TECHNICAL NOTE

Weld Defects in Electron-Beam Welds of Powder-Metallurgy Chromium Plate†

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KEY WORDS: (Chromium) (Electron-Beam Welding) (Weld Defects) (Solidification Cracking) (Cold Cracking) (Blow Hole)

Chromium metal has a strong possibility as an excellent heat-resistant materials because of its high melting point, high resistance to oxidation and corrosion. However, the serious drawback is its luck of ductility even near room temperature, which is also seen in molybdenum and tungsten metals.

To overcome this, many studies have been done until now[1–8]. Unfortunately the weldability of chromium metal has still unknown so far, because it was difficult to get a large size plate of chromium metal for welding.

Recently, it become more easy to get a large size chromium plate with comparably high purity as target materials for the sputtering coating in semi-conductor manufacturing field.

Therefore in this short note, by using pure chromium plate for target materials, a welding test has been tried for the first step to evaluate the weldability of chromium metal.

Chromium plate used is powder-metallurgy pure chromium (99.8% purity) and its dimension is 6 mm thick and 40 mm wide. As welding process, high vacuum electron-beam welding was utilized with a melt-run process to prevent the contaminations of oxygen and nitrogen from welding atmosphere and also to lower the deformation of specimen by welding heat cycle. Welding condition is 40 kV of accelerating voltage, 150 mA of beam current, 100 cm/min of travelling speed and 1.10 of ab value.

A general appearance of weld bead and its X-ray radiograph are shown in **Fig. 1(a)** and **(b)** respectively. Three types of weld defects are seen from these photos as a longitudinal cracking in weld-bead center, a transverse cracking occurred in weld metal and extending to base metal, and a blow hole in weld metal.

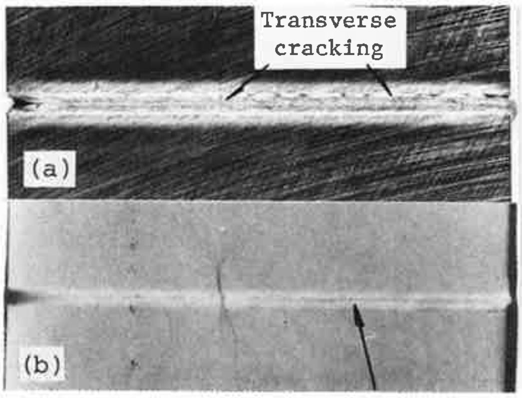

Fig. 1 (a) General appearance of weld bead and (b) its X-ray radiograph showing transverse and longitudinal crackings and blow hole.

Typical metallographical and fractographical features are as follows;

(1) Longitudinal cracking

Figure 2 shows a crosssectional photograph of weldment showing a longitudinal cracking which penetrated from top to back surfaces of weld bead. Its fracture surface observed by SEM is shown in **Fig. 3**. From these photos, it was divided into two types. One type occurred at middle part of penetration depth of weld bead in weld center at which columnar structures growing from each fusion boundary met each other. This type is considered to solidification cracking as shown in Fig. 3(c) showing typical dendritic pattern.

The other type is a transgranular cracking propagating across the coarse columnar structure at upper and lower

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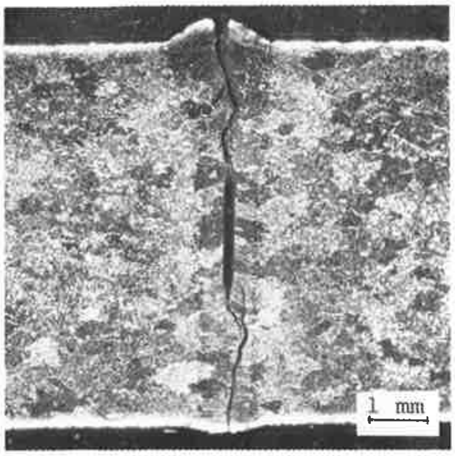

