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Short communication

Decarburization of stainless steel during selective laser melting and its influence on Young's modulus, hardness and tensile strength

Xiao Zhao [a], Bo Song [a,*], Yuanjie Zhang [a], Xiaomeng Zhu [b], Qingsong Wei [a], Yusheng Shi [a,*]

[a] State Key Laboratory of Materials Processing and Die & Mould Technology, School of Materials Science and Technology, Huazhong University of Science and Technology, Wuhan 430074, PR China
[b] School of Materials Science and Engineering, Wuhan University of Technology, Wuhan 430074, PR China

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ABSTRACT

Stainless steel was investigated in terms of the evolution mechanism of chemical elements during selective laser melting. It was found that 21% carbon was lost and the decarburization occurred. The carbon-gradient structure contributes to a low Young's Modulus and hardness in molten pool boundary and also anisotropic tensile properties.

1. Introduction

During selective laser melting (SLM) a high energy laser is applied to selectively melt metal powders layer by layer to create 3D-structured objects [1,2]. Based on the principle of accumulation fabrication, the object with an extremely complex configuration can be fabricated [3,4], and lots of material wastes are avoided, which makes SLM a new feasible technology to many applications. The reported researches of SLM are mainly focused on new material development [5–8] and effects of processing parameters on microstructure and performance [9,10]. However, SLM is a complex process exhibiting multiple modes of heat and mass transfer and chemical reactions [11]. Few works have been concentrated on the evolution mechanism of chemical elements, which has a significant effect on the microstructure and mechanical properties of parts made out of SLM.

In the present work, AISI 420 martensite stainless steel (AISI 420 SS), as a widely used commercial tool steel, was investigated in terms of the evolution mechanism of chemical elements during SLM process. The SLM processing parameters have been optimized and reported in the previous work [12]. Using the optimized parameters in this study, small cubes and tensile testpieces were fabricated. The relationship between the chemical elements in molten pools and molten pool boundary zones (MPBs) and the phase composition, Young's Modulus, hardness and tensile strength of SLMed AISI 420 stainless steel was systematically investigated.

2. Material and experiment

2.1. Feedstock material

Spherical AISI 420 steel powder (Changsha Hualiu Metallurgy Powder Co, Ltd., China) was used as feedstock material, which has an average particle size of 20 μm. As shown in Fig. 1a, [O] was found on the surface of the powder, which was involved under normal powder handling conditions.

2.2. SLM equipment and experimental setup

A HRPM-II-type SLM machine, equipped with a continuous fiber laser (maximum output of 400 W, $\lambda = 1.064$ mm, beam spot size of about 0.08 mm), developed by Huazhong University of Science and Technology (HUST), was used for the sample preparation in this work.

Small cubes with a dimension of 8 mm × 8 mm × 8 mm were prepared using the following processing parameters: laser power of 140 W, scanning speed of 550 mm/s, scanning space of 0.08 mm and layer thickness of 0.02 mm. Tensile testpieces were designed

* Corresponding authors.
E-mail addresses: bosong@hust.edu.cn (B. Song), shiyusheng@hust.edu.cn (Y. Shi).

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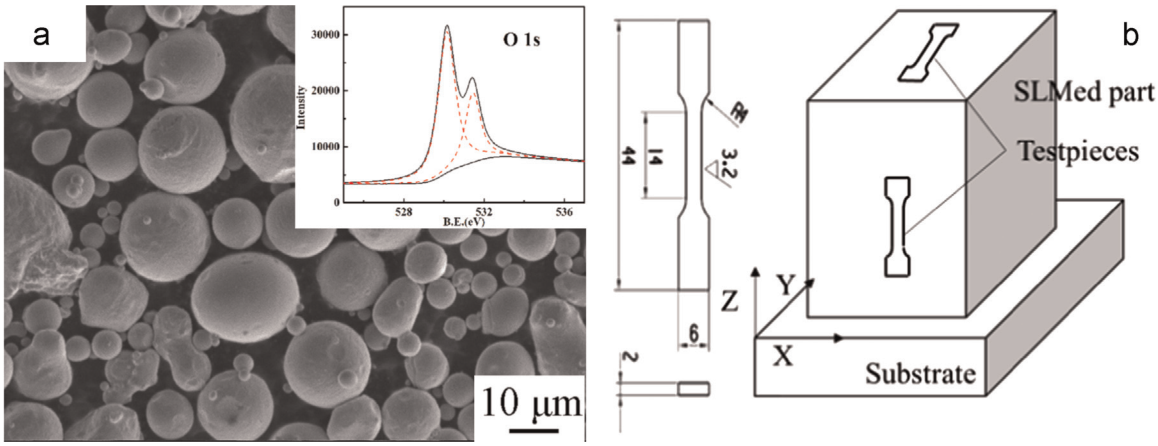

Fig. 1. (a) SEM observation and XPS spectra of gas atomized AISI 420 steel powder, (b) details of tensile pieces tested in this study.

and the details were shown in Fig. 1b. During SLM, the building direction of 3D cubes upwards the *Z* axis and the laser scans along the *X* axis during each melting process of 2D powder layer. Moreover, two batches of testpieces (horizontal and vertical ones) were cut and machined in *X–Y* plane and *X–Z* plane, respectively.

