PURDUE INNOVATES | Office of Technology Commercialization

Additive Manufacturing of an Ultrastrong, Deformable Al Alloy with Nanoscale Intermetallics

Additive process yields >600 MPa aluminum alloys with 10–20% plasticity using nanoscale intermetallics.

Aluminum alloys are widely used in the aerospace and automobile industries and have increasingly seen the use of selective laser melting (SLM) for creating parts that meet complex geometrical constraints. While near-eutectic Al-Si and Al-Si-Mg alloys, known for medium strength and high hot-tearing resistance, are frequently used for 3D printing, high-strength alloys like Al6061 and Al7075 are more prone to hot cracking during the additive manufacturing process. To reduce hot cracking, fine and hard particles such as TiN, TiC, TiB2 are introduced via external inoculation or Al3Zr, Al3Sc, and Al2Cu through aging. Though the introduction of fine particles provides benefits such as heterogenous nucleation to the Al alloy, the strength of additively manufactured (AM) Al alloys typically only ranges from 100-400 MPa. This limited strength underscores the need for ultra-strong AM Al alloys with both high strength and plastic deformability in the industry.

Purdue University researchers have developed a method for producing ultra-strong deformable Al alloys through the introduction of transition metal additives (titanium, iron, cobalt and nickel) into the microstructure. The developed AM Al alloys demonstrate high strength, exceeding 600 MPa, and notable plastic deformability under compression. The Al alloys is composed of a highly heterogenous microstructure containing coarse and fine rosettes in a cellular Al matrix. The technique used allows for co-precipitation of the Al with the transition metals to form refined precipitates. Such unique microstructure cannot be achieved with traditional casting of transition metals with Al alloys. The developed Al alloy shows significant improvement in mechanical strength (exceeding 600 MPa) as well as plastic strain (10-20% plasticity) under compression, much stronger than most traditional Al alloys and/or current AM Al alloys. The developed Al alloys have applications as light-weight aluminum structural parts with high strength and good compression deformability by additive manufacturing or selective

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laser melting.

Technology Validation:

-SEM (Scanning electron microscopy) imaging was used to validate the microstructure of fabricated Al alloys

-STEM (Scanning transmission electron microscopy) HAADF (High-angle annular dark-field) imaging was used to probe and determine the composition of fine and coarse rosette regions

-Bulk compression tests were performed to determine alloy strength and plastic deformability

-Micropillar compression tests were carried out to probe the influence of heterogeneous microstructures on mechanical behavior of the AM Al alloys, demonstrating high strength of around 1 GPa for fine rosette regions and 500 MPa for coarse rosette regions

-Cross-section TEM (XTEM) was used to determine the deformation of the AM al alloys

Advantages:

-Superior mechanical strength compared to traditional AM Al alloys

-Substantial plastic deformability

-Scalable manufacturing process for generating large Al alloy parts

Applications:

-Components for the aerospace industry

-Automotive industry

-Military equipment

TRL: 4

Intellectual Property:

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