საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 17, №4, 2023
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Materials Science

Structural Research of Al_2O_3-TiC System Nanoceramic Composite Material

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(Presented by Academy Member Ramaz Katsarava)

This paper presents structural research of the samples obtained by hot pressure of Al2O3-TiC system composite materials. Optical microscope research was carried out using Chinese device – Am Scope, X-ray – with DRON 3. Structural research was conducted using electronic microscopic – Cam Scan and micromechanic property – with CD Muecke Haerte device, at the Technical University of Clausthal, Germany. It is stated that at hot pressure up to 1550°C, titanium carbide and aluminum oxide do not interact with creation of some new phase. In case of hot pressure sintering, small additions of titanium carbide and oxides (MgO, Y_2O_3) prevent the growth of aluminum oxide grains, ensure material compactness and mechanical strength. As to the effect of carbon fiber, it has double meaning: it heightens composite bending strength and at the same time, helps to preserve titanium carbide stoichiometric composition, hardness – HRA=94; $\sigma_{compr.}$=3000 MPa; $\sigma_{bend.}$=680 MPa.

composite materials, cutting tool material, additives, C-fiber, microstructure

In spite of the fact that various cutting tool materials are created on the basis of aluminum oxide [1-4], they have not yet exhausted their possibilities. Therefore, because of their unique properties, they are considered quite perspective materials in the development of metal working industry.

In [5] we have presented composite material with different additives into aluminum oxide and titanium carbide system. The received material was characterized, on the one hand, with high hard ness 92-93.5 HRA and wear resistance, and on the other hand, with high bending strength – 680 MPa.

Experimental

The purpose of the present work was the investigation of additives effect on Al_2O_3-TiC system composites (MgO; Y_2O_3 and C-fiber) on the creation of the structure of samples received with hot pressure.

The samples were prepared according to technological scheme described in [5]. In composition of the first group composites only titanium carbide content* was changed, while to the content of the second group composites the combination of 2 types of activators in amount of 5 mass% was

Table. Mechanical properties of samples of Al_2O_3-TiC system composites received with hot pressure

Titanium carbide and additives content in Al_2O_3 - TiC composite, mass%	Sintering temperature, ^{0}C							
	1500				1550			
	Relative density	Hardness HRA	σ_{comp} MPa	σ_{bend} MPa	Relative density	Hardness HRA	σ_{comp} MPa	σ_{bend} MPa
TiC 10	0,84	92	1000	420	0.98	93	1900	480
TiC 20	0,90	92,5	1080	460	0.98	93.5	2500	550
TiC 40	0,92	93	1100	500	0.98	94	2700	550
TiC 20 add. 1	0.96	93	1700	520	0.99	93	2500	630
TiC 10 add. 2	0.90	92	1500	450	0.99	92.5	2250	580
TiC 20 add. 2	0.93	92.5	1850	560	0.99	93	3000	680
TiC 40 add. 2	0.96	93	2000	520	0.99	93.5	2700	650

added: 1. MgO-25; Y_2O_3-75; 2. MgO-11.1; Y_2O_3-33.4; C-fiber-55.5 mass% content.

Sintered samples were used to prepare sections with traditional method [6]. Some physico-technical indices of samples are presented in the Table.

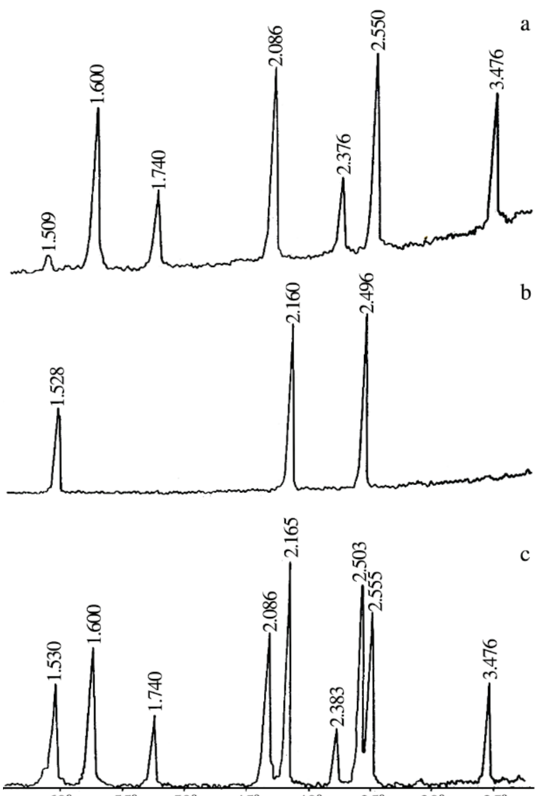


Fig. 1. X-ray patterns: a) TiC; b) Al_2O_3; c) TiC 20%-Al_2O_3 80% received at 1550°C with hot pressure.

