Agronomy Research **14**(S1), 1130–1137, 2016

Production and characterization of Ni-Co (WC) composites materials

A. Yonetken[1,*] and A. Erol[2]

[1]University of Afyon Kocatepe, Faculty of Engineering, Department of Electrical Engineering, ANS Campus, TR 03200 Afyonkarahisar, Turkey
[2]University of Afyon Kocatepe, Faculty of Technology, Department of Metallurgy and Materials Engineering, ANS Campus, TR 03200 Afyonkarahisar, Turkey
[*]Correspondence: yonetken@aku.edu.tr

Abstract. Ceramic-Metal Composite such as NiWC, CoWC are among advanced technology materials that have outstanding mechanical and physical properties for high temperature applications. Especially low density and high hardness properties stand out in such ceramic-metal composite. The microstructure, mechanical properties of %60Ni, %20Co and %20WC powders have been sintered by using tube furnace at 1,000–1,100–1,200–1,300–1,400 °C temperature. Mecahnical proporties and metalograhphic analysis were investigated after sintering. NiCo phases observed after metallographic analaysis. XRD, SEM (Scanning Electron Microscope)results showed us best microhardness of composites 174.16 HV, 8,563 g cm^{-3} density were obtained at 1,400 °C sintering tempareture.

Key words: ceramic-metal composite, powder metallurgy, sintering and high temperature.

INTRODUCTION

Electroless nickel plating is a chemical reduction process which depends upon the catalytic reduction process of nickel ions in an aqueous solution (containing a chemical reducing agent) and the subsequent deposition of nickel metal without the use of electrical energy. Several advantages like low cost, easy formation of a continuous and uniform coating on the surface of substrate with complex shape, and capability of depositing on either conductive or nonconductive parts have attracted a lot of interests from the academy and the industry (Zang et al. 2005).

WC-Co cermet is used in a wide range of hard metal manufacturing practices. Cutting tools, dies and drilling edges can be given as a couple of examples for its application. WC-Co composites are currently produced by various sintering techniques. Conventional production of powder metallurgy with thermochemical techniques still continues (Ma et al., 1996; McCandlish et al., 1992; Koc et al., 2000; Liu et al., 2008; Xiong et al., 2008;). Tungsten carbide-cobalt (WC-Co) ceramic metals have wide application due to their superior properties of high hardness and wear resistance (Nassaj & Mirhosseini, 2003; Upadhyaya & Bhaumik, 2003). Therefore, they are used in various branches of the manufacturing industry. The oxidation of WC-Co cermets was studied by many investigators (Gavriliu & Calu, 1979; Kang & Fromm, 1981; Shmatko et al., 1989). Oxidation of tungsten carbide, which is a base of hard metals, was studied with the use of both powders and sintered samples (Kieffer & Kolbl, 1950; Shmatko et al., 1956; Webb et al., 1981). In the temperature range 500–1,200 °C. Intensive oxidation of WC starts at temperatures of at least 500 °C. Oxidation follows a parabolic law (Ekemar et al., 1982; Kovalchenko et al., 1991). At the initial stage, after which oxidation proceeds by a linear law '43'. At temperatures up to 700 °C. At 800 °C oxidation is governed by a linear law. The scale becomes porous at 600 °C. With further temperature rise up to 800 °C cracking and spalling of scale were observed. XRD-data show that the scale is composed of W03-oxide (Voitovich & Pugach, 1973; Voitovich, 1981).

The purpose of this study was to braze Ni-Co-WC powder mixtures sintered in traditional tube furnaces at 1,000–1,400 °C for 2 hours. Hardness and Maximum shear strength behaviour of the as powder metallurgy Ni–Co–WC composites would be evaluated with a hope of developing an alloy suitable for biomedical application.

MATERIAL-METHOD AND PREPARATION OF SAMPLE

Starting powders employed in this study were as follows: the purity of 99.8% for Ni powders with a particle size lower than -325Mesh, the purity of 99.9% for Co powders a particle size lower than 150 μm and the purity of 99.9% for WC powders with a particle size lower than 50 μm. The composition of (%60Ni-%20Co-%20WC) powders specimens was prepared in 5 g cylindrical compressed pre-form. They were mixed homogenously for 24 hours in a mixer following the weighing. The mixture was shaped by single axis cold hydraulic pressing using high strength steel die. A pressure of 300 Bar was used for the compacting all the powder mixtures. The cold pressed samples underwent for a sintering at 1,000, 1,100, 1,200, 1,300, and 1,400 °C for 2 hours in a traditional tube furnace using Argon gas atmosphere. The specimens were cooled in the furnace after sintering and their micro hardness and shear strengths measurements were carried out using METTEST-HT (Vickers) micro hardness tester machine, respectively.

