The Effect of Adding Graphite on the Structural and Mechanical Properties of Titanium Carbide

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Abstract

The advances ceramics have many applications such as aerospace, refectory, medical, electronic,…etc. In this work, the preparation of titanium carbide by using powder metallurgy technique from titanium and graphite has been investigated with different weight percentages are ((86:14),(83:17),(80:20) and (77:23)) wt.% titanium and graphite respectively. Titanium carbide was formed at (1200°C) for (8hr). The mechanical properties (microhardness, compression strength and wear rate) and characterization (SEM and XRD) of titanium carbide samples were studied. The results found that the best mechanical properties for titanium carbide samples prepared at (80:20) wt.% titanium and graphite respectively.

Keywords: Titanium carbide, Titanium, Graphite, Microhardness, Compression strength.

الخلاصه

السيراميك المتقدم يمتلك تطبيقات عديدة مثل الفضاء، الحراريات ، الطبية ، الالكترونية .....الخ. في العمل الحالي تحضير كاربيد التيتانيوم باستعمال ميتالورجيا المساحيق من التيتانيوم و الكرافيت عند درجة حرارة (1200 م°) و فترة مكوث (8) ساعة حيث تم تحضير كاربيد التيتانيوم باستعمال نسب وزنية مختلفة وهي ((14:86) ، (17:83) ، (20:80) و (23:77)) للتيتانيوم والكرافيت على التوالي.

دُرست الخواص الميكانيكية (الصلادة المايكروية ،مقاومة الانضغاط و مقاومة البلى) و الخواص التركيبية (المجهر الالكتروني الماسح و حيود الاشعة السينية) لعينات كاربيد التيتانيوم . اوضحت النتائج ان افضل خواص الميكانيكية لعينات كاربيد التيتانيوم عند النسبة الوزنية (20:80) للتيتانيوم والكرافيت على التوالي.

الكلمات المفتاحية : كاربيد التيتانيوم، التيتانيوم ، الكرافيت ،الصلادة المايكروية ، مقاومة الانضغاط.

1.Introduction

Metal carbides are used for several years in high temperature structural applications because of their high strength, high melting temperature and ductility at high temperatures and they deform like fcc metals (Srivastava and Dhar, 2012). They are also being used in coating for protecting from corrosion, electronics, high power, aerospace, chemical industry, high-temperature engineering and nuclear industry(A.I. Gusev *et.al.*,2001). Among different types of carbides, the titanium carbide is a material of commercial interest because it is one of the hardest metal carbide and characterized by high hardness, short bonds, high strength , chemical stability and high thermal conductivity (Yao *et.al.*,1998).

Titanium carbide is the rock-salt structure (NaCl-type)(Ivashchenko *et.al.*,2004), with C at the interstitial octahedral sites of the (M) (f.c.c) lattice for(Ti). The B1 phases can be (non-stoichiometric) as ruslt written as MC_y, where y is the carbon to metal ratio. The carbon amount has a large influence on the lattice parameter (Yadav and Kumar, 2008). With increasing carbon amount the excess carbon starts to form an amorphous phase turning the MC system into a two-phase system of nc-MCy/a-C(Jansson and Lewin, 2013). T. Stewart synthesized TiC by a

direct reaction between carbon and titanium under vacuum at high temperatures of 1.900°C to 2.900°C at times from 5 to 20 hours (Stewart, 2014). In this work, the graphite was added to titanium carbide and the mechanical and structural properties of titanium carbide are studied.

2. Experimental

The samples consist from titanium and graphite. The particle size was measured by using laser analyzer type (Bettersize2000 laser particle size analyzer), the average particle size of titanium and graphite are (44.04µm) and (56.13µm) respectively. The particle size range are (6.336-91.14) µm, (1.161-116.1) µm for titanium and graphite respectively as shown in figures 1 and 2.

Titanium carbide was prepared at different weight percent are [(86:14), (83:17), (80:20) and(77:23)] wt.% for titanium and graphite respectively and these weight percentages are chosen according to phase diagram of titanium and carbon. The powders were first carefully weighed into the given percentages for each composition; every mixture has been mixed for (6hr) by using electrical mixer then the samples are pressed at (255 MPa) and sintered at (1200°C) for (8hr).

