[Article ID] 1003- 6326(2001)06- 0835- 03

Bond strength of W-Cu/CuCr integrated material①

FAN Zhi-kang(范志康), LIANG Shu-hua(梁淑华), XUE Xu(薛 旭)
(School of Materials Science and Engineering, Xi'an University of Technology, Xi'an 710048, P. R. China)

[Abstract] The bond strength of W-Cu/CuCr integrated material was investigated. The results show that the fracture of W-Cu/CuCr integrated material often takes place at W-Cu/CuCr interface. Some alloying elements enhance the bond of W and CuCr alloy, which results in the increase of the strength of the W-Cu/CuCr interface. And the fracture of the W-Cu/CuCr integrated material occurs in the CuCr alloy part, not at the W-Cu/CuCr interface. Chromium in CuCr alloy part of the integrated material can improve Cr diffusing from the CuCr alloy to W-Cu composite and can be alloyed (near the W-Cu/CuCr interface) in the W-Cu composite. Thus the strength of W-Cu/CuCr interface is also increased.

[Key words] bond strength; W-Cu; CuCr; integrated material
[CLC number] TF12 [Document code] A

1 INTRODUCTION

W-Cu/CuCr integrated material now is used as electric contact material in high power switcher[1]. Traditional process of bonding W-Cu composite and CuCr alloy is welding. Because welding defects often appear at W-Cu/CuCr welding interface, the interface bond is low and unstable[2]. A new infiltration sintering method has been developed by present authors to produce W-Cu/CuCr integrated material, which can make bond strength of W-Cu composite and CuCr alloy greater than 260 MPa, and meet the need of contact material for 126 kV and higher power breaker[3~7]. Now, new model high power switcher, such as gas insulated switch gear (GIS) for 220 kV power transmission network is with small size, which means arc resistance of W-Cu composite needs to be improved and W-Cu/CuCr boundary strength needs to be increased[8]. Some works were done on improving arc resistance[9,10] and microstructure[11,12] of W-Cu composite. The present exploratory work investigates the bond strength of W-Cu/CuCr material.

2 EXPERIMENTAL

W-Cu composites with 60% ~ 80% W (mass fraction) were prepared. W-Cu composites with certain additional elements were also prepared. The W-Cu/CuCr integrated material was made by infiltration sintering at 1300 ℃ for 2 h. Chromium in the CuCr alloy varied from 0.21% to 0.65% (mass fraction). The integrated material then was machined to tensile test bar with half part W-Cu composite and half part CuCr alloy to test bond tensile strength of W-Cu/CuCr interface. After tensile test, the fractures of W-Cu/CuCr interfaces were observed on SEM. A cross section perpendicular to the fracture was also prepared to analysis W-Cu/CuCr bond model.

3 EXPERIMENTAL RESULTS

Boundary tensile strengths of W60-Cu/CuCr, W70-Cu/CuCr and W80-Cu/CuCr interfaces are given in Table 1. From Table 1 it can be seen that boundary strength of W60-Cu/CuCr interface is a little greater than that of W70-Cu/CuCr and W80-Cu/CuCr interfaces. The integrated material fractures at the W-Cu/CuCr boundary during tensile test, as shown in Fig. 1(a).

Table 1 Boundary tensile strength of W-Cu/CuCr interface (MPa)

W60-Cu/CuCr	W70-Cu/CuCr	W80-Cu/CuCr
286.6	272.0	263.0
276.0	265.4	263.1
278.1	267.0	265.1

If tungsten content in W-Cu composite is kept at 70%, while content of chromium in CuCr alloy increases from 0.21% to 0.65%, boundary strength of W70-Cu/CuCr interface increases from 215.5 MPa to 322.0 MPa, as shown in Table 2.

