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Microstructural Characterization of WC-Co Cemented Carbide Processed Using Selective Laser Sintering

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Tungsten Carbide alloy (WC-Co), which is also known as cemented carbide, is used in many industries including manufacturing and mining due to their high hardness and strength [1]. Generally, parts made from cemented carbides are produced using the conventional powder metallurgy route which requires a high level of skill, a time-consuming process as well as strenuous post processing techniques to obtain a good part [2]. A possible alternative is the use of Powder Bed Fusion (PBF) techniques such as Selective laser melting (SLM) and Selective laser sintering (SLS). The advantage of lesser manufacturing time, flexibility of design, intricacy of parts produced and lightweight structures such as lattice structures makes it even more appealing [2]. Yet, PBF techniques do not have widespread adoption in industry because of challenges with parts fabricated using PBF processes. Rough surface finish, residual stresses, porosity, micro cracks, non-equilibrium phases and texture come up as a result of parts being affected by repeated thermal cycles, large temperature gradients and relatively high cooling rates during solidification and solid-state phase transformations upon cooling [3]. This affects the microstructural integrity and properties such as fatigue strength, hardness and fracture toughness. Most recently, there has been the need to adopt metal 3D printing for processing cemented carbides using SLM and SLS and evaluating the structure and properties of the processed parts [3, 4]. This is challenging because there are currently no approved powders for 3D printing cemented carbides such as WC-Co neither are there any 3D printers licensed to print cemented carbides. The aim of this study is to adopt SLS technique for printing WC-Co cemented carbide and evaluate the microstructural integrity of the as-printed material. An initial study was done to obtain powders for orienting including parametric studies on the optimum printing parameters that gave a relatively good printed part. After, printing, extensive microstructural characterization techniques including electron microscopy and X-ray Diffractometry (XRD) were used to ascertain the structure and properties of the printed material.

The as-printed WC-Co microstructure had 4 distinct structures which included prismatic and pyramidal WC chips, “foamy” W-C-Co structures, cobalt rich and dendritic structures as shown in Figure 1. Some of the WC phases were interlaced with Co strips which were confirmed using EDS analysis. The Co rich structures appeared as dark backgrounds and were confirmed to have high levels of Co which served as the matrix for the as-printed specimens. The observed “foamy” WC-Co structures had high levels of porosity which were not observed in the WC or the Co phases. Also, some of the observed “foamy” structures had agglomerations of tiny square WC phases at their boundaries as shown in Figure 1(d). The observed dendritic structures were usually observed in the cobalt rich matrix and these dendrites did not have any preferred orientations. Microcracks were observed usually around regions with high agglomerations of micro pores. Generally, it was observed that the aligned pores coalesced to form the microcracks. X-ray diffraction showed that there were W_2C, W_3Co_3C and W_2Co_4C. This demonstrated that the processing induces non-equilibrium phases in the as-printed microstructure which has been attributed to the repeated thermal cycles, large temperature gradients and relatively high cooling rates during solidification. There is therefore the need to use heat treatment processes to relieve residual stresses and induce more stable phases such as WC phases within the microstructure of the materials.

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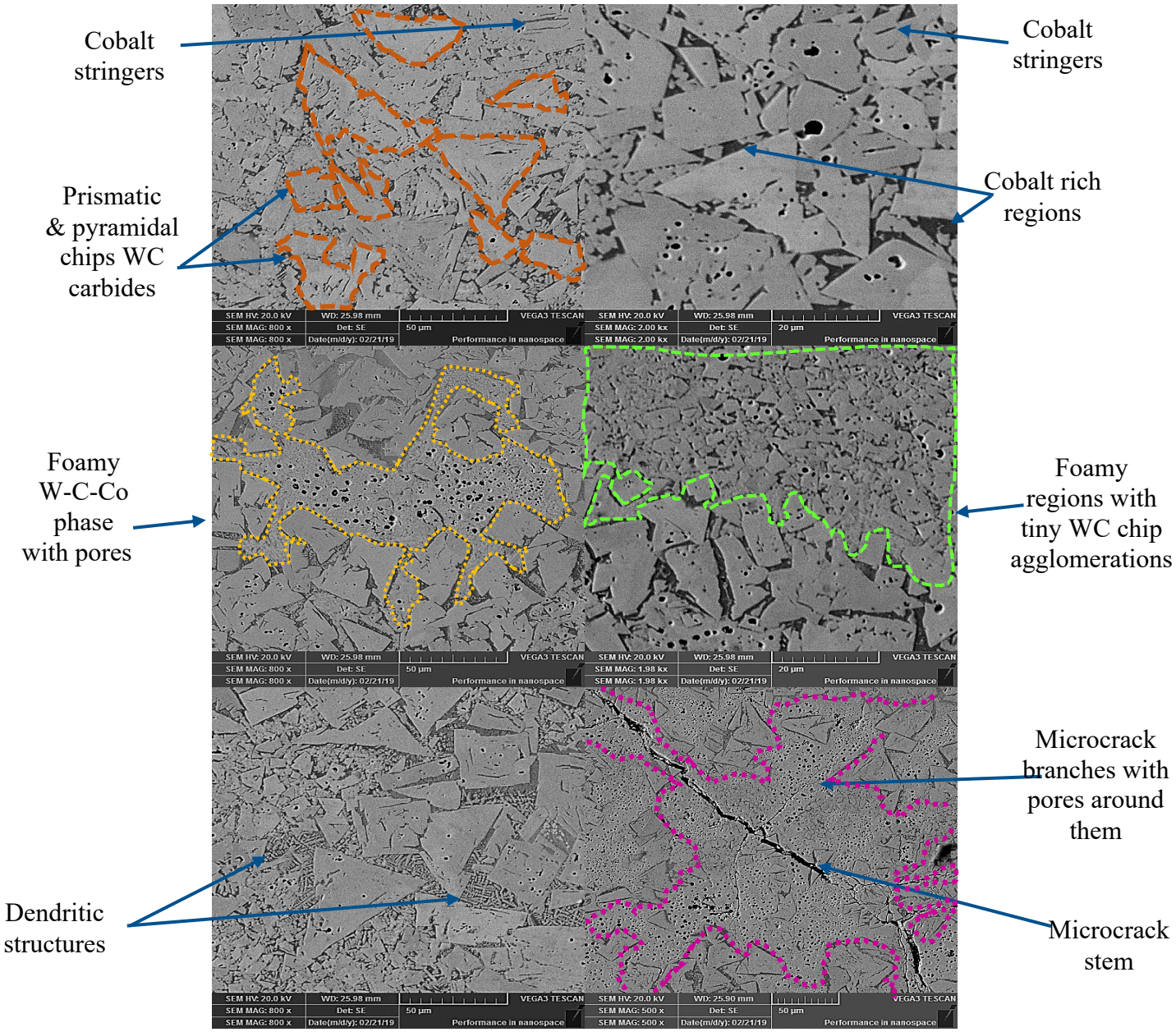

Figure 1. Scanning Electron micrographs for as-printed sample describing the microstructural features and discontinuities identified as a result of processing technique.

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