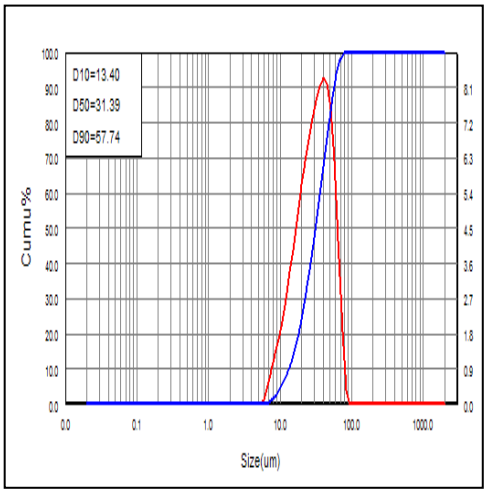

Figure 1: particle size of titanium.

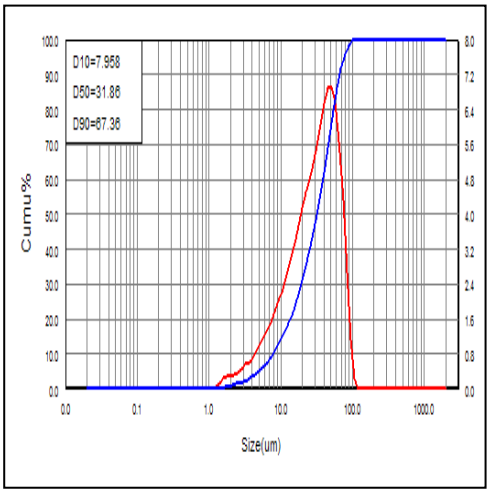

Figure 2: particle size of graphite.

The Vickers microhardness of the samples were measured on the (TH-717) device under loading 9.8 N. Their compression strength was determined by (Semacron Cube and Cylinder Compression Machines Ct340-Ct440) apparatus and wear apparatus, type (micro test) by pin-on-disk test (ASTM G99-95a) in dry conditions. The phase composition of the prepared titanium carbide were examined by X-ray diffraction instrument (SHIMADZU XRD- 6000) using Cu Kα radiation in the range of 20°−80° (2θ) with a step of 5(°)/min. The morphology was investigated by scanning electron microscopy (SEM, Inspect S50), the samples were prepared by grinding with silicon carbide (SiC) paper by using different grades (220, 400, 1000,1200) µm then polished by diamond paste in a grade of 1µm on a fine cloth.

3.Results and Discussions

The results of microhardness and compression strength with graphite weight percent were shown in figures 3 and 4 respectively. Microhardness and compression strength values increase with increase graphite weight percent but decrease at (23wt.%) graphite. The reasons for increase microhardness and compression strength values are graphite atoms fall vacancies and unit cell take normal size (TiC

stoichiometric). Then microhardness and compression strength values diminish because the unreacted graphite content is very well-distributed in the product while in some areas it is more concentrated, potentially due to highly localized energy transportation.

With increased carbon content, a separate carbon phase can be formed, yielding a composite structure consists of a carbide grains embedded in an amorphous carbon (C) matrix (denoted MC/ C) (Neil Clark, 1995).

This behavior is in agreement with the of K. Polychronopoulou et al. which showed the increase in the hardness for TiC_x coatings with stoichiometries in the range percent fraction of TiC_x increases and the decrease in the hardness for TiC_x coatings with $x \geq 1.1$because formation of over-stoichiometric TiC(Mukhopadhyay and Basu, 2007).The exact physical mechanism responsible for such decreases are changing in bonding configurations in the near region of TiC crystallites. This decrease could also be attributed to the change from a uniform to a non-uniform lattice expansion as more C in incorporated into the TiC lattice leading to the formation of overstoichiometric(Rebholz *et.al*.,1998).

