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Comparison of Additive Manufactured and Conventional 316L Stainless Steels

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Additive manufacturing (AM) technology provides a high degree of design freedom and is capable of producing near-net-shape sophisticated components with tailored properties [1, 2]. These unique properties provide savings in terms of raw material costs and a simplified manufacturing chain process. Thus, the prospect of microstructural design through AM is extremely attractive for manufacturing structural components for nuclear power plants. However, with this level of control, process-induced imperfections, such as porosity [3], residual stress [4] and preferential grain growth orientation [5], need to be addressed before AM can be used for 'real' engineering applications. In order to overcome these imperfections, it is crucial to understand the connection between microstructure, processing and mechanical properties of AM materials.

Stainless steels are commonly used in the AM process to manufacture near-fully dense components from 3D CAD models. The tribology and corrosion properties of stainless steel make it important in many engineering applications, including the nuclear energy sector. However, little information has been reported about the microstructure of AM stainless steels. In this work, the microstructures of an AM AISI Type 316L stainless steel and a conventional thermomechanically-processed Type 316L stainless steel were investigated. These 316L stainless steels produced via different processing routes were characterized by electron microscopy techniques, which provides microstructural information from the nanometer to micrometer level.

Electron backscattered diffraction (EBSD) analysis, as shown in Figure 1(a), indicates a high degree of anisotropy in the microstructure of the AM 316L stainless steel. Large columnar grains with a strong <101> texture parallel to the deposition/melting direction (Rolling Direction/Inverse Pole Figure-X direction; RD/IPF-X) were also observed, as shown in Figure 1(b). A high level of strain within the grains is clearly visible in Figure 1(c). The scanning electron microscopy (SEM) analysis revealed a very small volume of micro-porosity present in the AM 316L stainless steel. Figure 2(a) shows the scanning transmission electron images obtained from the AM 316L stainless steel. Numerous dislocations were observed in each grain, as shown in Figure 2(b). Also, numerous Ti-Mn oxides, which had not been observed in the conventional 316L stainless steel, were observed to decorate the grain boundaries and dislocation lines. Initial grain boundary analyses indicate that no segregation was observed at either high- or low-angle grain boundaries. The comparison of the AM 316L stainless steel and conventional wrought stainless steel will be further discussed in the presentation.

References:

