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3D-printed metals with contrasting properties made using new method

(Nanowerk News) Scientists have developed a new method that can make customised 3D-printed metal parts containing different properties – such as having some regions of the metal stronger than others.

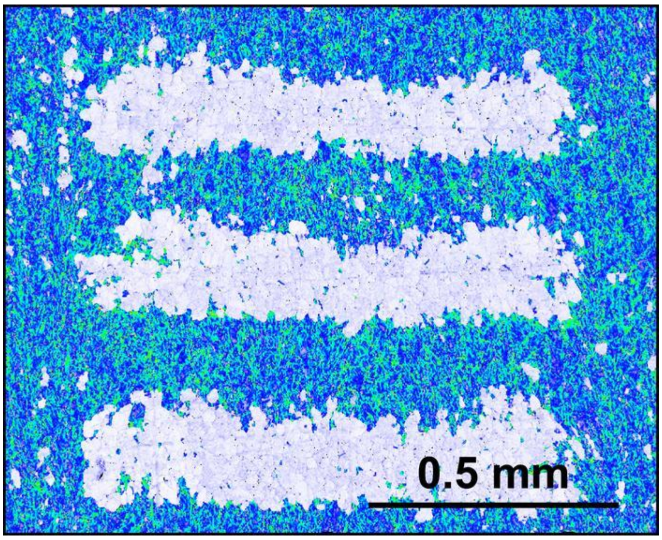
Key Takeaways

The technique eliminates the need for additional raw materials and mechanical treatments, potentially lowering manufacturing costs.

Inspired by traditional blacksmithing, the method enables precise control over the metal's internal microstructure, thereby fine-tuning its mechanical and functional properties.

Experimentation confirmed that metals printed with both strong and weak regions were slightly stronger than metals with only strong regions, challenging traditional theories about composite materials.

The technology opens up the possibility for future metals to have customized properties for specific applications, such as increased corrosion resistance in certain sections of a metal part submerged in seawater.



A scanning electron microscope photo of a stainless steel part 3D printed using the new method developed by NTU Singapore and the University of Cambridge. The white regions of the metal part are mechanically weak, while the blue-green regions are strong. (Image: NTU Singapore)

The Research

The new technique from the researchers – led by Nanyang Technological University, Singapore (NTU Singapore) and University of Cambridge – uses 3D-printing steps. Unlike traditional metal manufacturing processes, it does not require additional raw materials, mechanical treatment or drastic machining processes to achieve a similar effect, such as coating the metal with a different material, thus potentially helping to reduce manufacturing costs.

Besides designing a 3D-printed metal part with different strength levels, the new process should theoretically also allow manufacturers to design a part with other features, such as differing levels of electrical conductivity or corrosion resistance in the same metal.

The researchers – co-led by Professor Gao Huajian, a Distinguished University Professor at NTU Singapore, and Assistant Professor Matteo Seita from the University of Cambridge, who was an NTU faculty when the study was done – took inspiration from "heating and beating" methods similar to millennia-old steps involved in blacksmithing to develop the new process.

This led them to combine materials science and mechanical engineering principles and apply 3D-printing techniques usually used to remove and prevent defects in printed metals to alter microscopic structures in the metals to change their properties.

The novel method also lets manufacturers decide the type of internal microstructure they want – and thus the type of property – and where precisely it can be formed in the metal. This improves on traditional means that do not have such fine control.

Prof Gao, from NTU's School of Mechanical and Aerospace Engineering (MAE), said: "Our method opens the way for designing high-performance metal parts with microstructures that can be finetuned to adjust the parts' mechanical and functional properties, even at specific points, and allowing them to be shaped in complex ways with 3D printing."

The new process is described in a paper published in Nature Communications ("Additive manufacturing of alloys with programmable microstructure and properties"). It exemplifies a key focus of the NTU 2025 strategic plan to create high-impact interdisciplinary research.

The other scientists in the research team are from the Agency for Science, Technology and Research's (A*STAR) Singapore Institute of Manufacturing Technology; A*STAR's Institute of High Performance Computing; Switzerland's Paul Scherrer Institute; the VTT Technical Research Centre of Finland; and the Australian Nuclear Science and Technology Organisation.

Materials science meets 3D printing

The new 3D-printing method arose from an interdisciplinary solution developed by research fellow Dr Gao Shubo at NTU's MAE during his PhD studies at the University.

Dr Gao Shubo, the first author of the research paper detailing the new method, had tried to find a way to alter microstructures in 3D-printed metals and change their properties without resorting to "beating" the metal.

For traditionally made metals, the “beating” process, such as in blacksmithing, is commonly known for changing the external shape of the metal. But it can also be used to modify the metal’s internal microstructures, such as to change their strength.

However, the “beating” process can inadvertently destroy certain features of 3D-printed metals, such as their complex shapes and internal structures that are difficult to produce with traditional methods.

Dr Gao Shubo sought to address this problem. Applying his prior training in materials science, he realised that similar to what happens in blacksmithing, microstructures of the metal could be reconfigured by causing the metal to rapidly expand and shrink as it heats up and cools down during the 3D-printing process.

He theorised that this could be done by adjusting a 3D printer’s energy source, like a laser beam, to melt layers of metal powder to 3D print a metal part.

While this controls whether gaps form in the metal, the researchers showed that adjusting the laser also changes the type of microstructures that form in the metal after it is heated – one structure that makes the metal stronger and another that makes it mechanically weaker. They also remelted the printed metal layers to encourage the changes in the metal’s microstructures.

Experiments with 3D-printed stainless steel that the researchers later carried out confirmed Dr Gao Shubo’s theories.

And because 3D printing allows each layer of printed metal to be printed in exact ways, the characteristics of each 3D-printed metal can be finetuned to a different level at different specific points in the metal, which is impossible with conventional manufacturing processes.
The scientists were thus able to use 3D printing techniques and tweak printing parameters to produce a 3D-printed metal with different microstructures that create stronger and weaker regions in the exact locations in the metal that they wanted.

“Our strategy can target specific sites in the metal, which allows manufacturers to design and create complex microstructures that allow the properties of the metal to be customised to a degree not seen before. For instance, the same metal can have contrasting properties in the same part,” said Dr Gao Shubo.

Theoretically, the strength of such a printed metal part should be between that of materials with only strong regions and those with only weak regions. However, the research team found that 3D-printed metals with both strong and weak regions were slightly stronger than metals with only strong regions.

This synergistic interaction between strong and weak regions in the printed metal points to the potential of the new technique for making stronger and tougher materials than those described by the classical rule-of-mixture theory for composite materials comprising different materials.

The researchers believe their method can also produce printed metal with different functional properties. For example, a metal part could be printed so that the section submerged in seawater is more corrosion resistant, while other sections above water are less corrosion resistant.

Future work that could be done includes testing if the method can produce 3D-printed metals with other types of new microstructure designs that can lead to metals with even better mechanical and functional properties.

Source: Nanyang Technological University (Note: Content may be edited for style and length)

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