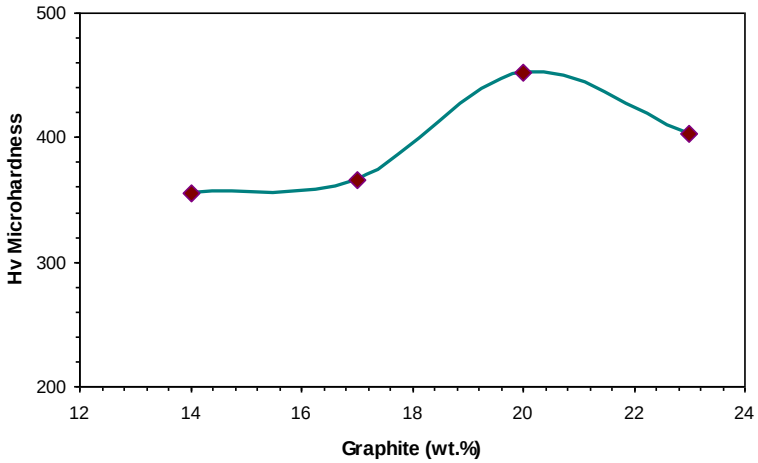

Figure 3: effect of different graphite weight percentages on microhardness for titanium carbide.

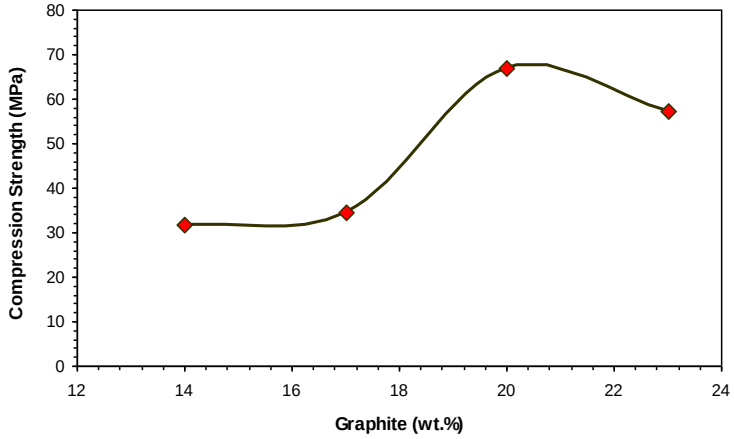

Figure 4: relationship between compression strength and different graphite weight percentages .

Figure 5: the relationship between wear rate and graphite weight percentages. The wear rate decreases with the increase of graphite weight percent until it reaches (20wt.%) graphite then it increases at (23wt.%) graphite. This can be attributed to the

following: (1) according to the XRD studies, this sample consists of TiC crystallites (substoichiometric phases) (at 14 and 17wt.% graphite), TiC (stoichiometric at 20wt.% graphite) and TiC (over stoichiometric and free graphite amounts at 23 wt.% graphite). (2) improvement in the hardness values leads to low wear rate, then the hardness values decrease at (23wt.%) graphite as a result the wear rate increases.

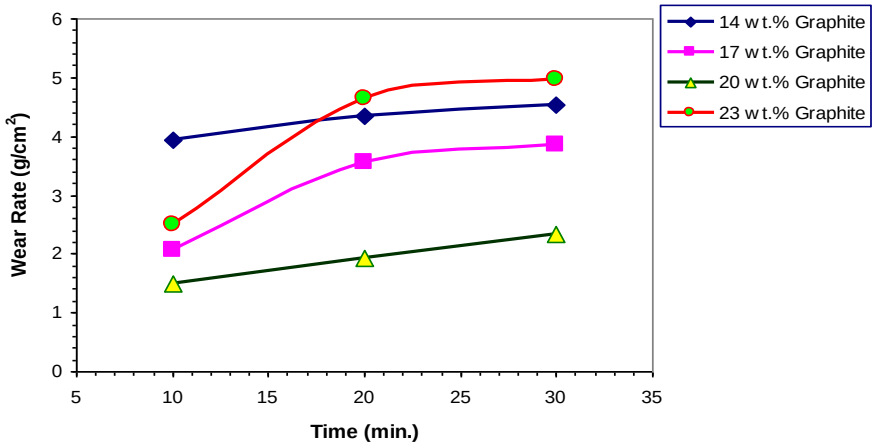

Figure 5 : relationship between wear rate and time with different graphite weight percentages.

Figure 6: SEM micrographs for titanium carbide which are formed at different weight percent for titanium and graphite [(86:14),(83:17),(80:20) and (77:23)] respectively. At lower magnification (100μm) of a typical point at the top surface of the polished product, the micrographs show black area represents unreacted graphite and porosity while gray regions act as titanium carbide.