2.3. Characterization

The powder morphology and microstructure of the SLMed parts were observed using a JSM-7600F Field Emission Scanning Electron Microscope equipped with energy dispersive X-ray spectroscopy (SEM–EDS, JEOL, Japan). An ESCALAB 250Xi X-ray Photoelectron Spectroscopy (Thermo Fisher) was used to identify oxygen element on powder surface. A CS2800 carbon/sulfur analyzer was used to obtain the accurate carbon element content of the feedstock powder and SLMed parts. XRD measurements were conducted on a XRD-7000S, operating with a cobalt anticathode in the angular range (2θ) of 20–90°. Metallographic samples were prepared using standard techniques and etched in $FeCl_3$ (5 g)/HCl (15 ml)/H_2O (60 ml) reagent. Instrumented nanoindentation experiments were performed at room temperature using a commercial available indenter (BerkovichIndenter, Hysitron, TI750).

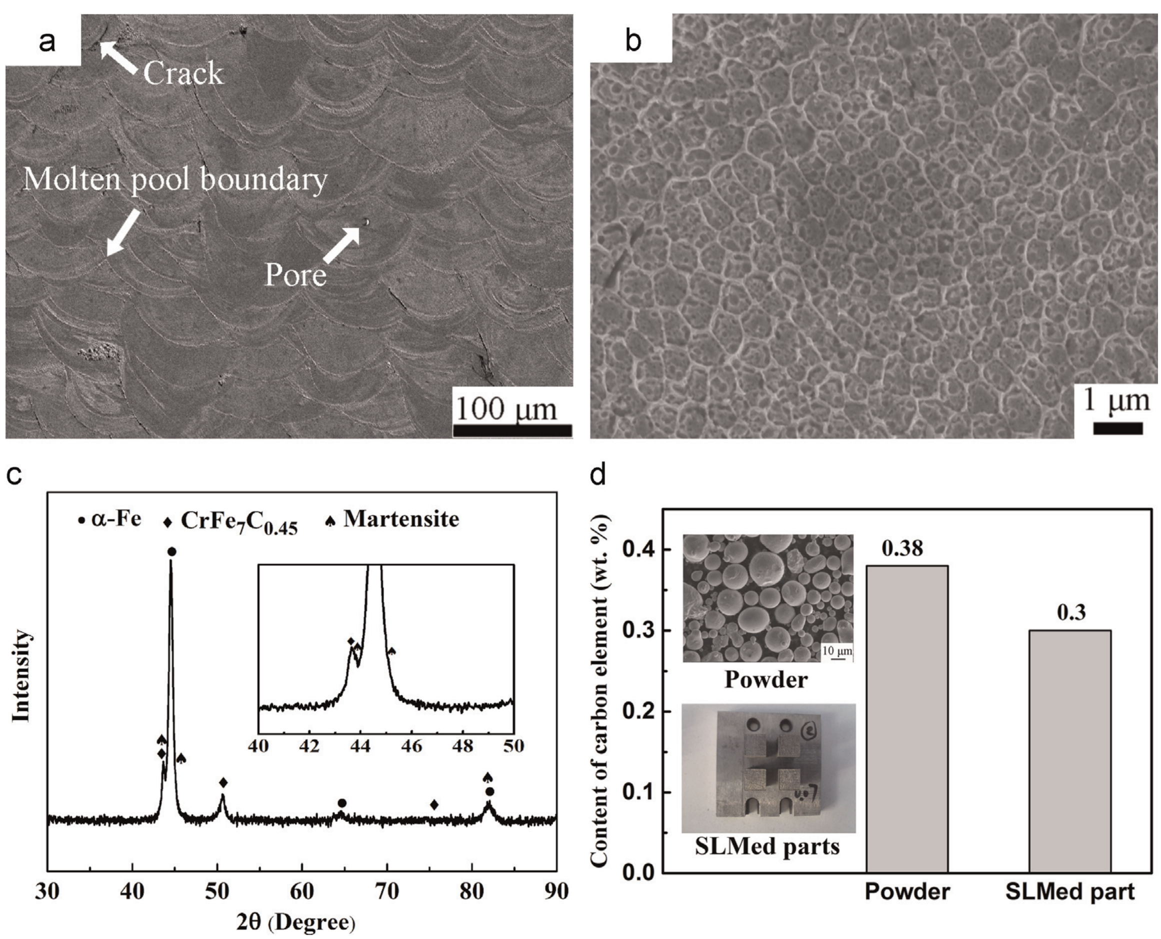

Fig. 2. (a) SEM cross-sections of SLMed AISI 420 SS part, (b) microstructure in molten pool at high amplification, (c) XRD patterns of SLMed part, (d) comparation of carbon content between the feedstock and SLMed part.