Laser additive manufacturing technology achieves 3D-printed Ni single crystals

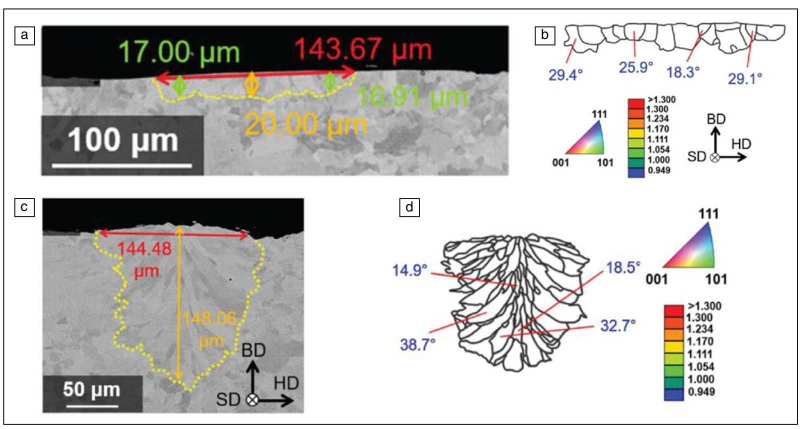
Dennis Edgard Jodi of the National Institute for Materials Science (NIMS) in Japan, Yuichiro Koizumi of Osaka University, and their colleagues have fabricated a nickel single crystal with very few crystalline defects by irradiating nickel powder with a large-radius, flat-top laser beam (i.e., a laser beam whose intensity is uniform across a cross section of the beam). This technique may be used to fabricate a wide variety of single-crystalline materials, including heat-resistant materials for jet engines and gas turbines.

Previous studies have reported that single crystals can be fabricated using electron-beam additive manufacturing. However, this technique requires expensive equipment and its operation is also costly, due to the need to create a vacuum, limiting its widespread use. Although laser additive manufacturing can be performed using cheaper equipment, previous efforts to fabricate single crystals using this technique have failed. When a raw metal powder material is irradiated with a laser beam, it melts, forming a solid–liquid interface. It had been difficult to grow grains near the interface in the same direction and to prevent the formation of strain-inducing defects caused by their solidification. This problem was found to be attributed to the intensity profile of conventional Gaussian laser beams (i.e., laser beams with a bell-shaped intensity across a cross section of the beam), which causes the formation of polycrystals composed of less oriented crystalline grains with many grain boundaries.

The NIMS–Osaka University–Kyushu University research team succeeded in fabricating single crystals using a flat-top laser beam, forming a flat melt pool surface on the nickel powders. As reported in a recent issue of *Additive Manufacturing Letters* (https://doi.org/10.1016/j.addlet.2022.100066), individual crystalline grains grew in the same direction with fewer strain-inducing defects. Single crystals without grain boundaries, which are susceptible to cracking, are very strong at high temperatures. This technique enabled the researchers to minimize strain generation and cracking of crystals during their solidification. In addition, this technique does not require the use of seed crystals, simplifying additive manufacturing processes.

In addition to nickel, this laser additive manufacturing technique can be used to process other metals and alloys into single-crystalline objects. Jet engine and gas turbine components are becoming more complex in shape and lighter, and demand for additive manufacturing of these components using heat-resistant nickel-based superalloys is growing.

Source: National Institute for Materials Science, Japan



Melt pool track observations. (a) Scanning electron microscope (SEM) image of a cross section of the flat-top-based fusion track shows the melt pool depth and width measured to be 20 µm and 143.67 µm, respectively; (b) schematic of the flat-top-based fusion track; (c) SEM image of a cross section of the Gaussian-based track shows the melt pool depth and width measured to be a greater depth of 148.06 µm, compared to its width of 144.48 µm; (d) schematic of the Gaussian-based fusion track. The melt pool geometry was observed on the build direction (BD)–hatch direction (HD) plane, which is perpendicular to the scanning direction (SD). Credit: *Additive Manufacturing Letters.*