Journal of Technology Innovations and Energy
https://doi.org/10.56556/jtie.v1i3.220
ISSN: 2957-8809

RESEARCH ARTICLE

Quantitative Study of Magnetic, Physical Properties and Microstructural Composition of Tungsten Carbide

Joseph Owolabi[1*]

[1]Kogi State University, Anyigba, Nigeria

Corresponding author: Joseph Owolabi, Josedeleowo85@gmail.com
Received: 27 May, 2022, Accepted: 03 July, 2022, Published: 07 July, 2022

Abstract
Tungsten Carbide is a hard and dense material with very high rigidity. The density is about 15.0g/cm^3 with thermal conductivity of 110w/m^{o}c and coefficient of thermal expansion of 6.2μm^{-1}K^{-1}. The melting and decomposition point is about 2,560^{o}c and boiling point of 6,200^{o}c. The poisson's ratio is 0.31 and the compressive strength at 20^{o}c is about 6200N/mm^2 with young's modulus ranging from 400 to 630 GPa. Tungsten Carbide is slightly magnetic and as an alloy, the magnetic property depends upon either mixed with cobalt or nicked. It is combination with other metals as an alloy make it hard and durable. The mixture of powdered carbon and tungsten heated at the temperature of 1600^{0}c(2,900^{0}F) formed tungsten-carbide. Tungsten Carbide is an important material for metal works, rock, metal manufacturing industries and geological drillings as a result of its hardness and wear resistance.

Keywords: Tungsten Carbide; physical; magnetic properties; microstructural composition

Introduction

Tungsten Carbide is a metal like substance, dense and light gray with a bluish tinge which decomposes at about 2,600^{o}c. Tungsten Carbide is a chemical compound that contains equal parts of Tungsten and carbon atoms. It is prepared by heating powdered Tungsten with carbon black in the presence of hydrogen at 1,600^{o}c. It can be pressed and formed into shapes through sintering for use in industrial machinery, cutting tools, chisels, abrasives, armor-piercing shells and jewelry for possible fabrication, the powdered Tungsten Carbide is mixed with another powdered metal like cobalt and pressed into the desired shape and heated to temperature of 1,600^{o}c, and melts, dissolves the grains of tungsten Carbide, this acts as a binder or cement. Thus, the cemented composites of tungsten Carbide cobalt are usually called Widia and carboloy (WC). It is highly resistance to deformation and keeps its stability at cold and hot temperatures. The combination of hardness, strength, toughness and chemical stability makes the cemented carbide excellent in performance (10). Tungsten Carbide is twice as stiff as steal with a young's modulus 650 GPa and double the density of steel. Tungsten Carbide has high strength for a material so hard and rigid (4). The tungsten carbide-cobalt as base materials, in its most applications, review on tungsten carbide, its physical, magnetic properties and microstructural composition has been presented.

this alloy will contain small addition of carbides such as Tic, Tac and N_bC to improve machinability of steels (1). Tungsten Carbide are cemented together by a tough and ductile binder (Co, Ni, Fe) (11) and the combination of hardness and toughness makes cemented carbides ideal materials for rock drilling inserts, and metal cutting tools (5), (6). Tungsten carbide compounds are also known as hard metals. The properties of hard metals are affected by cobalt concentration and the impurities present in the material and other metals such as tantalum, titanium, variadium and chromium, are added to tungsten carbide for various reasons but mainly to inhibit grain growth (2) in (7). With the continuous use, wearing of the cemented carbide happens which makes its service life drastically reduced (8). Tungsten carbide has resistance to galling and welding at the surface and also has sufficient resistance to corrosion – wear conditions for many applications. Tungsten carbide is used to make the rotating ball in the tips of ball point pens that disperse ink during writing, in the manufacture of ganged blocks, used as a system for producing precision lengths in dimensional metrology and tungsten carbide coating is good for brake discs in high performance automotive applications to improve performance, increase service intervals and reduce brake dust. In this paper, a