Shimadzu XRD-6000 X-Ray Diffraction analyzer was operated with Cu K alpha radiation at the scanning rate of 2 degree per minute. LEO 1430 VP model Scanning Electron Microscope fitted with Oxford EDX analyzer was used for micro structural and EDX compositional analysis.

The volumetric changes of (%60Ni-%20Co-%20WC) composites material after sintering were calculated by using ($d = m V^{-1}$) formula (Fig. 1). The volume of post-sintered samples was measured with Archimedes principle

EXPERIMENTAL RESULTS AND DISCUSSION

Characterization of specimens

In the study, the samples prepared and shape were sintered at temperatures ranging from 1,000, 1,100, 1,200, 1,300 and 1,400 °C in conventional furnace. And made ready for physical, mechanical and metallographic analyses. Density-temperature change curve is shown in Fig. 1. The composition of (%60Ni-%20Co-%20WC) highest sintered density was achieved at 1,400 °C as 8,563 g cm^{-3}.

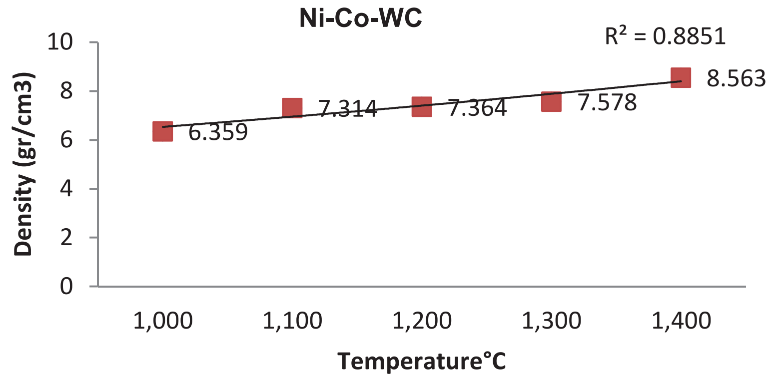

Figure 1. The density change with respect to sintering temperature.

The micro hardness-temperature change diagram is shown in Fig. 2. The micro hardness values of the composite samples produced using conventional sintering technique within the temperature range 1,000 1,200, 1,300 and 1,400 °C. According to this, the highest micro hardness value in the composite samples of (%60Ni-%20Co-%20WC) produced using powder metallurgy method was observed to be 174.16HV at 1,400 °C.

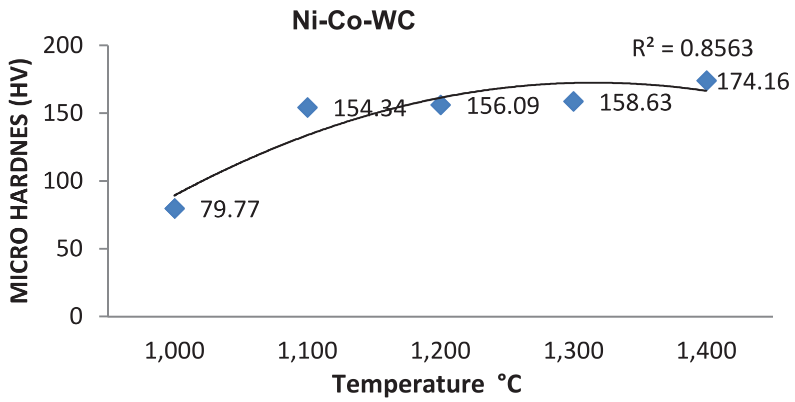

Figure 2. The micro hardness tests results from sintered specimens treated at various temperatures.

The Shear strength and hardness of the metal-matrix composite specimens were also determined. The relation between the sintering temperatures and Shear strength values is shown in Fig. 3. The shear strength value in the composite samples was observed to be 85,51MPa at 1,400 °C.