Titanium carbide is formed at different weight percent for titanium and graphite [(86:14),(83:17),(80:20) and (77:23)] wt.% respectively as shown in figure 7 for (XRD) patterns. For these patterns, the values of (2Θ) decrease with increase graphite content then increase at (77:23) wt.% for titanium and graphite respectively, the reason for this behavior is nonstoichiometric of TiC at [(86:14) and (83:17)] wt.% this means the vacancies are present in unit cell and the increase graphite content from (14wt.% to 17wt %) leads to the fall of some vacancies in unit cell while at (20 and 23) wt.% the graphite atoms fall vacancies (TiC stoichiometric and overstoichiometric) with some unreacted graphite.

According to Powder Diffraction File (PDF) card 01-071-0298, the relevant lattice parameters of TiC as shown in table 1 for (111). The calculated results indicate that the values move away from the standard value in [(86:14) &(83:17)] and become close to it when (80:20) titanium and graphite respectively which is attributed to sub-stoichiometric composition exists in the prepared TiC samples for TiC exists over a very wide compositional range (the calculated lattice parameter (a) has less than the standard value) therefore, sub-stoichiometric TiCx(x<1) may exist in TiC samples. TiC is stoichiometric in the (80:20) wt.% and TiC is overstoichiometric in (77:23) wt.% , in TiC (77:23) wt.% composition has calculated lattice parameter (a) less than the standard value because the increase of the graphite content.

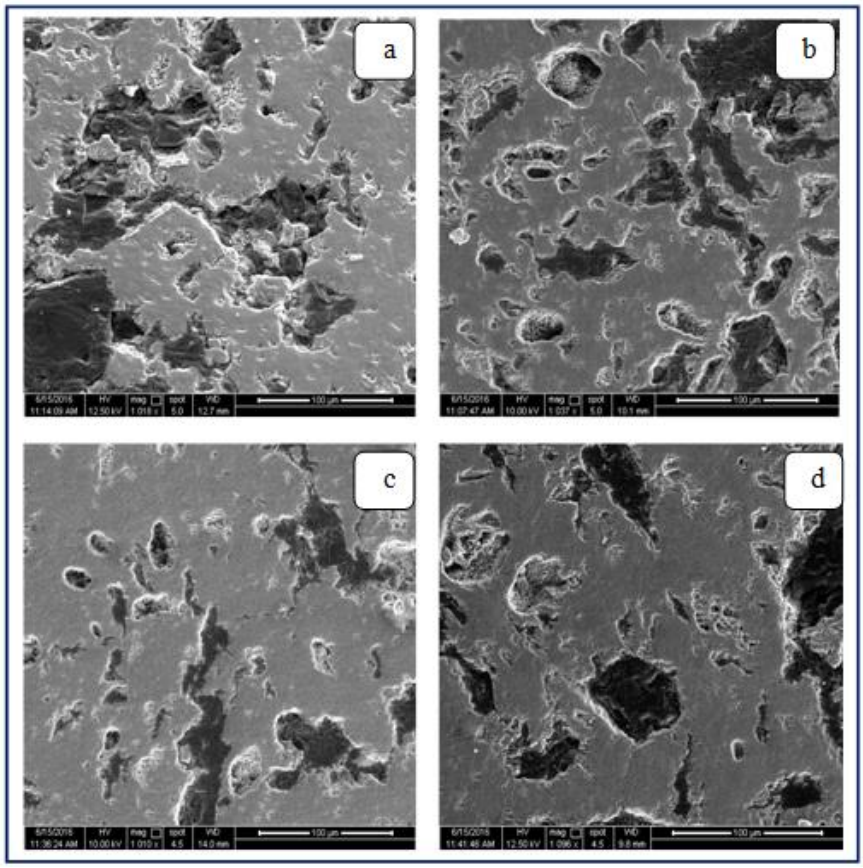

Figure 6 : SEM Micrograph for TiC samples. (a) (86:14)wt.%. (b)(83:17)wt.%. (c)(80:20) wt.%. (d)(77:23)wt.%. (Ti:C) respectively.