In order to select the optimum infiltration sintering process, five sintering temperatures and eight infiltration temperatures have been tested. After the optimum infiltration sintering process is used and certain additional elements are added in W-Cu composite, the bond strength of W70-Cu/CrCu interface became greater than the tensile strength of CrCu alloy itself. During tensile test, fracture of the integrated

① [Foundation item] Project (2000C30) supported by the Natural Science Foundation of Shaanxi Province
[Received date] 2001- 04- 16; [Accepted date] 2001- 02- 23

Table 2 Effects of Cr on bond strength of W70-Cu/CrCu interface

w(Cr)/%	Bond tensile strength/MPa	w(Cr)/%	Bond tensile strength/MPa
0.21	215.5	0.52	285.0
0.37	247.0	0.65	322.0
0.47	284.3		

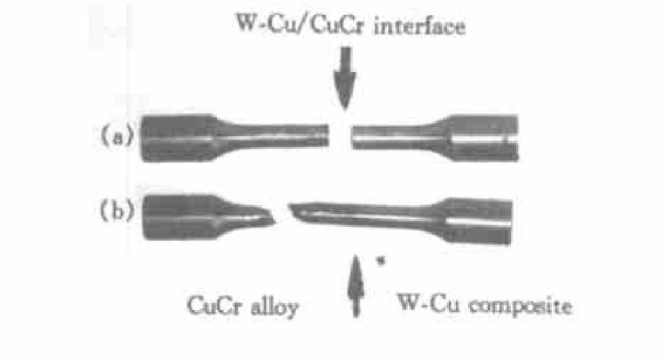

Fig. 1 W-Cu/CuCr integrated material tensile test bars after fracture

material occurs in the CuCr alloy part, not at the W-Cu/CuCr interface, as shown in Fig. 1b.

W-Cu/CuCr solid contacts were put on a new model LW-126 kV SF6 breaker. The breaker successfully opened and closed for 20 times at 40 kA. The mechanical service life reached 10000 times.

4 DISCUSSION

SEM morphology of perpendicular section to W-Cu/CuCr boundary is showed in Fig. 2. From Fig. 2, it can be seen that W-Cu composite and CuCr alloy are well connected. No transition layer is found between tungsten and CuCr alloy. EDS analysis shows there is neither tungsten solution in CuCr alloy, nor chromium and copper solution in tungsten.

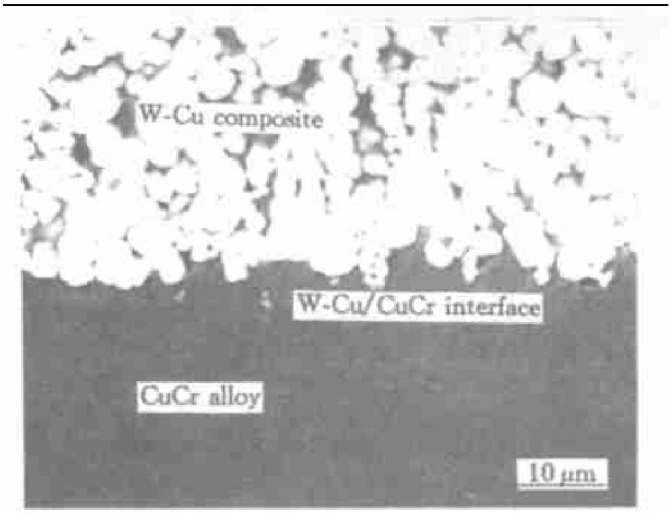

Fig. 2 SEM morphology of perpendicular section to W70-Cu/CuCr interface (not etching)

W-Cu/CuCr interface strength is enhanced with the increase of Cr content. This is because CuCr alloy has higher strength under this condition. More Cr particles precipitated in the CrCu alloy (as shown in Fig. 3) makes CuCr alloy has higher tensile strength (as listed in Table 3). Moreover, Cu in W-Cu composite is also alloyed by Cr diffused from CuCr alloy. EDX analysis shows that with the increase of Cr content in CrCu alloy, more Cr from CrCu alloy diffuse into W-Cu composite. While Cr content in CuCr alloy increases from 0.21% to 0.65%, Cr content in Cu of W-Cu composite (at 5 mm away from W-Cu/CuCr interface) increases from 0.09% to 0.32%.

