

Mechanical Properties and Thermal Shock Resistance of Zr, Cr Doped WCu Composite



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Abstract: WCu composites were fabricated by infiltrating Cu alloys doped with Zr and Cr into W skeleton in order to strengthen the W/Cu interfaces. The effects of Zr and Cr on the mechanical properties including flexural strength and impact toughness, and thermal shock resistance of WCu composites were investigated. The results show that the addition of a small amount of Zr and Cr can increase the flexural strength and the impact toughness of WCu composites. With the increase of thermal shock temperature, the flexural strength of WCu composites decreases. However, the addition of Zr and Cr in WCu composite can reduce the effect of thermal shock on mechanical properties obviously, improving the thermal shock resistance of WCu composites.

Key words: WCu composite; microstructure; flexural strength; impact toughness; thermal shock resistance

Considering the high thermal conductivity of copper and the excellent high-temperature strength of tungsten, WCu composites have been widely used in a variety of fields, such as electrical contacts especially at high voltage, welding electrodes, electric discharge machine, electronic packaging materials and heat sinks^[1-4]. Moreover, the good combination of Cu and W elements leads to the optimization of material properties, such as ductility, mechanical strength, corrosion and wear resistance at elevated temperature. As WCu composite is usually applied under a thermal shock load, the surface is subjected to fracture derived from internal thermal stress^[5]. Therefore, a number of investigations have been made on the improvement of the mechanical behaviours of WCu composite by doping some extra elements^[6, 7], enhancing sintering temperature^[8], refining W particle size^[9-12], tungsten fibre-reinforced^[5,6] and so on. Among these methods, the addition of some extra elements is convenient to control and beneficial for the improvement of mechanical behaviours. With the addition of Cr, W-Cr solid solution transition layer is formed between the W grain boundaries^[13], and then W skeleton is strengthened. As

mentioned in Ref. ^[14], cracks appear mostly at the interface of W/Cu under external load. Therefore, it is necessary to strengthen W/Cu interface by some methods including the addition of some extra elements.

Previous studies demonstrated that the addition of Group VIII transition metals, including Ni, Pd, Pt, Co, Fe, Cu, and Cr can enhance the sintering kinetics of W powder, thus reducing its sintering temperature^[15]. On the other hand, the transition metals (Ni, Cr, Nb, Zr, Mo, W, Ta) will form solid solution phase probably among the interfaces each other. In order to strengthen the W/Cu interfaces, Zr, Zr and Cr were doped in WCu composite, and then mechanical properties and thermal shock resistance of WCu composite were analyzed.

1 Experiment

WCu composites used in the present study were fabricated by infiltrating the copper alloys into tungsten skeleton. Tungsten powder (purity>99.8%, 4~6 μm) was used to prepare skeletons, CuZr (0.15wt%~0.3wt%Zr) and CuCrZr (0.8wt%~1.2wt%Cr, 0.1wt%~0.2wt%Zr) alloys were used for infiltration. Tungsten powder mixed with

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activated element Ni was first pressed into cylindrical compacts under a pressure of 340 MPa in a hydrostatic machine, and then copper alloy blocks were placed above each compact in the graphite crucibles followed by activated sintering and infiltrating at a hydrogen atmosphere in a sintering furnace. Tungsten skeletons were sintered at 1000 °C for 2 h, and then held at 1350 °C for 2 h to infiltrate copper alloys. After annealing at 450 °C for 4 h, WCu composites were obtained.

The flexural strength and the impact toughness were tested by a HT-2402-100KN Computer Servo Control material testing machine and a JB-300 Charpy impact test machine, respectively. For flexural tests, the specimens were machined into the dimensions of 3 mm×4 mm×35 mm. In each case, three-point bending loading tests were performed with a span of 30 mm. Flexural test procedures were performed at room temperature and with a load rate of 0.5 mm/min. For the flexural properties analysis, the load versus displacement curves were obtained directly and the stress was calculated by a linear bending beam relationship. Charpy impact tests were performed using square 10 mm×10 mm notched specimens. A sharp notch with 2 mm depth and at a 45° flank angle was machined in each specimen. Afterwards, the tests were carried out on a 50 mm span. The absorbed energy was directly measured by the difference in potential energy between the starting and the after-impact highest position of the pendulum. Then the

impact toughness value was obtained by the absorbed energy divided by the cross-section area of specimen.

