MECHANICAL PROPERTIES AND MICROSTRUCTURES OF Ti(C, N) BASED CERMETS①

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ABSTRACT The mechanical properties and microstructure of Ti(C, N) based cermets have been studied. The experimental results have shown that the cermets investigated are of good mechanical properties, and their microstructures consist of ceramics and metals. The ceramics in cermets are divided into two types depending on their diameter sizes. Small particle ceramics with diameter less than 0.7 μm is the single ceramics (Ti, W, Mo)(C, N), and the large one with diameter greater than 1μm consists of core and rim, in which case the core is pure TiC and the rim is (Ti, W, Mo)(C, N). This work suggests that the core and rim have the same crystal structure, lattice parameter and orientation. An orientation relationship between the ceramics and metals has also been found.

Key words Ti(C, N) based cermets mechanical properties microstructure

1 INTRODUCTION

As a new kind of tool materials, which appeared in the 1970s, the Ti(C, N) based cermets have been widely used abroad, especially in Japan, due to many of its advantages such as high resistance to wear, high temperature, corrosion and oxidization, as well as low frictional coefficient and density[1,2]. Several new Ti(C, N) based cermets have been studied by adding more, binder nickel, to improve the strength and toughness, in order to provide a theoretical basis for appliying to other areas besides cutting tools such as die and wear resistant parts.

2 EXPERIMENTAL MATERIALS AND METHODS

The materials tested were manufactured using a conventional powder metallurgy technique. Their compositions were as follows(%):

40Ni-1C-13Mo-10TiN-15WC-21TiC;
35Ni-1.2C-14Mo-10TiN-15WC-24.8TiC;
30Ni-1.3C-15Mo-10TiN-15WC-28.7TiC.

The average diameter of powders was measured with a SA-CP3 analysis instrument, and the results are as follows: Ni 14.89 μm, C< 30 μm, Mo 6.91 μm, TiN 1.22 μm, WC 0.84 μm, TiC 0.93 μm.

The transverse rupture strength(TRS) tests were conducted on a universal testing machine WJ-10B by three point bend method, with specimen size 5 mm × 5 mm × 30 mm; the step was 25 mm, and the load decrease rate was 1 mm/min. The impact tests were conducted on an impact testing machine XCJ-50, with specimen size 10 mm × 10 mm × 55 mm without notch, using 7.5 and 15 J pendulums, respectively, depending on their toughness values. The fracture toughness tests were also conducted by three point bend method, using the specimens of 5 mm × 10 mm × 55 mm in size and with a notch about 5 mm in

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depth the testing step was 40 mm, and the load decrease rate was 0.5 mm/min.

The SEM JSM-35C and ASM-SX were used to examine the structures of the cermets. The TEM H-800 and CM-12 were also used to analyze the microstructures, the thin films were cut from the specimens, and mechanically thinned below 30μm, then, ion-thinned with a double-jet ion-thinning instrument Gatan 600. The data in this paper are the average value of twelve tested pieces.

3 RESULTS AND DISCUSSION

3.1 Mechanical properties

The mechanical properties of Ti(C, N) based cermets are shown in Table 1. It can be seen that the cermets are of high strength and toughness.

Table 1 Mechanical properties of Ti(C, N) based cermets

Cermets	TRS /MPa	Hardness HRA	K_{IC} /MPa·m$^{1/2}$	a_K /J·cm^{-2}
40Ni	1980	84.6	20.0	9.2
35Ni	1880	87.2	19.1	7.7
30Ni	1750	88.3	17.8	4.6

3.2 Microstructures

The SEM micrographs shown in Fig. 1 denote that the rim of large particle ceramics with diameter greater than 1 μm appears as white spots and the core appears as dark or grey spots; the small particle ceramics with diameter less than 0.7 μm appears as white spots. The structures of three types of cermets have been measured, and they all consist of ceramics TiC and metallic nickel[3], no spare diffraction peaks of WC exist by using X-ray diffraction techniques. The line scanning images of wave dispersion spectroscopy of cermets containing 40% nickel, shown in Fig. 2, denote that the element carbon mainly distributes in the ceramics, nitrogen in the rim of large ceramics and in the small ceramics; tungsten and molybdenum in the rim, small ceramics and metals; nickel in the metals, and titanium mainly in the ceramics.