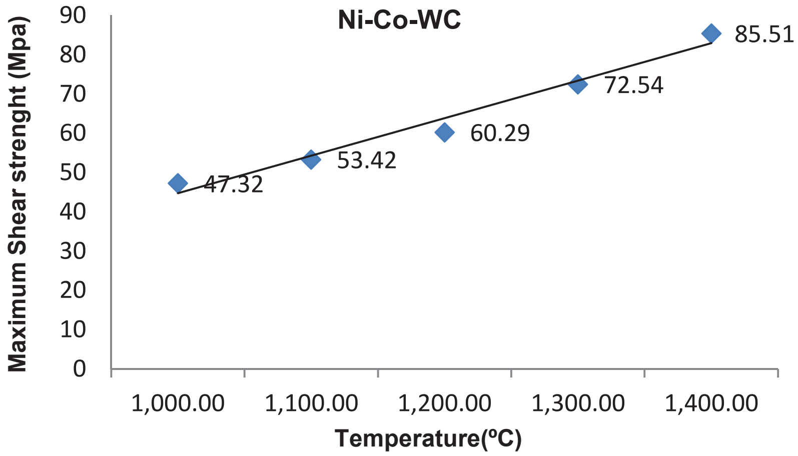

Figure 3. Shear strength results from specimens sintered at different temperatures.

Metallographic Analysis

The SEM analysis result of the metal matrix composite specimen obtained from (%60Ni-%20Co-%20WC) powders sintered at 1,400 °C is shown in Fig. 4 grain growth is observed and a homogeneous structure and grain boundaries can be seen that the pores very smaller and different shapes. (%60Ni-%20Co-%20WC) powders sintered at 1,400 °C is shown In Fig. 4, 1,400 °C to become apparent degree of grain boundaries and Sintering is not better understood at (%60Ni-%20Co-%20WC) composition at 1,400 °C temperature. This density, and hardness values are confirmed (Figs 1 and 2).

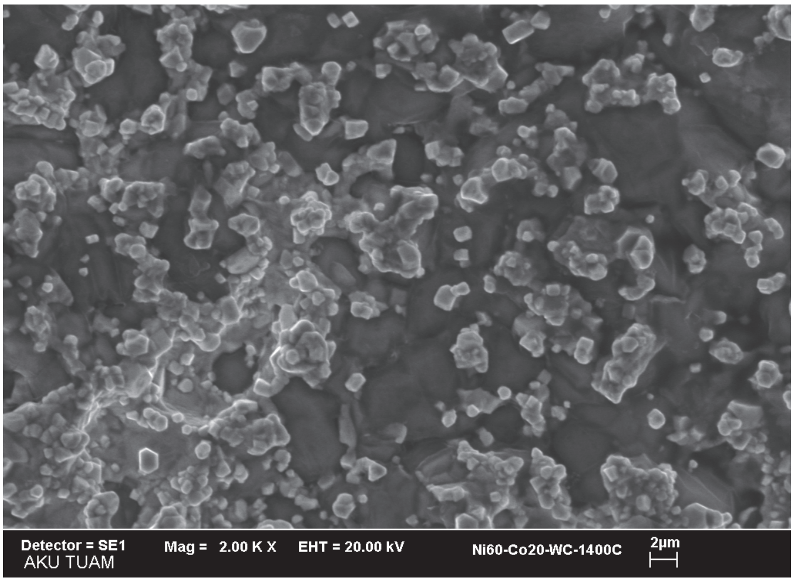

Figure 4. SEM view of (Ni-Co-WC) composite 1,400 °C.

The SEM picture(can be seen Fig. 5) is shown there are some little limitted porous, which comparing samples produced at 1,000 °C, 1,100 °C, 1,200 °C. Grain boundry can be seen also clearly in Fig. 5.