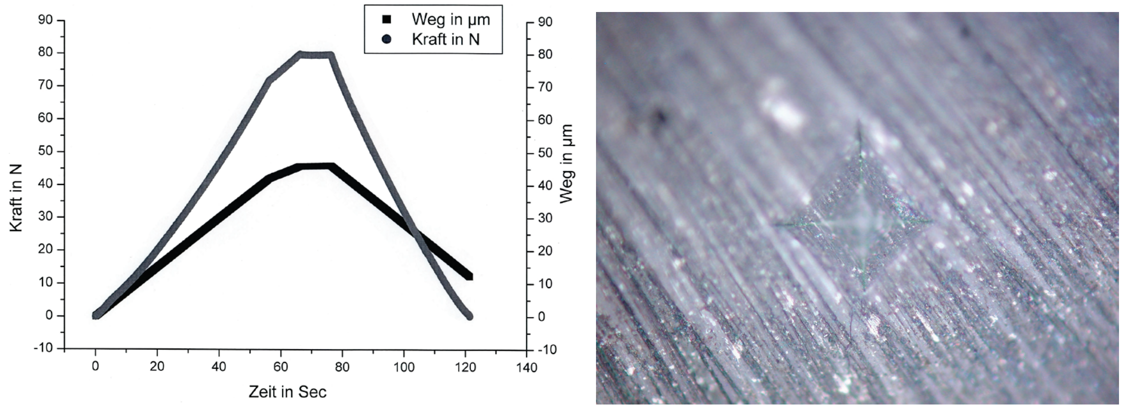
Microscopic research of microsections was done at the University of Clausthal (Germany), on Cam Scan microscope; micro hardness was measured on CD Muecke-Haerte device at the Department of ceramic materials and items of the Bremen University.

With consideration of X-ray (DRON 3) phase analysis (Fig. 1) and microscopic pictures of Al_2O_3-TiC system composites the opinion presented in [6,7] proves that at hot pressure up to 1550°C between aluminum oxide and titanium carbide there is no interaction by creating some new phase. The microstructure of researched composites consists of two phases (Al_2O_3 and TiC).

The same is proved with parameter value of titanium carbide crystalline lattice TiC and micro hardness index of titanium carbide 25 GPa which absolutely conforms with the indices presented in [6].

As the microscopy pictures of the first group samples show titanium carbide is homogeneously redistributed in aluminum oxide matrix, the jointing of their grains is not noted. The form of titanium carbide grains nears to spherical, their average diameter Dav is 3 μM and is almost not depended on titanium carbide amount. Porosity is as more as less is titanium carbide content in sample.

The hardness of each composite of the first group (Table) absolutely satisfies the demands put to cutting material [8] but it is desirable that ultimate hardness to be higher. In this case, intensive growth of aluminum oxide grains does not occur but microstructure intergrain spaces are not completely filled which affects negatively on mechanical properties of these composites.



a b

Fig. 2. HV data of TiC 20% - Al_2O_3 80% composite: a) time dependence of indentor load on the sample and distance; b) indentor imprint, x500.

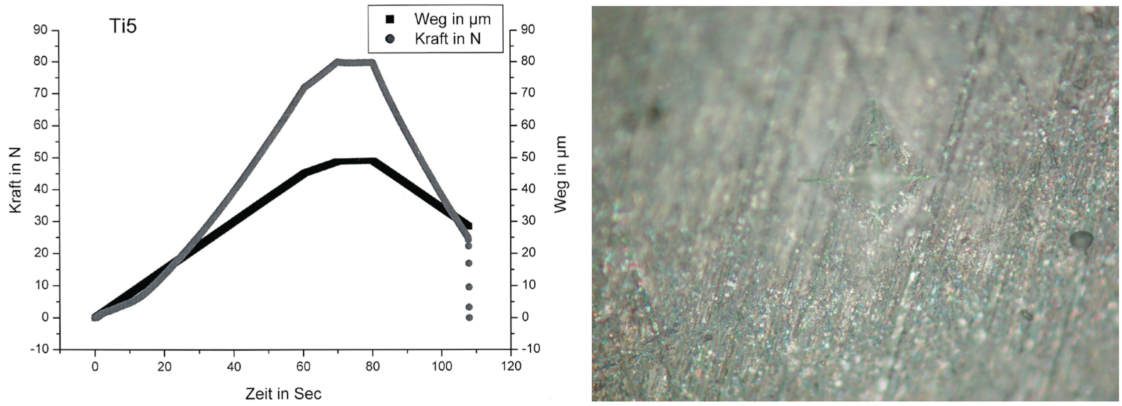


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Fig. 3. HV data of TiC 20% –Al_2O_3 80% composite (with additives): a) time dependence of indentor load on the sample and distance; b) indentor imprint, x500.

