COMMUNICATION

Rafting-Enabled Recovery Avoids Rec
3D-Printing-Repaired Single-Crystal S

Kai Chen, Runqiu Huang, Yao Li, Sicong Lin, Wenxin*
Zhi-Wei Shan, and Evan Ma**

The repair of damaged Ni-based superalloy single-crystal turbine blades has been a long-standing challenge. Additive manufacturing by an electron beam is promising to this end, but there is a formidable obstacle: either the residual stress and γ/γ' microstructure in the single-crystalline fusion zone after e-beam melting are unacceptable (e.g., prone to cracking), or, after solutionizing heat treatment, recrystallization occurs, bringing forth new grains that degrade the high-temperature creep properties. Here, a post-3D printing recovery protocol is designed that eliminates the driving force for recrystallization, namely, the stored energy associated with the high retained dislocation density, prior to standard solution treatment and aging. The post electron-beam-melting, pre-solutionizing recovery via sub-solvus annealing is rendered possible by the rafting (i.e., directional coarsening) of γ' particles that facilitates dislocation rearrangement and annihilation. The rafted microstructure is removed in subsequent solution treatment, leaving behind a damage-free and residual-stress-free single crystal with uniform γ' precipitates indistinguishable from the rest of the turbine blade. This discovery offers a practical means to keep 3D-printed single crystals from cracking due to unrelieved residual stress, or stress-relieved but recrystallizing into a polycrystalline microstructure, paving the way for additive manufacturing to repair, restore, and reshape any superalloy single-crystal product.

Modern turbine blades are made of superalloy single crystals, strengthened by cuboidal precipitates of ordered γ' phase in

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strengthened by cuboidal precipitates of ordered γ'-phase in the γ-phase matrix.[1] Single-crystal Ni-based superalloys outperform their polycrystalline counterparts by a large margin, in many aspects including the resistance to creep, fatigue, and oxidation,[2] by eliminating most of the defects that form during

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Prof. K. Chen, R. Huang, S. Lin, W. Zhu, Prof. Z.-W. Shan
Center for Advancing Materials Performance from the Nanoscale
State Key Laboratory for Mechanical Behavior of Materials
Xi'an Jiaotong University
Xi'an, Shaanxi 710049, P. R. China
E-mail: kc_xjtu@xjtu.edu.cn; zwshan@xjtu.edu.cn

Dr. Y. Li
School of Materials Science and Engineering
Chang'an University
Xi'an, Shaanxi 710064, P. R. China

The ORCID identification number(s) for the author(s) of this article can be found under https://doi.org/10.1002/adma.201907164.

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Dr. N. Tamura
Advanced Light
Lawrence Berke
Berkeley, CA 94

Prof. J. Li
Departments o
and Materials S
Massachusetts
Cambridge, MA
E-mail: liju@m

Prof. E. Ma
Department of
Johns Hopkins
Baltimore, MD
E-mail: ema@jl