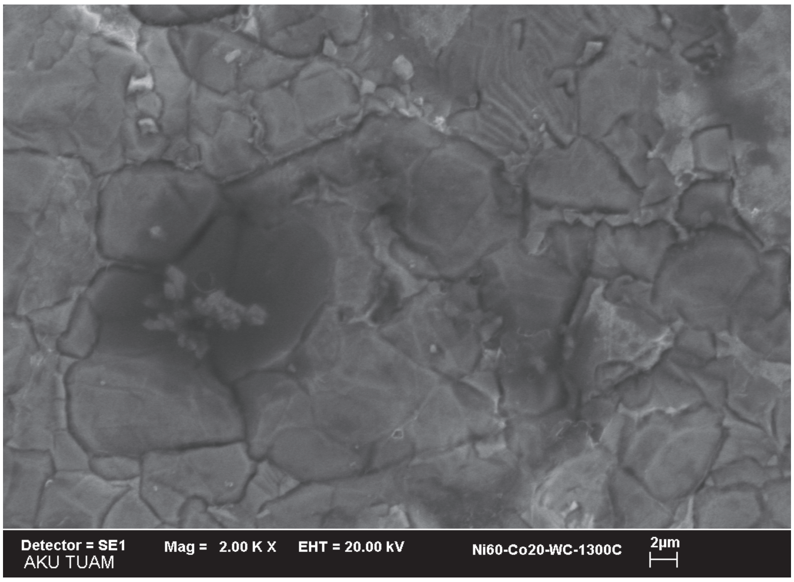

Figure 5. SEM view of (Ni-Co-WC) composite 1,300 °C.

At 1,200 °C, sintered samples SEM pictures shown there are porous which are homogeniusly distrubuted can be seen in Fig. 6. This picture also seems 1,200 °C is not good temperature for sintering.

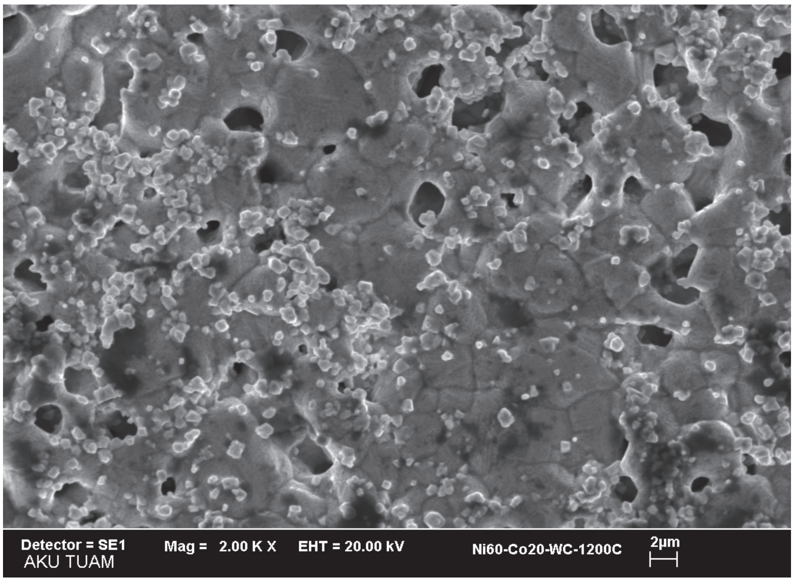

Figure 6. SEM view of (Ni-Co-WC) composite 1,200 °C.

Ni-Co, WC composites are sintered at 1,000 °C , 1,100 °C. The SEM picture Fig. 7 shown some porous unclear phases.

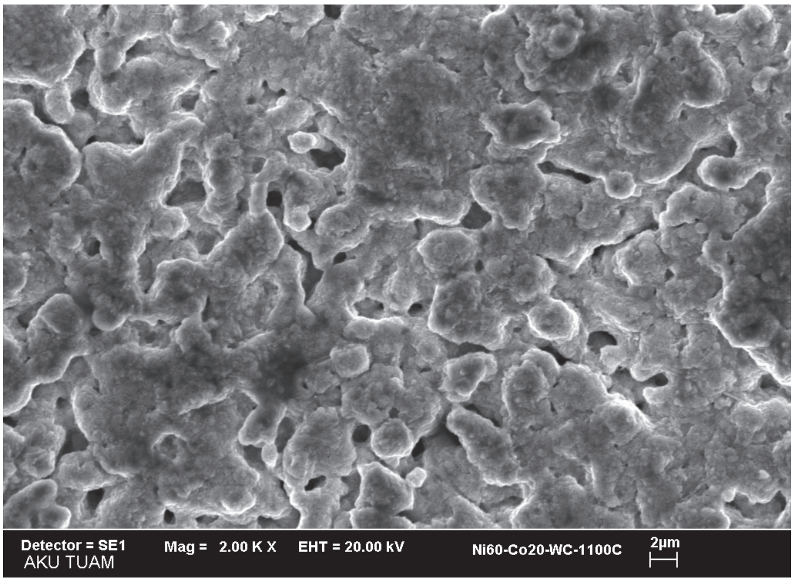

Figure 7. SEM view of (Ni-Co-WC) composite 1,100 °C.