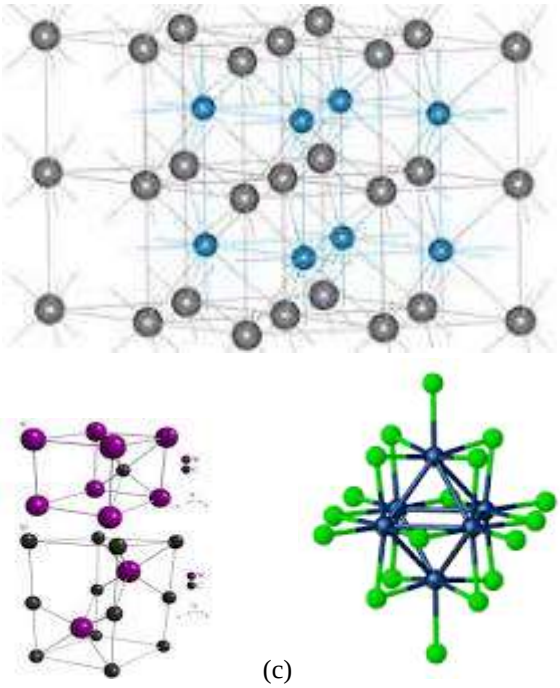
Physical characterizations of Tungsten Carbide

Tungsten Carbide is a hard material with very high rigidity and the impact resistance is high because it is in the range of hardened tool steels of lower hardness and compressive strength of about 2.6 GPa. The density is about 15.0g/cm^3 with thermal conductivity of 110W/m^{o}C and coefficient of thermal expansion of 6.2µ m^{-1}K^{-1}. It undergoes no phase changes during heating and cooling, Tungsten Carbide retains its stability indefinitely and retains toughness and impact strength in the cryogenic temperature ranges. The melting point is about 2560^{o}c and boiling point of 6,200^{o}c. Its hardness varies with WC grain size and co content. The poison's ratio is 0.31 while the compressive strength at 20^{o}c is about 6200N/mm^2 with young's modulus ranging from 400 to 630 GPa which is two to three times higher than that of steel (3). According to (10), it is highly dependent on grain size of 3-20µm and its value approaches 523 GPa when WC grain size becomes 30µm. It is inversely proportional to the Co content (9). Tungsten Carbide has coefficient of friction of 0.25, it is slightly magnetic. In a molten phase with cobalt, an abnormal grain growth occur in the sintering of Tungsten Carbide and this have enormous effects on the performance of the product material. It has ability to resist fracture or energy needed for mechanical failure.

Magnetic Properties of Tungsten Carbide

Tungsten Carbide is slightly magnetic. Tungsten Carbide is an alloy and its magnetic property depends upon either mixed with cobalt or nicked binder (3). Cobalt strongly attracts a magnet but nickel does not. As tungsten carbide has nickel-binder, it will not attract a magnet, but only if the binder is cobalt. Tungsten has a very low susceptibility to magnetism but tungsten Carbide which is an alloy of tungsten and carbon is slightly magnetic because the elements in it are susceptible to magnetism. Tungsten is paramagnetic, so it is weakly attracted to magnets. The Carbide parts of tungsten are magnetized both during production and in use. It is not always possible to identify a single source of the residual magnetism and the common cause is magnetic clamping during grinding that can results in strong magnetization. Tungsten is more valuable as an alloying element to create improved metal alloys when added to base metals while tungsten is an invaluable element in the alloying process, where dements are blended to form new and improved metals known as alloys. Tungsten Carbide is corrosion resistance. Pure cobalt in cemented carbides has normal magnetic properties. The combination of metals in the alloy is what makes tungsten carbide so strong and durable as well as shiny and expensive looking. A regular wire cutter or hacksaw will not even be able to put a dent on the ring but a rotary saw with a diamond coated blade can cut through a tungsten carbide ring in seconds.

Microstructure of Tungsten Carbide



(a) (b) (c)

Figure 1: (a) Chemical composition (b) Micro Structure and (c) molecular structure of tungsten carbide

Tungsten- Carbide formation consist of a gray powder which is heated at temperature of 1600^{0}c after which can be pressed and mold into different shapes through sintering. Chemically, tungsten carbide has structure similar to diamond structure which are surrounded tetrahedral by atoms of both carbon and silicon. This compound is extremely hard and inert and the formula of Tungsten Carbide (Widia $ Carboloy) is **WC.** The compound of tungsten with different non- metallic elements has covalent bonds chemically in which the electrons are shared between the atoms of the elements. In the preparation process, binder materials are usually added to hold the powder form together for easy pressing into shapes.