The TEM micrograph shown in Fig. 3 denotes the microstructure of cermets containing 40% nickel. The dark spots in this micrograph are the examining positions of energy dispersion spectroscopy. The analyzing results are shown in Fig. 4.

It is shown from Fig. 4 that the core is pure TiC. No spare peaks were examined by a large amount of X-ray diffraction works, it denotes that the core and rim of large ceramics are of the same crystal structure and lattice parameter. It is suggested that the rim is (Ti, W, Mo) (C, N). The fact that dislocations can pass through the core/rim interface, shown in Fig. 5(a), denotes that the core/rim interface is different from the conventional grain or phase boundaries. The core/rim structure of cermets does not give

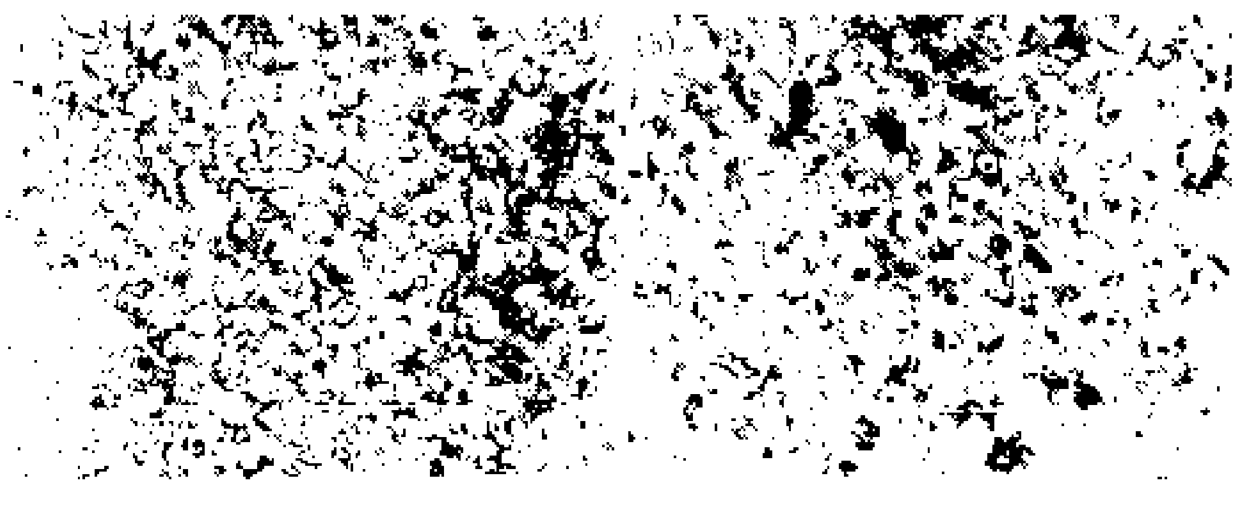

Fig. 1 SEM micrographs showing microstructures of Ti(C, N) based cermets
(a) —40% nickel; (b) —30% nickel