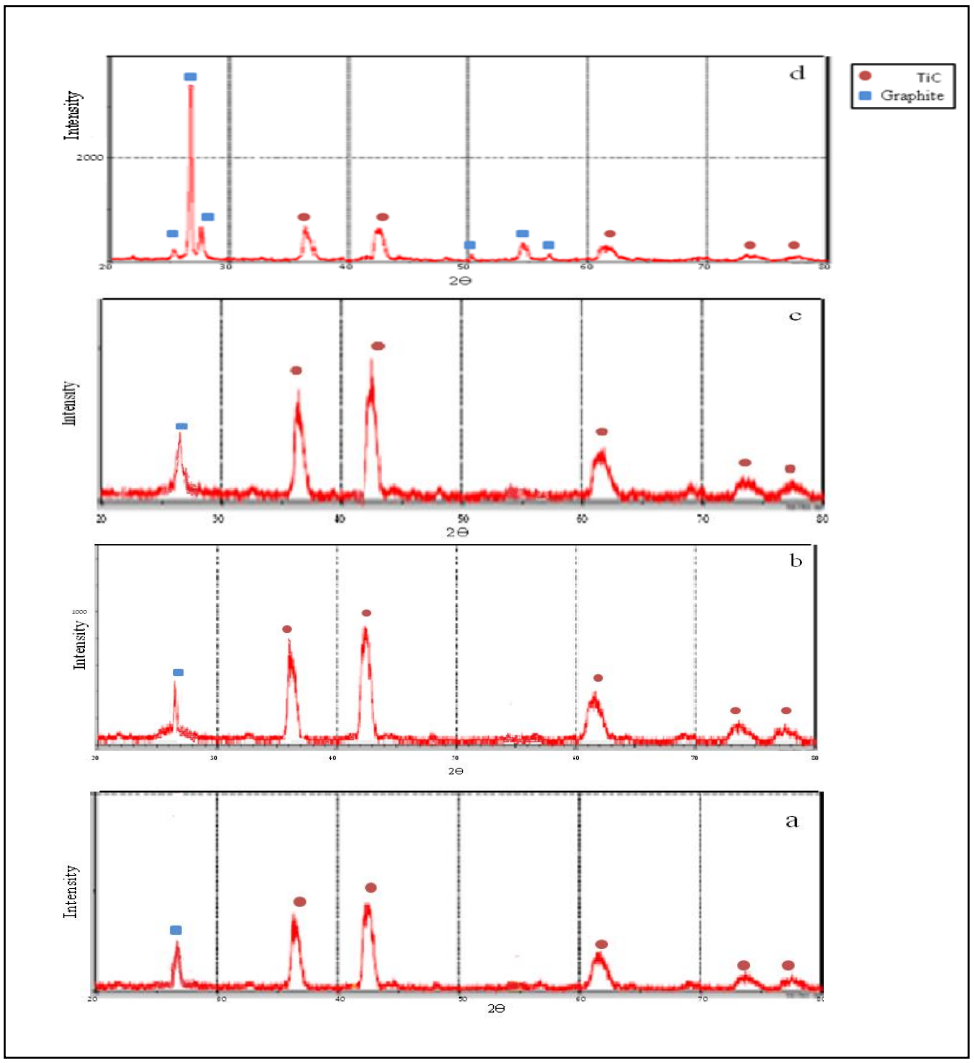

Figure 7: (XRD) for titanium carbide formation at (a)(86:14)wt.% (b)(83:17)wt.% (c)(80:20)wt.% (d) (77:23)wt.% (Ti:C) respectively.

Table 1: lattice parameters of titanium carbide.

(Titanium: graphite) wt.%	2Θ	Lattice parameter a(A°)	d (A°)
standard value (79.95:20.05)	35.909°	4.328	2.49866
(86:14)	36.22°	4.292	2.478
(83:17)	36.17°	4.297	2.481
(80:20)	36.12°	4.303	2.484
(77:23)	36.3°	4.283	2.472

4.Conclusions

1. TiC formed from (Ti:C)(80:20)wt.% respectively has better mechanical properties which include (microhardness, compression strength and wear rate).
2. SEM micrographs showed uniform distribution of TiC and graphite.
3. The results of XRD show the formation of titanium carbide and graphite.
4. Lattice parameter (a) of titanium carbide increased with the increase additive graphite until it reaches 20wt.% graphite then it decreases.

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