For the thermal shock tests, firstly, flexural specimens of WCu alloys were placed into an electrical resistance furnace and held for about 1 min at the temperature of 400, 600, 900 °C, respectively, and then the specimens rapidly were put into 20 °C water for about 1 min. After thermal cycling 10 times, the flexural tests were conducted at room temperature.

2 Results and Discussion

2.1 Microstructures of WCu composite

Fig.1a~Fig.1c are the SEM images of the WCu composites without Zr and Cr addition, doped with Zr and doped with Zr and Cr, respectively, in which the light region is W phase and the rest region is Cu phase. It can be seen that the sintered necks bonded between W grains are formed after sintering and the Cu phase is surrounded by tungsten matrix skeleton throughout the microstructure. Hence, there is no obvious difference in microstructure of the three WCu composites.

2.2 Mechanical behaviours

Fig.2 shows the flexural stress-displacement curves of WCu composites. In the case of no Zr and Cr addition, the curve shows approximately linear until failure, indicating the classic brittle behaviour. With the addition of Zr and Cr, the curves exhibit non-linear stress-displacement

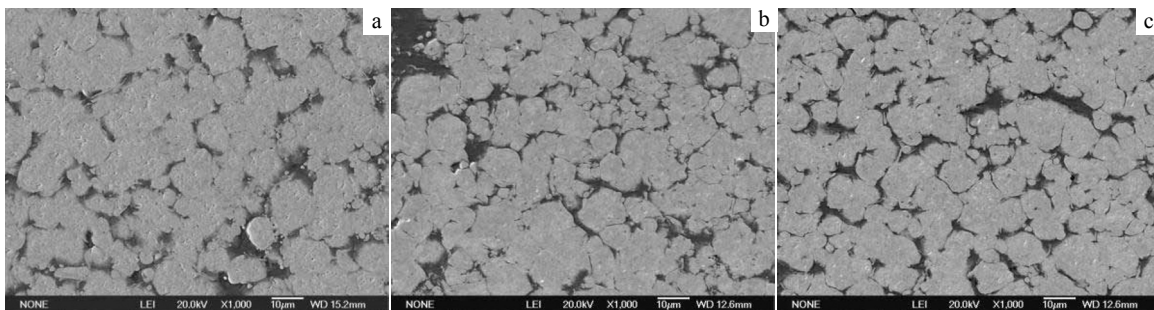


Fig.1 SEM images of microstructures of WCu composites: (a) without Zr and Cr addition, (b) doped with Zr, and (c) doped with Zr and Cr

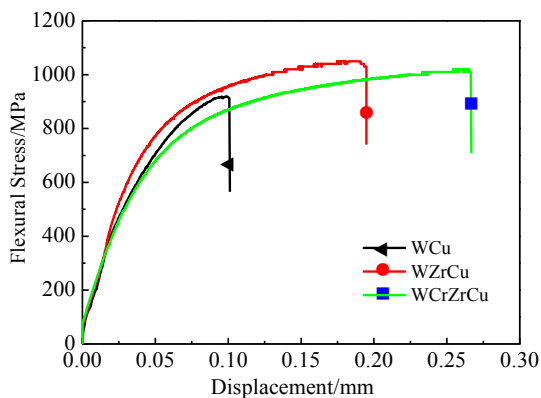


Fig.2 Flexural stress-displacement curves of WCu composites

relationship and more plastic deformation appears. As seen in Fig.2, the flexural strengths of WCu composite doped with Zr, Zr and Cr increase from 919 MPa to 1050 MPa and 1020 MPa, respectively, increase by 14.25% and 10.99%, respectively. In addition, with the addition of extra element, the bending deformation of WCu composites doped with Zr, Zr and Cr increase by 92.49% and 104.20%, respectively. Therefore, the curves show an evident improvement of strength and ductile due to the addition of Zr and Cr.

The impact toughnesses of three WCu composites are summarized in Fig.3. It is clear that the WCu composite without any element additions has an impact toughness of 0.330 J·cm⁻², while the impact toughnesses of the WCu composites doped with Zr, Zr and Cr are both 0.368 J·cm⁻²,

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