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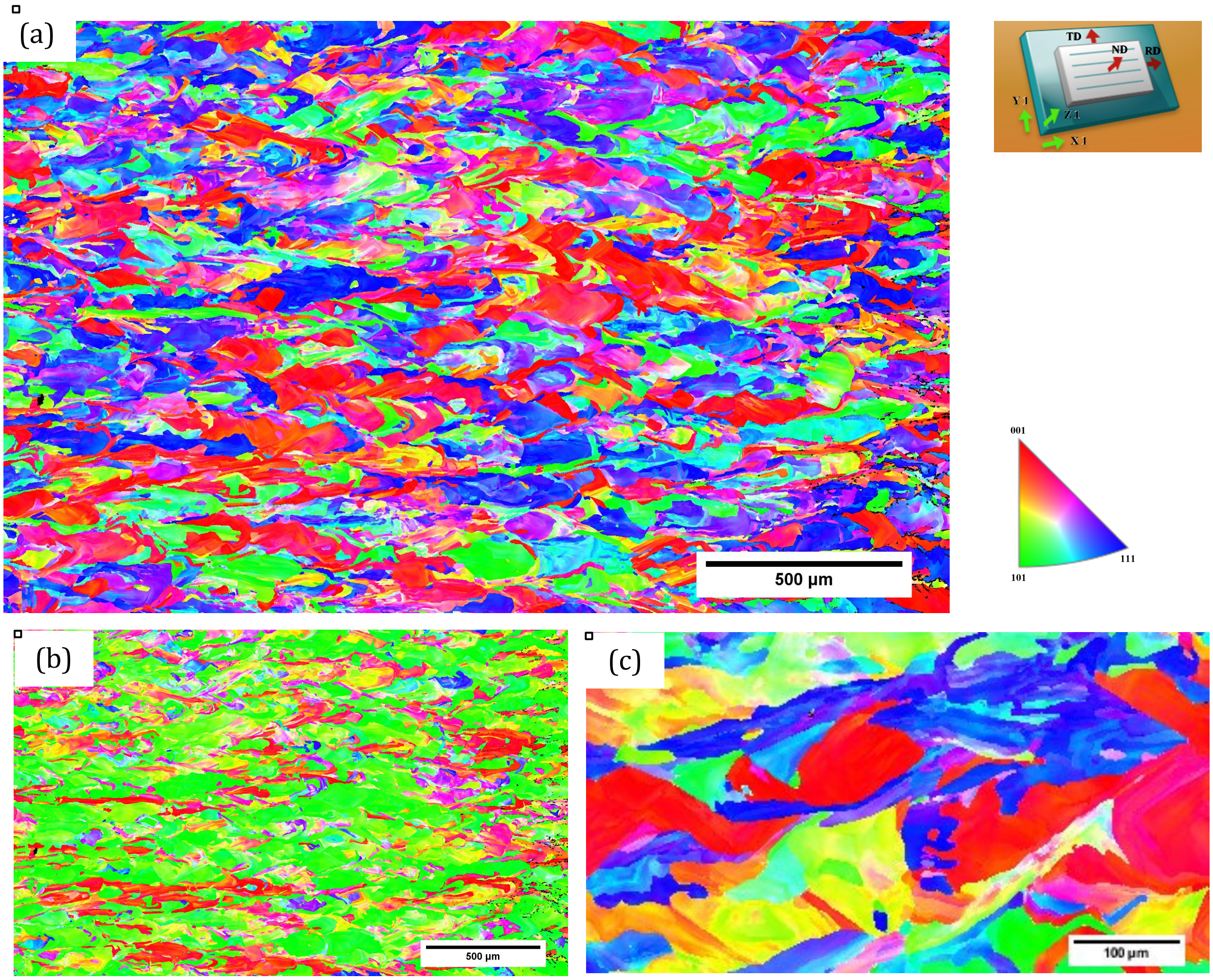

Figure 1: EBSD grains orientation maps showing (a) grain orientation at direction of IPF-Z, (b) grain orientation along the deposition/melting direction, i.e. IPF-X or RD, & (c) higher magnification of grain orientation along the direction of IPF Z

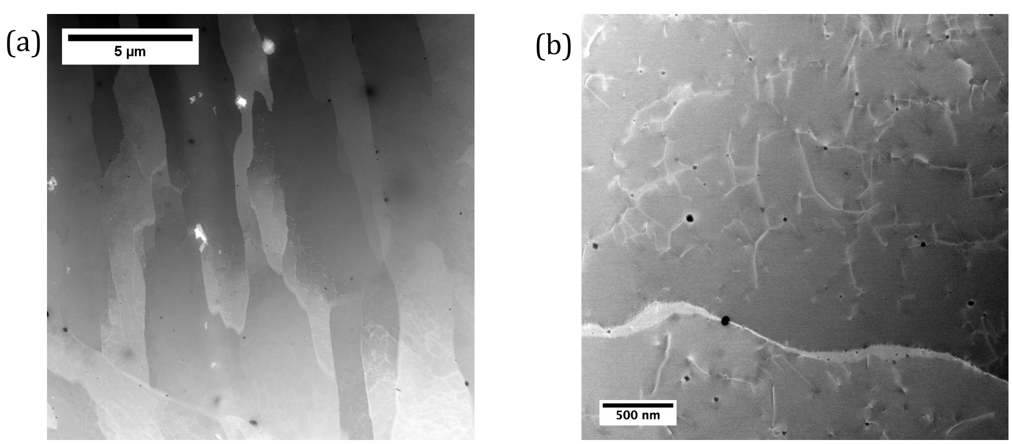

Figure 2: (a) High-angle annular dark field (HAADF) micrograph showing the columnar grains of AM 316L stainless steel, (b) Medium-angle annular dark field (MAADF) micrograph showing high number density of dislocations present in a grain of AM 316L stainless steel. The line features with brighter contrast are dislocations. Ti-rich oxides that appear in darker contrast are clearly visible and are decorated along grain boundary or associated with dislocation lines.