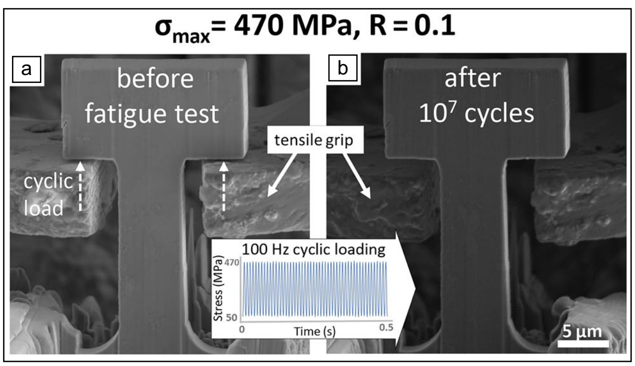
Ultrahigh fatigue resistance achieved in additively manufactured aluminum alloy

The development of many alloys requires tremendous effort to ensure that they can withstand multiple cycles with a high fatigue resistance of the materials. A group of researchers has significantly increased the fatigue life of an additively manufactured aluminum alloy, nano-TiB_2-decorated AlSi10Mg, as reported in *Nature Materials* (https://doi.org/10.1038/s41563-023-01651-9).

Chengyi Dan of Shanghai Jiao Tong University, China, and colleagues developed a three-dimensional (3D) dual-phase cellular nanostructure (3D-DPCN) in a AlSi10Mg alloy, which is a well-connected grain boundary network of Si phases carefully decorated with TiB_2 nanoparticles. This was formed during selective laser melting and subsequent rapid cooling in the additive manufacturing process. The reinforced network suppressed crack initiation and greatly improved the resistance to localized deformation in the alloy under ultrahigh fatigue cycles.

During fatigue testing, possible dislocation movements in the alpha Al matrix are arrested at the engineered grain boundaries without initiation of cracks or formation of persistent slip bands, which enhances fatigue resistance. With a sample free from manufacturing defects—such as pores, lack of fusion, and cracks—tested at 10^7 loading cycles, the recorded maximum strength was over 470 MPa. The study recorded a fatigue strength-to-tensile strength ratio of 0.85.



Micro-fatigue-testing results (*in situ*). (a) Scanning electron micrograph of a micro-sample before the fatigue test; (b) after loading with 10^7 cycles at the maximum stress of 470 MPa. Inset: loading curve, revealing 50 cycles in 0.5 s. Credit: *Nature Materials*.

In email correspondence with *MRS Bulletin*, Zhe Chen of Shanghai Jiao Tong University said, "This study unveils an ultrahigh fatigue resistance mechanism benefiting from the 3D dual-phase cellular nanostructure formed during the rapid cooling stage in SLM [selective laser melting]." The researchers extended the effectiveness of the 3D-DPCN technique to the fabrication and testing of multiscale samples. Chen said, "This nanostructure effectively curbs the fatigue damage accumulation, serving as a formidable barrier against crack initiation and significantly enhancing fatigue properties."

In a separate correspondence, Christopher Hutchinson of Monash University, Australia—an expert in the field of fatigue research who was not involved in the study—said, "If this is true, one might speculate that the critical stress condition leading to failure is associated with fracture of these cages. More work is required to understand all the details but there are clearly ideas that may be applied to other systems and alloys to try and improve their fatigue performance." Hutchinson published a review of this research in *Nature Materials* (https://doi.org/10.1038/s41563-023-01666-2).

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