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Microstructural inspection of the M_6C phase in heat-treated WC-AISI 304 stainless steel powders

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Cemented carbides are two phase composite materials, in which hard refractory carbide phases, typically tungsten carbide, are bonded by an iron-group metal, usually cobalt. The attractive properties of such composites are related to the carbide hardness combined with the binder toughness. AISI 304 stainless steel (SS), an iron, chromium and nickel alloy has been investigated as an alternative binder to Co, aiming at applications needing higher oxidation/corrosion resistance with more competitive prices and using less toxic binders. To improve the binder distribution and the thermal reactivity in the composite powders an original powder coating process by a modified sputtering technique was applied [1]. Composites obtained by sintering of WC-SS sputter-coated powders showed the presence of large quantities of M_6C phase, usually called eta-phase, which affects the mechanical performance [2]. The main objective of this work is to investigate the chemical and morphological characteristics of the eta-phase in WC sputter-coated powders with 16 wt.% AISI 304, heat-treated at different temperatures. For such purpose, heat treatments were performed in vacuum, at 1000 ºC and 1400 ºC, bellow and above the liquid phase formation, respectively, since the presence of eta-phase was detected at both temperatures using X-ray diffraction [3]. In order to explore the microstructure, scanning electron microscopy (SEM, Hitachi SU-70), energy dispersive spectroscopy (EDS, Bruker, QUANTAX 400) and electron microprobe microanalysis (EPMA-SX50, Cameca) were performed. WC particles present rough surfaces after sputtering, coming from the columnar growth of nanometric SS particles on the WC surfaces (as-coated in Fig. 1). The M_6C phase is formed by reaction among SS and WC during heating and could be detected by XRD, from temperatures around 750 ºC, far below the liquid phase appearance [2]. At 1000 ºC, it can be observed that most of the WC particles surfaces are coated by the Fe- rich phase (SS), as shown in point α, Fig.1 and Table 1, but there are discrete regions where W and Fe can be detected (as in point β, Fig. 1 and Table 1). Those regions may correspond to the early M_6C phase with the determined composition $(Fe_{3.0}Ni_{0.2})(Cr_{2.4}W_{0.4})C$. For temperatures higher than 1150ºC a Fe-rich liquid phase is formed, dissolving M_6C phase [3]. However, precipitation of M_6C occurs during cooling and a secondary phase distributed among the WC grains can be observed in Fig. 1. The morphology of the eta-phase, surrounding the WC grains, is consistent with a reminiscent viscous matrix at sintering temperatures, being yet detectable small regions of Fe-rich phase, near the grains. The M_6C composition at 1400 ºC, determined by EDS (point χ, Fig. 1 and Table 1), was $(Fe_{2.5}Ni_{0.3})(Cr_{0.7}W_{2.5})C$, while the composition achieved by EPMA is almost similar, $(Fe_{2.6}Ni_{0.2})(Cr_{0.6}W_{2.6})C$. Comparing with the composition at 1000ºC, a huge increase of W in the $(M,W)_6C$ structure was observed, which may be a consequence of the significant WC decarburization occurring at high temperatures, together with a decrease of the Cr content, probably caused by the increased solubilization of this element in the Fe-rich binder with increasing temperature.

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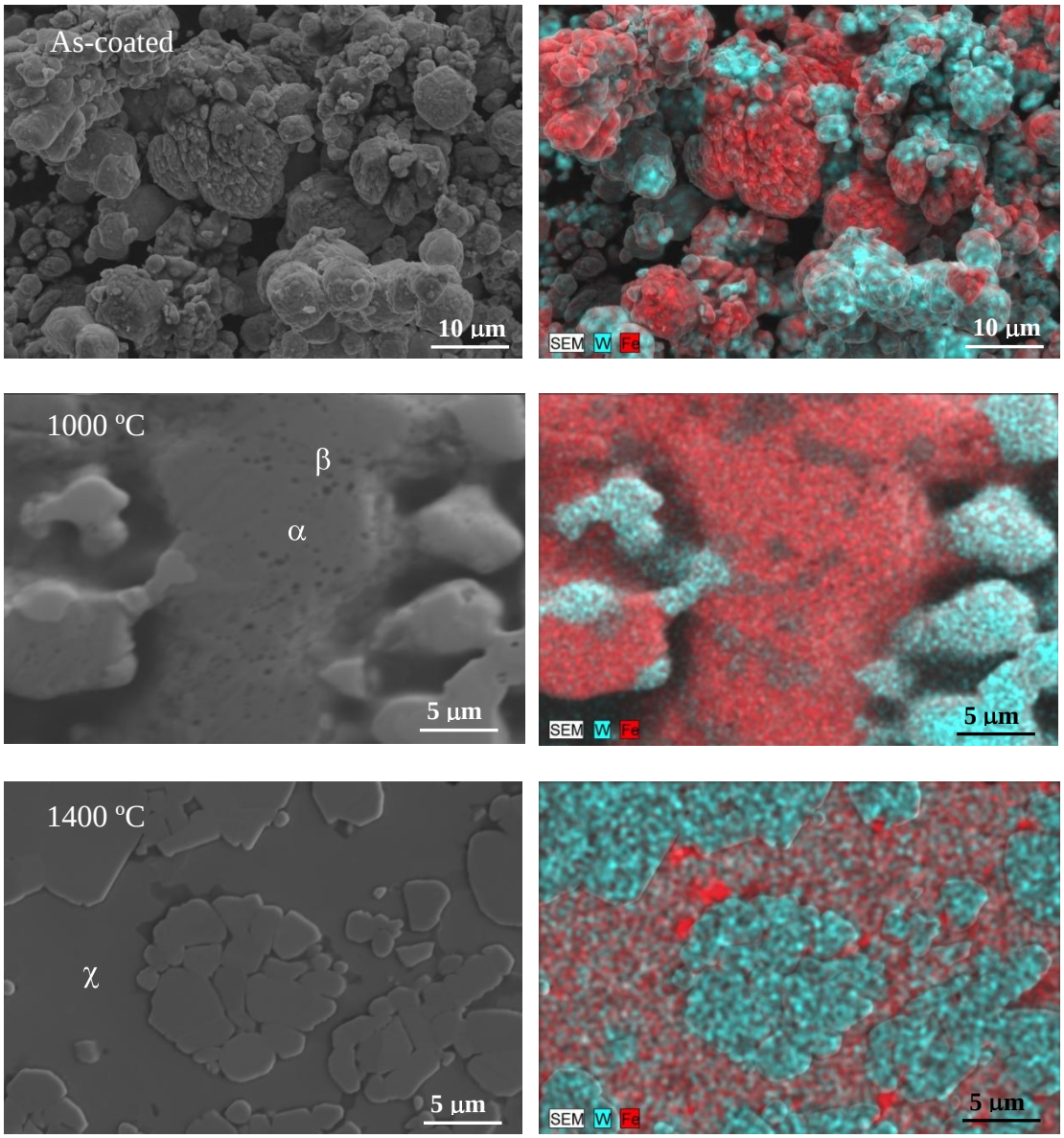

Figure 1. SEM micrographs and respective X-ray maps of iron and tungsten elements of WC powder sputter-coated with 16 wt.% SS; (a) as-coated powder; (b) heat treated at 1000ºC and (c) heat treated at 1400ºC.

Table 1 – EDS semi-quantification analysis (atomic percentages).

Point	W (at.%)	Fe (at.%)	Cr (at.%)	Ni (at.%)
α	1.5	81.1	11.3	6.1
β	6.4	50.1	40.5	3.0
χ	41.7	41.9	11.2	5.2

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