Atomic Mass	183.84U
Electron Configuration	[X_e] 6S^{2}4f^{14}5d^4
Oxidation State	+6
Year discovered	1783

The general properties of carbides includes brittle, hard, and relatively resistance to corrosion. They are gray or black in color and have a metallic luster. The most common carbides are those of carbon and silicon.

The Compositions of Tungsten- Carbide

Tungsten- Carbide with the formula of WC contains both tungsten and carbon atoms shared. Thermal conductivity : 110w/mk, crystal structure: hexagonal, hp2. It is an organic

compound of tungsten W and carbon C that is stable at low temperature. WC has tetrahedral structure of diamond and make up of tungsten and carbon at different percentages of combination as observed in the phase diagram.

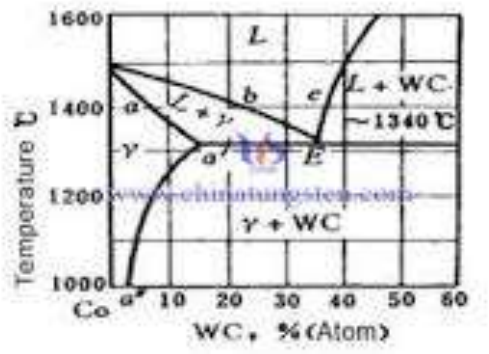


Figure 2: Phase diagram of tungsten carbide.

Tungsten carbide would be very difficult to melt. For commercial purposes, the high tungsten melting point makes liquid tungsten very impossible. High quality tungsten carbide mixed with nicked binder is chemically inert and will not oxide, that is, react with oxygen or tarnish or rust except at temperature reaching 600C.

Conclusion/Summary

Tungsten Carbide is a very important tool material for metal work, drillings, cutting, and mining works.

i. Tungsten carbide is very hard, durable, shining with good looking.
ii. It melts or decomposes at the temperature of 2,600^{o}c (4,700^{o}F).
iii. It is processed by heating the mixture of powdered tungsten with carbon at temperature of 1,600^{o}c (2,900^{o}F).
iv. Powdered tungsten carbide can be easily mixed with cobalt as binder to form WC .
v. Tungsten Carbide is hard, rigid substance and high strength.
vi. It has wear resistance and very tough
vii. Tungsten Carbide behaves well in oxidizing atmosphere at 1200^{o}F and non-oxidizing atmospheres at 1600^{o}F.
viii. It retains its stability of hardness, toughness, strong strength and rigidity as temperature changes..

Reference

Brookes J.A (1990). Hard metals and other hard material. International Carbide Data.

Brooks J.A (2001). Metal Powder Report. 56(4), 8-14.

Beste U (2004). On the Nature of Cemented Carbide wear in rock drilling. Acta Universitatis Upsaliensis. Comprehensive summary of Uppasala dissertations from the faculty of science and technology, 964.

Dayton T (2010). Properties of Tungsten Carbide. Carbide Probes Inc. 12-16.

Engqvist H, Beste U, Axen N (2000). The Influence of PH on sliding wear of WC - based materials. International Journal of Refractory Metals and Hard Materials, 18, 103-109.

Jiak (1996). Abrasion resistance of nanostructured and conventional cemented carbides. Wear, 200, 206-214.

Marcelle A, Robert I, McCruidle, Egmout (2003). Analysis of cobalt tantalum, vanadium and chromium in Tungsten carbide by inductively coupled plasma-optical emission spectrometry. Journal of Anal. Spectrum 18,1493-1496.

Maidlb, Schmid L, Ritz W. (2008). Hard rock tunnel boring machine, Ernst& Sohn, Berlin.

Okamotos, Nakazonor, Otsuka (2005. Mechanical properties of WC/Co cemented carbide with larger WC grain size. Materials characterization, 55, 281-287.

Sakuntala N, Saurabh D, Sommath C (2018). Discussion on importance of tungsten carbide-cobalt cemented carbide and it's critical characterization for wear mechanisms based on mining applications. Arch. Mini. Sci. 63(1), 229-246.

Voorhies J.D. (1972). Electrochemical and chemical corrosion of tungsten carbide (WC). Journal of Electrochem. Soc, 119, 219-222.

www.carbideprobes.com
https://www.coursehero.com
https://en.w.wikipedia.org