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Anisotropy in the microstructure and mechanical property for the bulk and porous 316L stainless steel fabricated via selective laser melting

Decheng Kong [a], Xiaoqing Ni [b], Chaofang Dong [a,*], Liang Zhang [b], Cheng Man [a], Xuequn Cheng [a], Xiaogang Li [a]

[a] Corrosion and Protection Center, Key Laboratory for Corrosion and Protection (MOE), University of Science and Technology Beijing, Beijing 100083, China
[b] Shanghai Engineering Research Center of 3D Printing Materials, Shanghai Research Institute of Materials, Shanghai 200437, China

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ABSTRACT

Microstructural anisotropy widely exists in the additive manufactured components during the rapid solidification process, slender columnar grains were formed along the building direction due to the higher thermal gradient caused by the previously deposited layer heat sink. The resistance to deformation along the *x*-axis or *y*-axis was confirmed to be larger than that of the *z*-axis both for the bulk and porous selective laser melted 316L, which was attributed to that most of the grain boundaries were perpendicular to the loading direction for the first two axes. However, the anisotropy in the microstructure and mechanical property can be eliminated after recrystallization.

1. Introduction

3D printing is a burgeoning manufacturing technology and attracts more and more attention nowadays, it is thought to be a potentially disruptive technology across multiple industries that challenges the traditional manufacturing methods [1,2]. 316L stainless steel has been widely used as structural materials and biomaterials due to the outstanding mechanical property, good anti-corrosion property and biocompatibility [3–5]. However, the actual structure in service is complex and precise, thus makes the traditional casting process more time-consuming and expensive, especially when the temporary replacement parts are required. In this case, selective laser melting (SLM), one of 3D printing methods, exhibits significant advantages in fabricating high-performance components with complex structure [6,7]. Up to now, researches were mainly focused on the effect of printing parameters on the microstructure of selective laser melted (SLMed) parts, in order to obtain superior substrate with low porosity, cracks and surface roughness [8–10], and the optimized process parameters can usually result in better mechanical properties, such as high strength and ductility [11–13]. However, there were not many related studies about the anisotropy in the microstructure and mechanical property for the SLMed components, especially for the porous structure [14,15]. The anisotropy was usually caused by the heat dissipation during the rapid solidification process through conduction, convection and radiation, and the heat conduction direction was the main reason to cause the difference in the microstructure, and further affected the mechanical properties. Thus, in our work, the bulk and porous 316L were fabricated via SLM with optimized printing parameters, respectively, and the related microstructures were characterized using electron back-scattered diffraction (EBSD) and scanning electron microscopy (SEM), the mechanical property was investigated via compressive experiments and the aim of this work was to clarify the relationship between microstructural features and mechanical property for the bulk and porous SLMed 316L.

2. Experimental details

2.1. Sample preparation

The average diameter of the gas-atomized 316L powders was around 25 μm and the chemical compositions of the powders used for the SLMed components were similar with the traditional wrought 316L. Samples were manufactured using an EOS M290 system (Germany), the detailed printing parameters and fabrication process were described in our previous work [16,17]. A heat treatment (HT) was conducted at 1200 °C for 120 min in argon

* Corresponding author.
E-mail address: cfdong@ustb.edu.cn (C. Dong).

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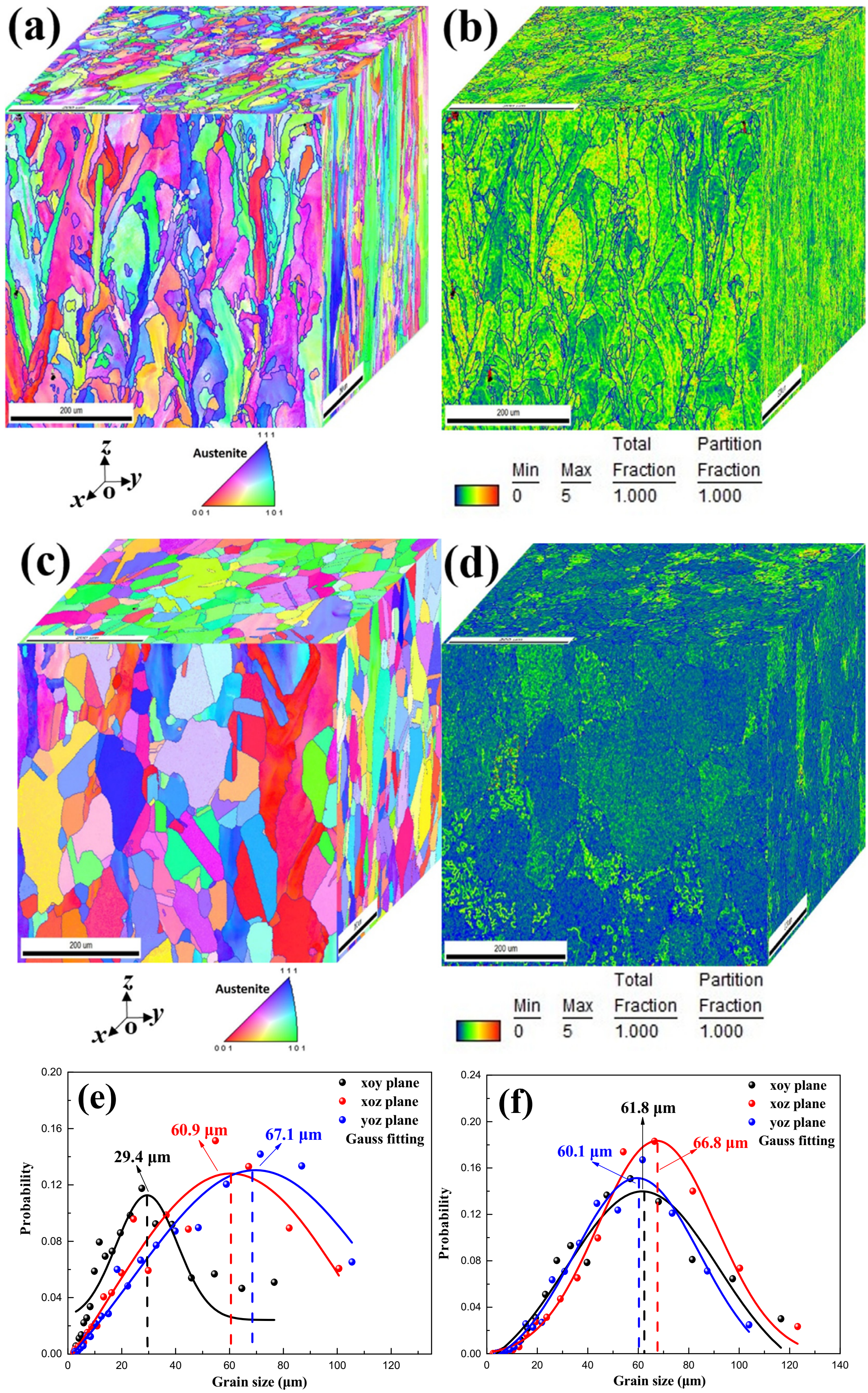

Fig. 1. Three-dimensional IPF and KAM of the SLMed 316L obtained via EBSD: (a) (b) as-received, (c) (d) recrystallized, the grain size distribution on different planes: (e) as-received, (f) recrystallized.