Although strength of W-Cu/CuCr interface is enhanced with increase of Cr content in CuCr alloy, fracture still takes place at the W-Cu/CuCr interface. From the fact that copper and CuCr alloy have taken plastic deformation during tensile test, as shown in Fig. 4, it can be deduced that fracture first occurs at W-Cu/CuCr interface. This implies that bond of W/

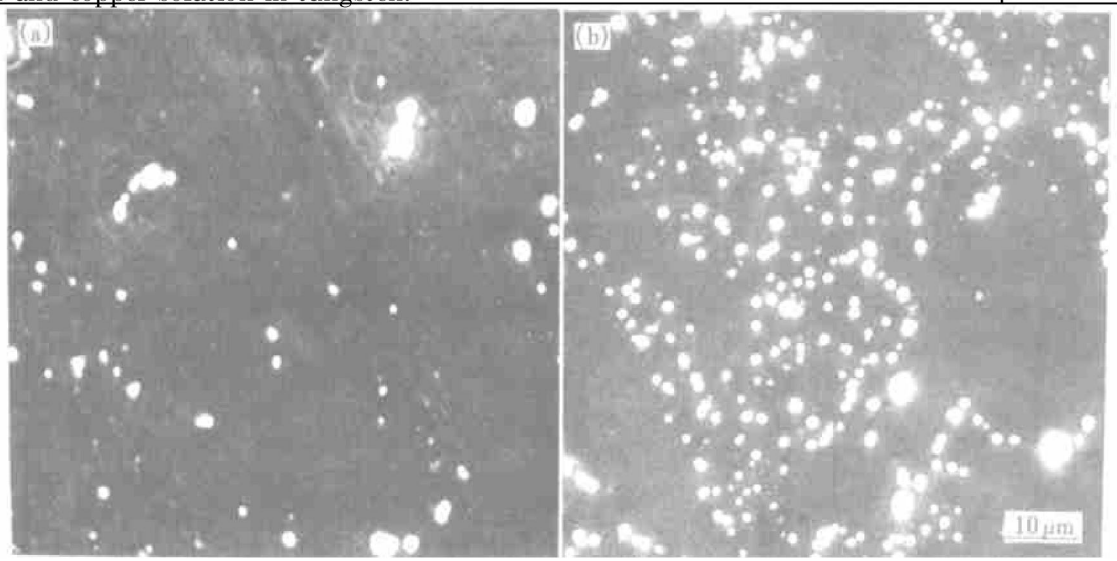

Fig. 3 SEM morphologies of chromium particles in CuCr alloys (chemical etching)
(a) —0.24% Cr; (b) —0.65% Cr

Table 3 Effects of Cr content on properties of CuCr alloy

w(Cr)/%	Tensile strength/MPa	Hardness (HB)	Elongation/%	Electrical conductivity/%
0.21	267.0	89.7	24.0	82.3
0.37	302.0	110.0	20.0	83.9
0.47	341.0	118.0	22.1	82.4
0.52	360.0	122.0	20.5	83.5
0.65	367.0	124.0	19.8	82.8

CuCr interface is lower than tensile strength of CuCr alloy itself. The fact that the interface strength of W60-Cu/CuCr is greater than that of W80-Cu/CuCr interface also supports this.