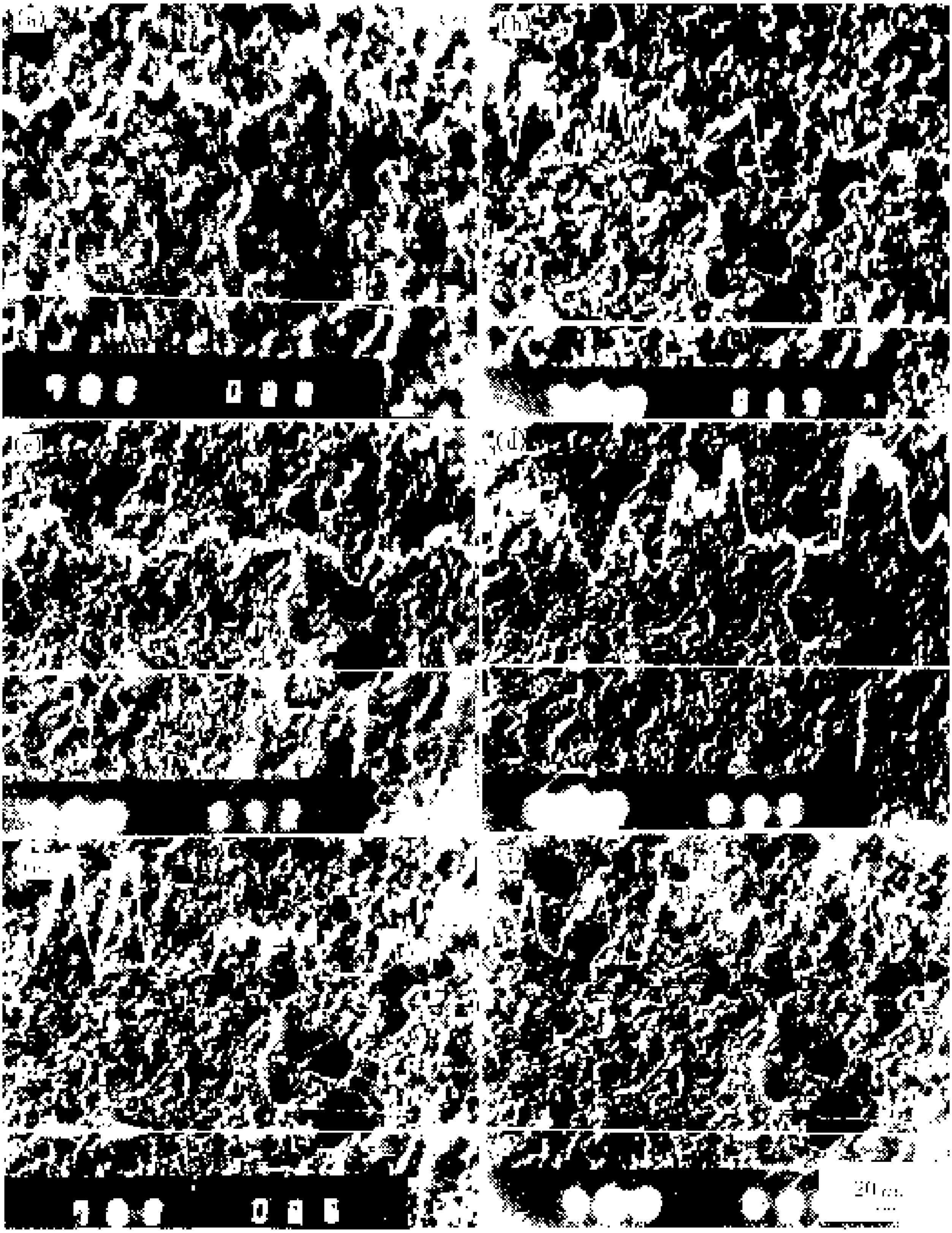

Fig. 2 Line scanning image of wave dispersion spectroscopy of cermets containing 40% nickel

(a) —element C; (b) —element N; (c) —element W; (d) —element Mo; (e) —element Ni; (f) —element Ti

any evidence indicating the presence of two different phases, only one single diffraction pattern has been obtained with no spot splitting, as shown in Fig. 5(b). This suggests that the core and rim have the same crystal structure, lattice parameter and orientation, corresponding to the

X-ray analyzing results as well. It is considered that the core/ rim interface is caused by the lattice distortion, i. e. the positions of titanium and carbon in the rim are replaced partly by tungsten, molybdenum and nitrogen respectively, which will increase the lattice distortion and shows the interface.

The TEM micrographs shown in Fig. 6 also denote that the microstructure of cermets containing 35% nickel consists of ceramics and metals, and only exists a set of spots of ceramics. An orientation relationship at the ceramics/ metals interface, i. e. $(\bar{2}44)_{Ni} // (\bar{6}40)_{TiC}$, $[\bar{2}23]_{Ni} // [001]_{TiC}$, shown in the same figure, has also been found.

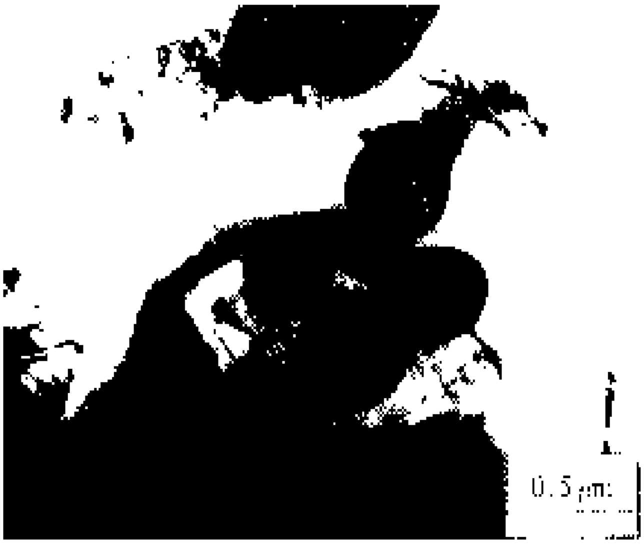

Fig. 3 TEM micrograph showing microstructure of cermets containing 40% nickel

4 CONCLUSIONS

(1) Three types of Ti(C, N) based cermets have been studied, and they are of good mechanical properties.