Fig. 8 is a SEM photograph taken at 1,000 °C of the produced sample. It shows the start of the neck formation between particles. Porosity is the moment the samples are more. Grain boundaries are unclear. The density and hardness of samples are the lowest.

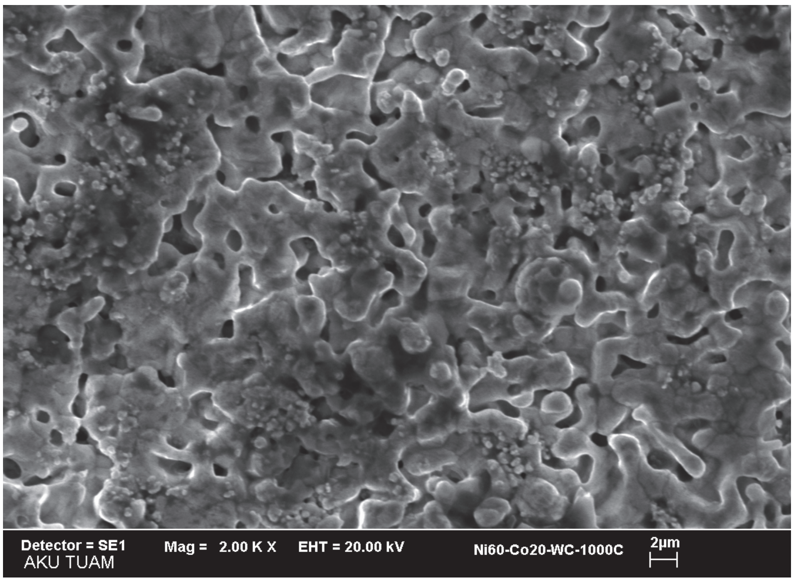

Figure 8. SEM view of (Ni-Co-WC) composite 1,000 °C.

XRD Analysis

After SEM analysis of specimens which are produced at 1,000, 1,100, 1,200, 1,300 and 1,400 °C. It will decide to X-ray analysis taken sample from sintered at 1,400 °C According to the X-ray analysissome pics are determined belong to Ni, NiCo, and WC. It can be seen Fig. 9 The Fig. 9 also shown WC reinforced to NiCo metallic phases.

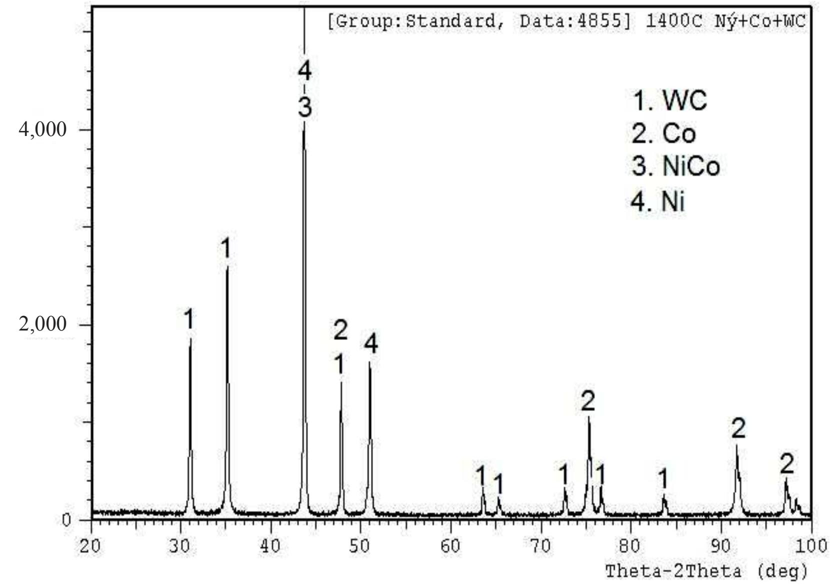

Figure 9. The XRD analysis (Ni-Co-WC) composite Sintered in tube furnace at 1,400 °C.

CONCULUSION

Ni-Co and WC mixture powders were produced samples were investigated. Metal powders are reinforced with ceramic powder. The samples produced at different temperatures were characterized. Ni-Co-WC metallographic analysis of samples produced at 1,300 °C in samples of manufactured sintered powders showed good way. The best sintering temperature of 1,300 °C was found to be investigated compositions.

The following results were concluded from the experimental findings.