Fig. 2 Crosssectional macrostructure of weld bead of PM-Chromium

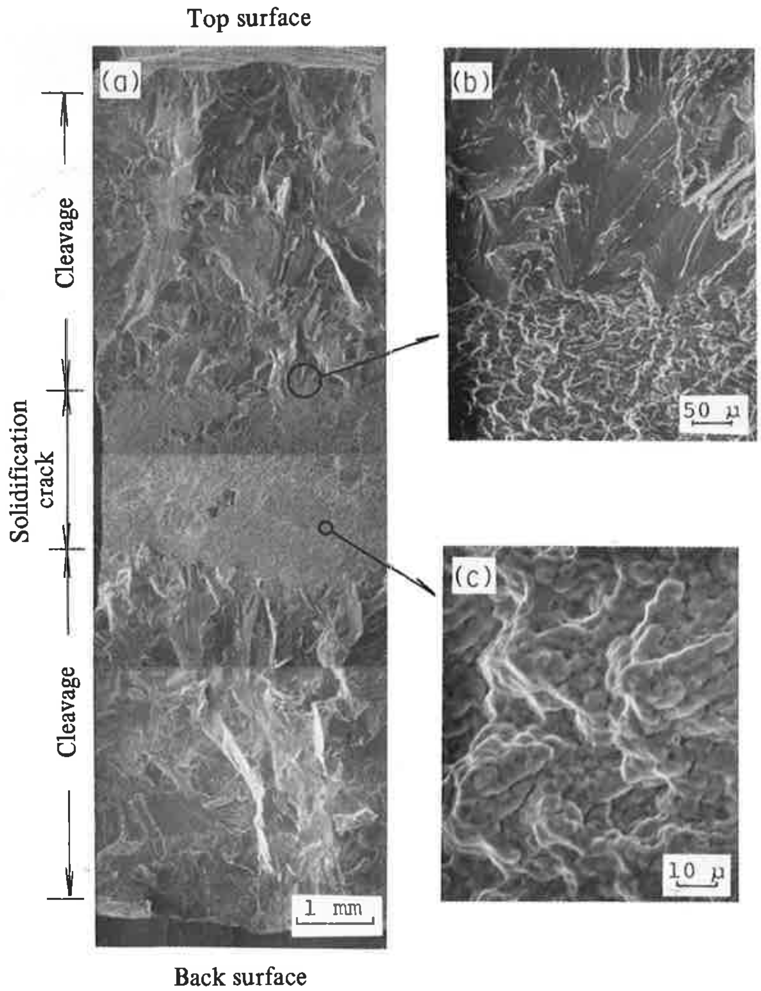

Fig. 3 (a) Fracture surface of longitudinal crack and its close-up photos showing (b) cleavage fracture and (c) solidification cracking

parts of weld bead and its fracture surface shows typical cleavage pattern. And its origin is solidification cracking judging from a river pattern as shown in Fig. 3(b). Therefore this type is considered to cold cracking occurred at a cooling stage of weld bead due to notch effect of pre-occurred solidification crack.

(2) Transverse cracking

Figure 4(a) shows a fracture surface of a transverse crack where welding direction is vertical to photo's face.

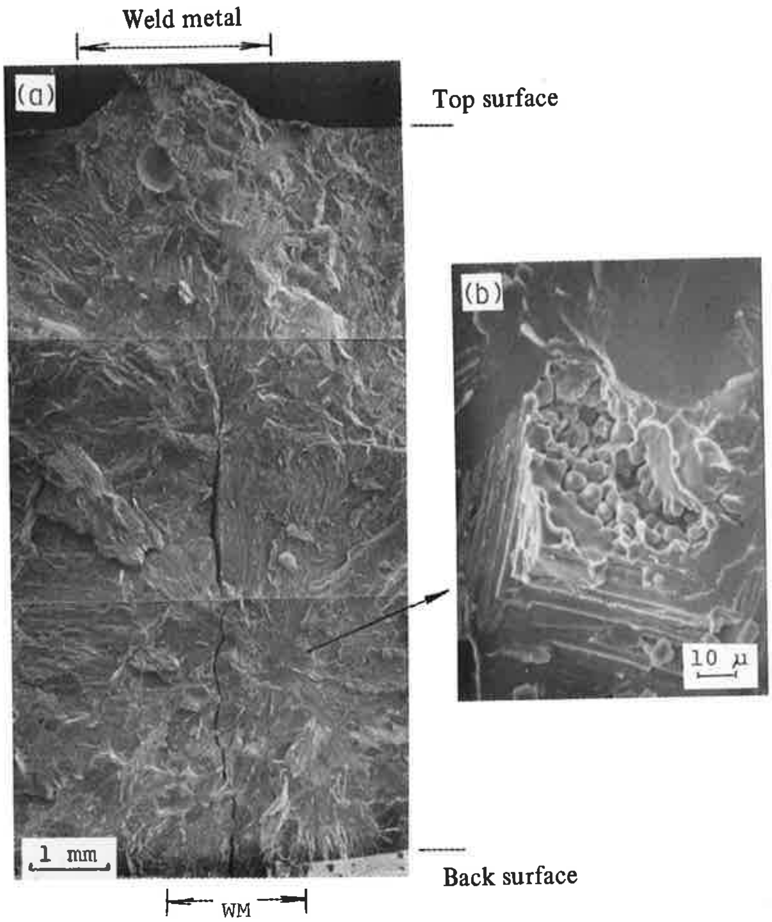

Fig. 4 (a) Fracture surface of transverse crack and (b) its fracture origin

Its fracture surface shows cleavage pattern at both weld metal and base metal. Therefore this type is also considered to cold cracking after the weldment was cooled to its brittle temperature. From a river pattern, its origin is also decided to be solidification crack or blow hole as shown in Fig. 4(b).

(3) Blow hole

There are some blow holes in weld metal as shown in Fig. 3(a) and 4(a) near weld bead surface, but those diameter were comparably small less than 0.15 mm. However, there were many microvoids less than 1 μ in diameter in grains of weld metal. **Figure 5** shows a typical blowhole surface observed on fracture surface.

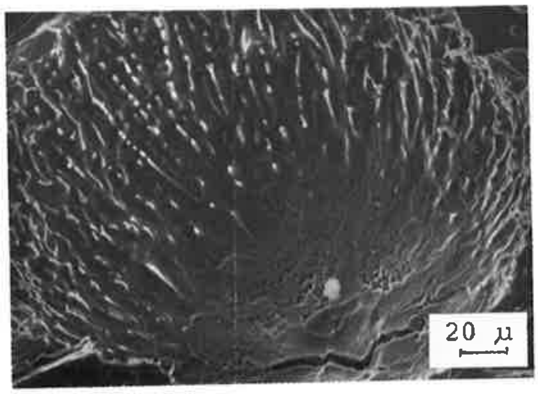

Fig. 5 Typical inner surface of blow hole

Among these weld defects, solidification cracking and blow holes were also frequently observed in electron-beam welds of powder-metallurgy molybdenum and tungsten[9–12], because of their high gasious content such as oxygen. With regards to cold cracking, its fracture origin was solidification cracking (or blow hole). Consequently, at first it is the most important to prevent the formation of solidification cracking and blow hole to get a defect-free weld bead. For this purpose, it is necessary to increase the purity of pure chromium metal and select more adequate welding condition. These subjects will be investigated further.

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