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The characterization of borided pure tungsten

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Abstract

This study reports on mechanical properties of borided pure tungsten. Boronizing heat treatment was performed in a solid medium consisting of Ekabor powders at 940 °C for 2, 4, and 8 h. The presence of WB on the surface of pure tungsten was confirmed by XRD analysis. Metallographic studies revealed an almost uniform and compact boride layer on the surface of the pure tungsten. The thickness of boride layer ranged from 10 to 42 μm with some scatters. The hardness of borided specimens decreased with the distance from the surface to the interior of the test material. The hardness of the boride on the substrate was 2500 HV while the hardness of the substrate was 445 HV.

Keywords: Boronizing; Tungsten; Borides; Hardness; Tungsten boride

1. Introduction

Transition metal borides have numerous useful physical and chemical characteristics that make them important materials to study. Prominent characteristics include heat resistance, great hardness, wear resistance, and high-temperature electrical resistance. Tungsten borides are resistant to thermal shock and are good thermal conductors. They are used in temperature applications such as crucibles and ingot molds for precision metallurgy [1]. Coating with certain compounds is one way of improving the mechanical properties of materials. Therefore, the hardness of tungsten can be increased by coating techniques. One of the coating techniques is boronizing. Boronizing is a thermochemical diffusion surface treatment in which boron atoms diffuse into the surface of the work piece to form hard borides with the base materials [2–9]. Boronizing is a prominent choice for a wide range of tribological applications where the control of friction and wear is of primary concern. Boronizing, being a thermochemical diffusion treatment, can be applied to a wide range of steels including carbon steel, low-alloy steel, tool steel, and stainless steel. Boronizing of tungsten based materials such as WC-Co wire-drawing dies or carbide-cobalt hard alloy has been studied [10,11]. When cemented carbides (such as WC-Co wire-drawing dies) are commercially pack borided with a powder mixture containing 40% B_4C, 45% SiC, and 5% KBF_4, three distinct zones are found to be formed in the boride layer comprising the exterior, intermediate, and interior regions. In the exterior region, the mixture of CoB, W_2B_5, and WC or the mixture of CoB and WC are claimed to be found. In intermediate region, the mixture of W_2CoB_2, WCoB, and WC, or the mixture of Co_2B and WC, are observed. In the interior region, the mixture of $W_2Co_2B_6$, WC, and Co, or the mixture of Co_3B and WC, are formed [10]. The other study investigated the interaction of WC-Co hard alloy with powder B_4C and the product Borozar-HM. As a result of thermal treatment with Borozar-HM, the phase CoWB is formed in the diffusion layer, whereas in the case of B_4C, the boron-richer CoW_2B_2 and CoB

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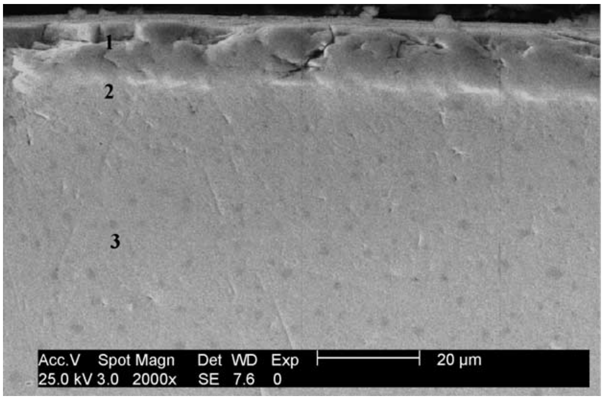

Fig. 1. SEM image of pure tungsten borided at 940 °C for 2 h, showing the boride layer (1), the transition layer (2), and the base metal (3).

phases prevail [11]. Although many studies have been done on the boronizing of tungsten-based alloy [10–14], to our knowledge, there is no sufficient study available on the boronizing of pure tungsten in the literature.

The present paper reports on a study performed at 940 °C for 2, 4, and 8 h for boronizing of pure tungsten in solid boron medium. The primary purpose of this study was to investigate the formation of boride on pure tungsten. The second purpose was to examine the mechanical properties of the boride formed on the surface of the pure tungsten.

