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English translation

Amazing! Nature publication on alloy additive manufacturing technology enables direct control of microstructural features

Introduction: In metallurgy, mechanical deformation is essential for designing the microstructure of metals and adjusting their mechanical properties. However, this practice does not apply to near-net-shaped metal parts produced by additive manufacturing (AM), as this will inevitably compromise their well-designed geometry. This paper shows how this limitation can be overcome by controlling the dislocation density and thermal stability of alloys produced by laser powder bed fusion (LPBF) technology. By manipulating the solidified structure of the alloy, it is possible to "design" heat treatment and recrystallization without the use of mechanical deformation. When site-specific, this strategy enables the design and creation of complex microstructures, combining recrystallized and non-recrystallized regions with different microstructural characteristics and properties. The paper shows how this inhomogeneity may be beneficial for having superior properties compared to materials with monolithic microstructures. This work has provided inspiration for the use of additive manufacturing techniques to design high-performance metal parts with artificial microstructures.

Many of the metal fabrication techniques used in society rely on a combination of mechanical and thermal processes to shape a material into the desired geometry while simultaneously designing its microstructure and properties. For example, mechanical strains introduced during the forging and extrusion of metals can control the hardening of materials through dislocation accumulation, or trigger microstructure recrystallization during heat treatment (HT): a new phenomenon of defect-free grain nucleation and growth, resulting in higher toughness and more isotropic mechanical properties.

This prototype "heat and beat" approach, which has been used since the Bronze Age, broke down with the use of modern additive manufacturing (AM) technology. Additive manufacturing (AM), also known as three-dimensional printing (3D), joins materials layer by layer to produce near-net-shaped parts with unprecedented geometric complexity. Since materials and geometries are formed simultaneously during the additive manufacturing process, it is not possible to drive controlled microstructural changes by further machining of solids without irreparably damaging the complex shape of the part. As a result, additive manufacturing offers fewer opportunities to control the microstructure of metals and tweak their properties than traditional manufacturing methods. As a result, a great deal of research has focused on designing additive manufacturing processes aimed at optimizing printed microstructures.

Here, Huajian Gao from the School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, and Matteo Seita, from the Department of Engineering, University of Cambridge, conducted the study, and showed how to control the microstructure evolution of additively manufactured stainless steel without relying on mechanical deformation. Using Laser Powder Bed Fusion (LPBF) technology, they designed a processing strategy to "plan" the thermal stability of the printed alloy, which pre-determines how the microstructure of the material will evolve with HT. These strategies restore some of the microstructure control that traditional metalworking provides. What's more, they allow the creation of new materials by programming the microstructure of the alloy, especially in 3D and with high spatial resolution. Site-specific microstructural control of metals is one of the most unique and intriguing capabilities of AM. Their strategy demonstrates this advanced approach that broadens the design space for engineered materials with optimized mechanical and physical properties by enabling direct control over the evolution of multiple microstructural features. The research results were published in Nature Communications under the title "Additive manufacturing of alloys with programmable microstructure and properties".

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