of titanium microspheres. After mixing the two materials together for half a day, they observed the mixture could be spread more evenly for SLM use, which was favorable for the printing process. Microscopy experiments revealed that the titanium's spherical shape was retained after mixing which was key to this success.

"The titanium powder acts as a rolling medium," explains Wiria. "It pushes the tantalum powder along and makes the processing by SLM possible."

By applying a 'checkerboard' laser scanning pattern that melted metals in alternate up/down or side-to-side movements to reduce thermal stress, the researchers successfully produced titanium-tantalum 3D shapes with SLM. Surprisingly, X-ray and imaging technology showed that addition of tantalum, coupled with rapid solidification, promoted and stabilized the formation of strong, laminar titanium grains.

The researchers envision the titanium-tantalum alloys could lessen 'stress shielding' effects that occur when implants are too elastic and transfer insufficient loads to neighboring bones. "These alloys are specifically designed for orthopedic applications, and even have the potential to show a type of 'shape-memory' after being deformed," says Yeong. "This opens up the possibilities of printing personalized devices to improve patient care."

More information: Swee Leong Sing et al. Selective laser melting of titanium alloy with 50 wt% tantalum: Microstructure and mechanical properties, *Journal of Alloys and Compounds* (2016). DOI: 10.1016/j.jallcom.2015.11.141

Provided by Agency for Science, Technology and Research (A*STAR), Singapore