The Advanced Photon Source

How to 3D-Print One of the Strongest Stainless Steels

A team of researchers from the National Institute of Standards and Technology (NIST), the University of Wisconsin-Madison, the Missouri University of Science and Technology, and Argonne National Laboratory has identified particular 17-4 steel compositions that, when printed, match the properties of the conventionally manufactured version. 17-4 precipitation hardening (PH) stainless steel is used in airliners, cargo ships, nuclear power plants and other critical technologies

The new findings could help producers of 17-4 PH parts use 3-D printing to cut costs and increase their manufacturing flexibility. The approach used to examine the material in this study and obtain data about the printing process was time-resolved high-energy x-ray diffraction at the Advanced Photon Source (Fig. 1). They followed that study with ultra-small-angle x-ray scattering measurements to determine the nanoscopic microstructural features in the as-printed 17–4 steel.

While iron is the primary component of 17-4 PH steel, the composition of the alloy can contain differing amounts of up to a dozen different chemical elements. The authors, now equipped with a clear picture of the structural dynamics during printing as a guide, were able to fine-tune the makeup of the steel to find a set of compositions including just iron, nickel, copper, niobium, and chromium that did the trick.

As a bonus, some compositions resulted in the formation of strength-inducing nanoparticles that, with the traditional method, require the steel to be cooled and then reheated. In other words, 3-D printing could allow manufacturers to skip a step that requires special equipment and additional time and production costs.

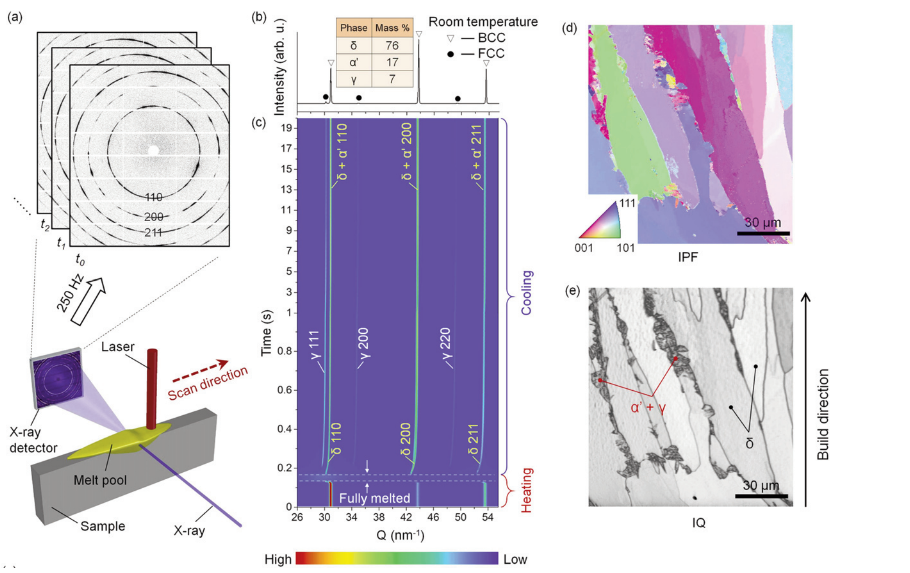

Fig. 1. Characterization of phase transformation dynamics of commercial additively manufactured 17–4 stainless steel (C_17–4) during laser melting. (a) Schematic illustration of in-situ laser-melting x-ray diffraction experiment. A vertical laser beam scans the sample to create a localized melt pool. The micro-focused high-energy x-ray beam is used to probe the phase transformation dynamics with a frame rate of 250 Hz. (b) Room temperature XRD pattern of as-solidified C_17–4 after laser melting. (c) XRD intensity map (XRD peak intensity evolution as a function of time) during laser melting of C_17–4 from 0 s to 20 s. The liquid gap near 0.15 s without any diffraction peaks denotes the period when all the material in the X-ray path was fully melted. The time axis is enlarged in the 0–1 s range to highlight the phase transformation details during the initial solidification stage. From Q. Guo et al., Additive Manu. **59** 103068 (2022). Copyright © 2022 Elsevier B.V. or its licensors or contributors.

The techniques used in this study could have an impact beyond 17-4 PH steel, allowing optimization of other alloys for 3-D printing in the future.

See: Qilin Guo, Minglei Qu, Chihpin Andrew Chuang, Lianghua Xiong, Ali Nabaa, Zachary A. Young, Yang Ren, Peter Kenesei, Fan Zhang, and Lianyi Chen, "Phase transformation dynamics guided alloy development for additive manufacturing," Additive Manu. **59** 103068 (2022).
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The original NIST news release can be read here.

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