- The highest density in composite made from (%60Ni-%20Co-%20WC) powders sintered at different temperatures was obtained as 1,400 °C The highest density sample was found as 8, 563 gr cm^{-3} at 1,400 °C.
- The highest microhardness in (%60Ni-%20Co-%20WC) composite samples fabricated using powder metallurgy method was found as 174.16HV at 1,400 °C.
- The highest shear strength in (%60Ni-%20Co-%20WC) composite samples fabricated using powder metallurgy method was found as 85.51MPa at 1,400 °C.
- It was also found out for composition (%60Ni-%20Co-%20WC) at 1,400 °C suggest that the best properties.

ACKNOWLEDGEMENTS This research was supported by the University of Afyon Kocatepe project no: 15.TEKNOLOJI.04 We would like to extend our gratitude to the Scientific Research Coordination Unit.

REFERENCES

Ekemar, S., Lindholm, I. & Hartzcll, T. 1982. Nickel as a binder in WC-based ccmentcd carbides. *Int.I. Refi Metuls & Hard Mater*. **1**, 37–40.

Fiedler, M.-L. & Stadelmaier, H.H. 1975. The ternary system nickel-tungsten carbon. *Z. Metallkde* **66**, 402–404.

Gavriliu, S. & Calu, N. 1979. Etude de *l'oxydation dansl'air du systeme carbure de wolfram-cobalt*. *Bull. Inst. Politechn. Jasi.* **25**(2), 9–16.

Kang, S.G. & Fromm, E. 1981. *Reaction von MO& W2C, WC und WC-Co - Hartmetallen mit Sauerstoff beiHohen Temperaturen*, *Proc. 10th Plansee Seminar* **2**, pp. 679–93.

Kieffer, R. & Kolbl, F. 1950. Uber das Zunderverhalten und der Oxydationsmechanismus warm- und zunderfester Hartlegierungen, insbesondere solcher auf Titankarbid-Basis. *Z. Anorg. Chem*. **262** 229–247.

Koc, R., Kodambake, S.K., Euro, J. 2000. *Ceramic Materyals* **20**, 1859.

Kovalchenko, M.S., Sverdcl, V.V., Cyr Yurchuk, N.A. 1991. *The ultra-fine grained cemented tungsten carbides with a nickel binder. Abstracts Mat-Tech'91 –* The Second European Em-West Symposium on Materials and Processes, Helsinki, Finland, p. 1.

Liu, W., Song, X., Zhang, J., Zhang, G., Liu, X. 2008. Thermodynamic Analysis For In Situ Synthesis Of WC–Co Composite Powder From Metal Oxides, *Materials Chemistry And Physics* **109**, 235–240.

Ma, X. M., Ji, G., 1996, Nanostructured WC-Co Alloy Pepared By Mechanical Alloying. *Journal of Alloys And Compounds* **245**, 30–32.

McCandlish, L., Kear, B.H., Kim, B.K., 1992, Processing And Properties Of Nanostructured WC-Co. *Nanostructured Materials* **1**, 119–124.

Nassaj, E.T., Mirhosseini, S.H. 2003. An in situ WC–Ni Composite Fabricated By The SHS Method. *Journal Of Materials Processing Technology* **142**, 422–426.

Shmatko, O.A., Larikov, L.N., Tishkova, T.T. & Tyshkevich, V.M. 1989. Investigation of oxidation kinetics of W-Co and WC-Co alloys. *Zasch. Metall.* **25** 659–60.

Upadhyaya, G.S., Bhaumik, S.K. 1988. Sintering Of Submicron WC–10% Co Hardmetals Containing Ni And Fe. *Materyal Sciences Engineering-A* **249**, 105–106.

Voitovich, R.F. & Pugach, E.A. 1973. Features of hightemperature oxidation of transition metal carbides of VI groups. Poroshk. *Metall*. **4** 59–64.

Voitovich, R.F. 1981. The Oxidation of Carbides and Nitrides. Naukova Dumka, Kiev.

Xiong, Y., Lau, K., Zhou, X., Schoenung, J.M. 2008. A Streamlined Life Cycle Assessment On The Fabrication Of WC-Co Cermets. *Journal of Cleaner Production* **16**, 1118–1126.

Webb, W.W., Norton, J.T. & Wagner, C. 1956. Oxidation studies in metal-carbon systems. *J. Electrochem. Sot.* **103** 112–7.

Zhang, Q., Wul, M. & Wen, Z. 2005. Electroless nickel plating on hollow glass microspheres *Surface & Coatings Technology* **192**, 213–219.