2. Experimental procedure

2.1. Substrate materials

The substrate material used for this study was pure tungsten of 99.95 wt.% that had a cylindrical shape having 6.3-mm diameter and 5-mm height.

2.2. Boronizing

Boronizing was performed in a solid medium by using Ekabor powders that had grain sizes of less than 850 µm

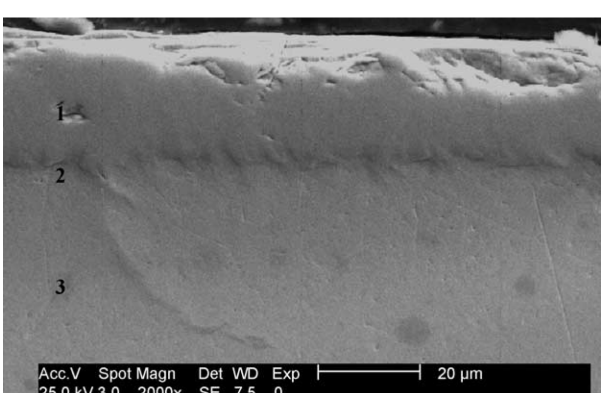

Fig. 2. SEM image of pure tungsten borided at 940 °C for 4 h, showing the boride layer (1), the transition layer, (2) and the base metal (3).

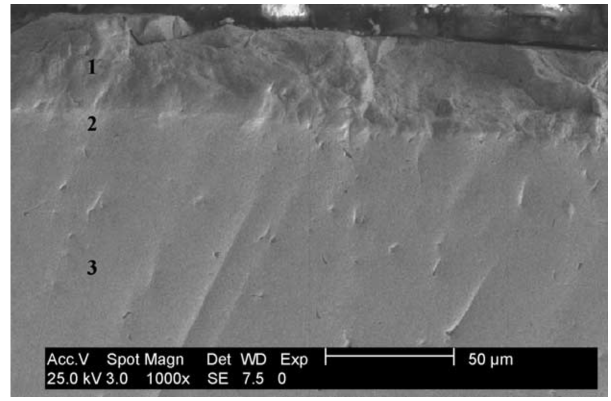

Fig. 3. SEM image of pure tungsten borided at 940 °C for 8 h, showing the boride layer (1), the transition layer (2), and the base metal (3).

and had a nominal chemical composition of 90% SiC, 5% B_4C, and 5% KBF_4. The test materials to be boronized were placed in contact with Ekabor powders and then transferred to an electrical resistance furnace in a stainless-steel crucible of 5-cm diameter and 8-cm height. The test materials were heated to a temperature of 940 °C under atmospheric pressure and held in the furnace for 2, 4, and 8 h. This procedure was followed by cooling in air.

2.3. Microstructure characterization

The morphology and types of boride formed on the surface of pure tungsten substrate were examined by conventional metallographic techniques. Rigaku X-ray diffractometer, with a Cu Kα radiation source of a wavelength of 1.504 Å, was employed for the characterization of the boride. Philips field emission scanning electron microscope (SEM) was used to study the morphology of the boride. In addition, an optical microscope was utilized to reveal the structure of borided test samples.

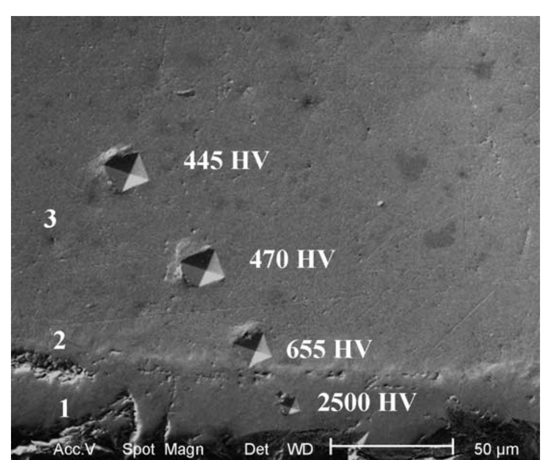

Fig. 4. SEM image of the pure tungsten borided at 940 °C for 8 h, showing the hardness indentation variation with distance from the outer layer to the interior layer.