The form and distribution character of carbide grains do not change under the effect of additives added to composites while porosity substantially decreases. At the same time, the additives together with titanium carbide prevent intensive growth of aluminum oxide grains which is very intensive at sintering of pure aluminum oxide. The fact of grain size retaining is most clearly noticed in 10% titanium carbide containing composite where the amount of titanium carbide grains is less and aluminum oxide matrix is seen more clearly. Aluminum oxide grains are quite well sintered to each other, although some intergrain pores are noticed.

Microstructure dispersion and material compactness degree are reflected on the indices of physico-technical properties of these samples (Table), mechanical strength of samples with additives comparatively exceeds strength indices of composites without additives.

Composites with and without additives almost do not differ from each other in micro hardness indices, only careful studying of indentations revealed that cracks at the tops of indentations in case of composites with additives are not fixed compared to some composites obtained without additives (Figs. 2,3).

As to the effect of carbon fiber, we think it has double load. It increases composite bending strength (Table) and at the same time, helps to preserve titanium carbide stoichiometric composition. But it should be noted that if carbon fiber particle occurs on cutting tool edge, in the process of cutting it may be burnt out or torn out from the surface which may negatively affect cutting material properties [4]. Carbon fiber in material is located undirected. The damaged boundaries of carbon fiber as a result of section preparation are shown in Fig. 4.

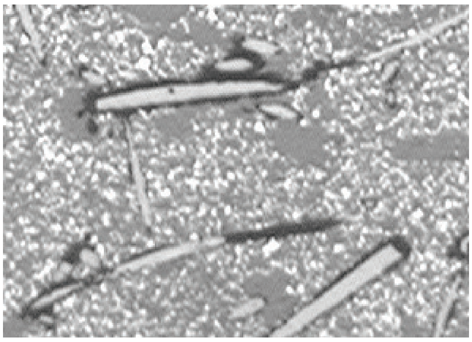

Fig.4. Microscopic pictures, X400; TiC 20% - Al_2O_3 80% (with additives 2).

From composites of TiC 20% - Al_2O_3 80% (with additives 2) composition (Table) cutting plates with sizes 12 x 12 x 5 mm were prepared and tested for wear resistance in cutting process. Steel 40 was taken as processed material. Cutting rate was 300 m/min, supply – S-0.3 mm/rot., cutting depth – t=0.5 mm. Before wearing to 0.6 mm the test plate worked for 400 hours.

Conclusion

The results of the research of structural and physico-technical properties of Al_2O_3-TiC system composite materials received with hot pressure are presented. An opinion is expressed that the set of MgO, Y_2O_3 and carbon fiber additives, the use of aluminum oxide nanopowder and hot pressure makes desired conditions that at receiving of Al_2O_3-TiC system composite materials, no intensive growth of corundum grains happens. At the same time, practically poreless material with high mechanical and cutting properties is received.

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მასალათმცოდნეობა

Al_2O_3-TiC სისტემის ნანოკერამიკული კომპოზიციური მასალის სტრუქტურული კვლევა

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** საქართველოს ტექნიკური უნივერსიტეტი, ბიონანოკერამიკისა და ნანოკომპოზიტების ტექნოლოგიის ინსტიტუტი, თბილისი, საქართველო*

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ნაშრომის მიზანია Al_2O_3-TiC სისტემაში კომპოზიციური მასალის მიღება ცხელი წნეხვით და სტრუქტურული კვლევა. მასალა შესწავლილ იქნა Cam Scan ფირმის ელექტრონული მიკროსკოპის საშუალებით. ოპტიკურ-მიკროსკოპიული კვლევა ჩატარდა ჩინურ Am Scope მიკროსკოპით. რენტგენოსტრუქტურული ანალიზი – DRON 3-ზე, მიკრომექანიკა – CD Muecke Haerte დანადგარზე გერმანიის ქ. კლაუსტალის ტექნიკურ უნივერსიტეტში. კვლევის შედეგად დადასტურებულია, რომ 1550°C-მდე ცხელი წნეხვის დროს ტიტანის კარბიდსა და ალუმინის ოქსიდს შორის არ მიმდინარეობს ურთიერთქმედება რაიმე ახალი ფაზის წარმოქმნით. ცხელი წნეხვით შეცხობის პირობებში ტიტანის კარბიდი და ოქსიდების (MgO, Y_2O_3) მცირე დანამატები, ხელს უშლის ალუმინის ოქსიდის მარცვლების ზრდას, უზრუნველყოფს მასალის კომპაქტურობას და მექანიკურ სიმტკიცეს, ხოლო რაც შეეხება ნახშირბადის ბოჭკოს გავლენას, ჩვენი აზრით, მას ორმაგი დატვირთვა აქვს: იგი თავისთავად ამაღლებს კომპოზიტის სიმტკიცეს ღუნვისას და, ამავე დროს, ხელს უწყობს ტიტანის კარბიდის სტექიომეტრიული შედგენილობის შენარჩუნებას, სიმაგრე – **HRA=94; $\sigma_{compr.}$=3000 MPa; $\sigma_{bend.}$=680 MPa.**

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