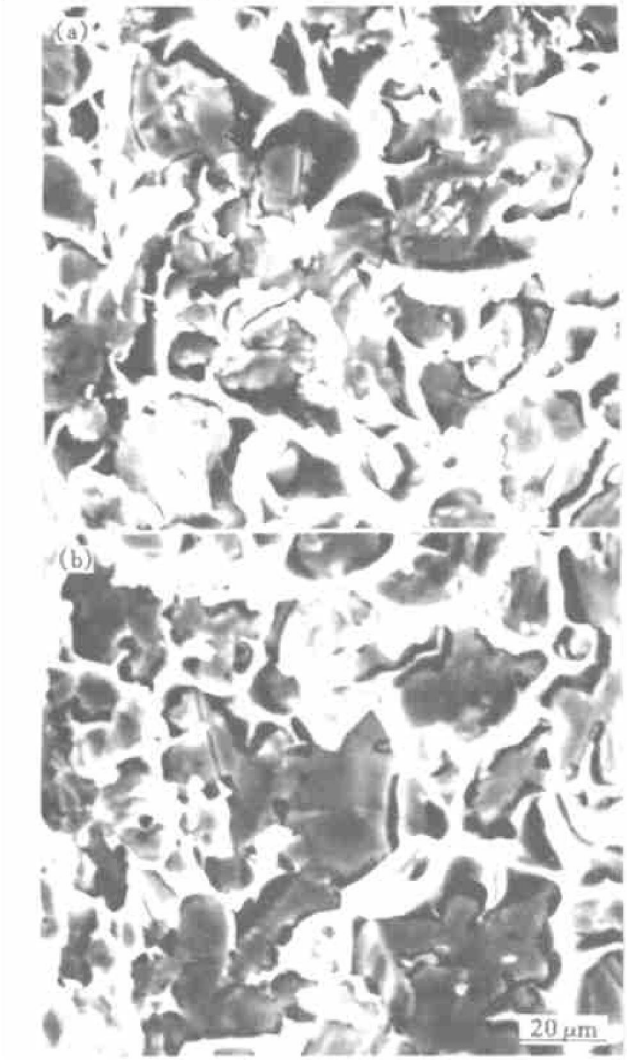

Fig. 4 Fracture morphologies of W60-Cu/CuCr material
(a) —W60-Cu side; (b) —CuCr alloy side

However, by improving infiltration sintering process and adding certain additional elements, the integrated material fractures in the CuCr alloy part, not at the W-Cu/CuCr interface. The bond strength of W/CuCr interface is greater than the tensile strength of CuCr alloy. Under this condition, the tensile strength of the W-Cu/CuCr integrated material is equal to the tensile strength of CuCr alloy, usually greater than 320 MPa.

5 CONCLUSIONS

1) Increasing chromium content in CuCr alloy part of the integrated material can improve Cr diffusing from the CuCr alloy part to W-Cu composite part. Copper (near the W-Cu/CuCr interface) in the W-Cu composite is alloyed and the boundary strength of W-Cu/CuCr interface is increased.

2) The fracture of W-Cu/CuCr usually takes place at W-Cu/CuCr interface. Certain additional elements can improve the bond of W and CuCr alloy, so as to increase the interface strength of W-Cu/CuCr interface. Under this case, the fracture of the W-Cu/CuCr integrated material occurs in the CuCr alloy part, not at the W-Cu/CuCr interface.

[REFERENCES]

[1] Contact components for medium and high voltage power engineering [EB/OL]. www.amidoduco.com, 2000.
[2] ZHEN Y N, WANG S, TAO J. Application and test of integrated CuW-CrCu contact by powder metallurgy [J]. High Voltage Apparatus, (in Chinese), 1994, 30(4): 29– 33.
[3] FAN Z K, LIANG S H, XIAO P. Properties of integrated W-Cu/CrCu arc contact by sintering infiltration method [J]. Electric Alloys, (in Chinese), 1998, 69(4): 25– 27.
[4] FAN Z K, LIANG S H, YANG H W. Investigation on arc resistance of integrated W-Cu/CrCu contact by sintering infiltration method [J]. Electric Alloys, (in Chinese), 1999, 70(2): 27– 29.
[5] FAN Z K, LIANG S H, YANG H W. The effect of Chromium on bonding strength of W-Cu/CrCu interface [J]. Electric Alloys, (in Chinese), 1999, 70(3): 22– 25.
[6] LIANG S H, FAN Z K. Defects and their controlling methods of W-Cu contact material [J]. High Voltage Apparatus, (in Chinese), 2000, 36(3): 20– 22, 47.
[7] FAN Z K, LIANG S H, CHENG W G. Infiltration Sintering W-Cu/CuCr Integrated Contact for High Voltage Apparatus [P]. China Patent, 98112840.8.
[8] LIANG S H, FAN Z K. Preparation of W-Cu/CuCr integrated contact by standing sintering infiltration [J]. Materials for Mechanical Engineering, (in Chiese), 1999, 23(3): 19– 21.
[9] Yang B, German R M. Powder injection moulding and infiltration sintering of superfine grain W-Cu [J]. PMI, 1997, 33(4): 55– 63.
[10] Moon I H, Kim E P, Petzow G. Full densification of loosely packed W-Cu composite powders [J]. 1998, PM, 41(1): 51– 57.
[11] Kaczmar J. Effect of production engineering parameters on structure and properties of Cu-W composite powders [J]. PM, 1989, 32(3): 171– 175.
[12] CAI Y X, LIU B W. Densification method for CuW composite [J]. Powder Metallurgy Technology, (in Chinese), 1999, 17(2): 138– 142.

(Edited by YANG Bing)