(2) The microstructures of Ti(C, N) based cermets consist of ceramics and metals. The ceramics in cermets can be further divided into two types, the first of which consists of core and rim with diameter greater than 1 μm. The core and rim have the same crystal structure and orientation , and have very near spot parameter, in

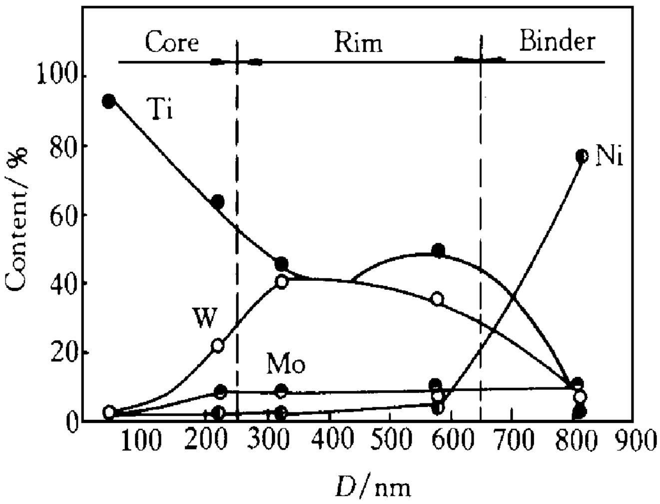

Fig. 4 Energy dispersion spectroscopy results of microstructure of cermets in Fig. 3

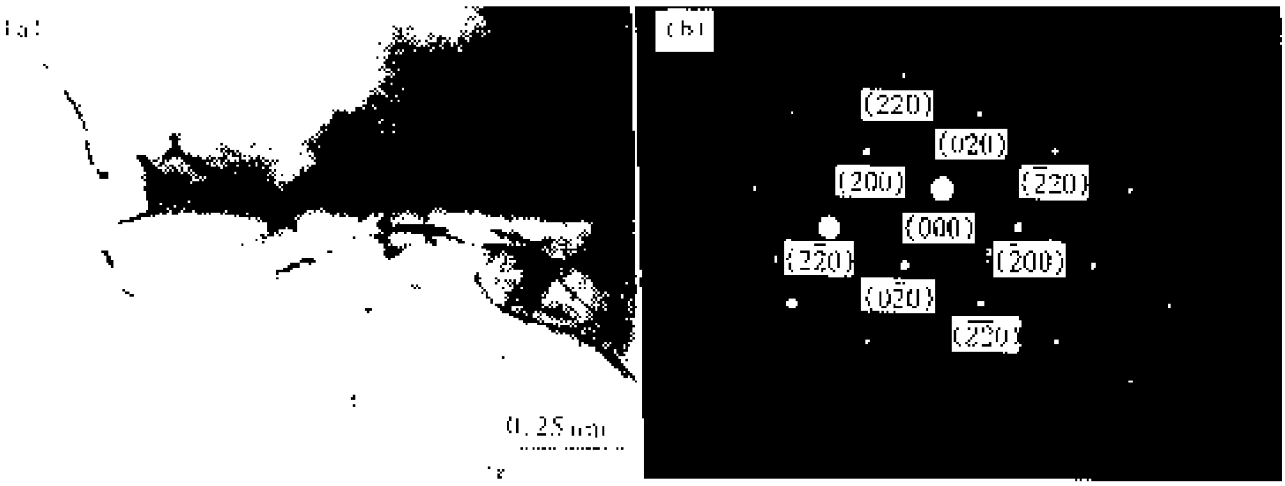

Fig. 5 TEM micrograph showing core/ rim interface of cermets
(a) —bright field; (b) —selected area diffraction spots

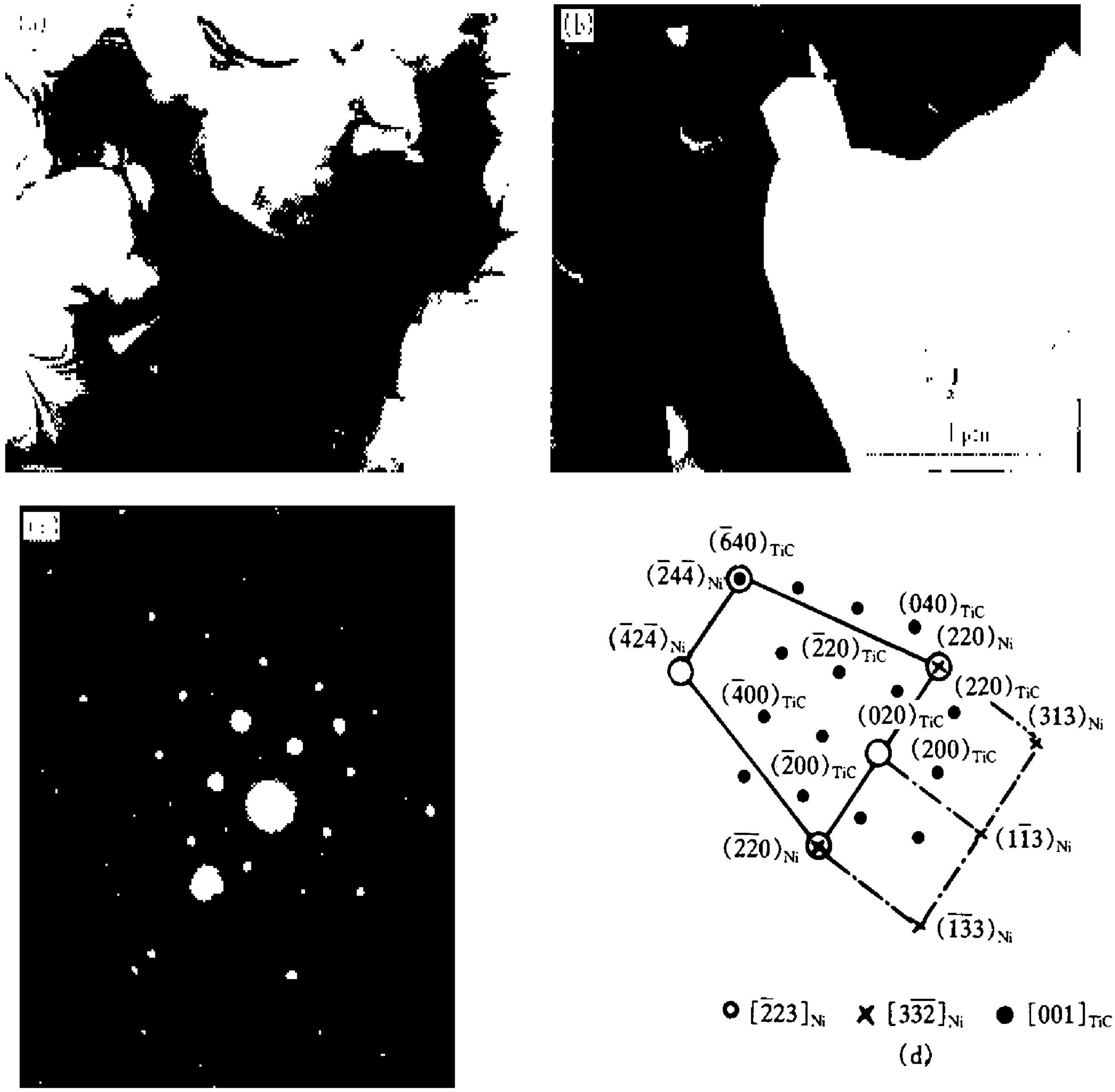

Fig. 6 TEM micrographs showing microstructures of cermets containing 35% nickel
(a) —bright field; (b) —dark field; (c) —selected area diffraction spots; (d) —index of (c)

fact, the core is pure TiC and the rim is (Ti, W, Mo)(C, N). The second type of ceramics with diameter less than 0.7 μm is (Ti, W, Mo)(C, N). The metals in cermets are the solution of elements titanium, tungsten and molybdenum in nickel.

(3) An orientation relationship between the ceramics and metals i. e. $(\bar{2}4\bar{4})_{Ni} \parallel (\bar{6}40)_{TiC}$, $[\bar{2}23]_{Ni} \parallel [001]_{TiC}$, has been found. There may also be other orientation relationship, of course, between the ceramics and metals.

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