Effect of Yttrium on the Microstructure and Properties of Pt-Ir Electrical Contact Materials

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Abstract. The Pt-10Ir and Pt-10Ir-1Y were prepared by high frequency induction melting, then the samples were obtained by powder metallurgy, hot extrusion and drawing. The influence of Y addition on microstructure and electrical contact properties of Pt-10Ir alloy has been investigated by using optical microscopy, SEM, electronic balance and the contact material test system. The results show that the addition of Y leads to the micro-structural refinement and directional change of material transfer, but has almost no influence on erosion morphology.

1. Introduction

As compared with other electrical contact materials, Pt-Ir alloy features high hardness, high melting point, high corrosion resistance, low and stable contact resistance, making it a excellent electrical contact material. It is widely used in aircraft engine ignition contact, electrical contacts of high sensitive relay, micro-motor relay, and ship gravity pendulum relay, potentiometer and conducting ring of the heading device, the horizon and the gyroscope in the planes, the missiles and the ships and so on[1,2]. But because the precious metals are scarce resource, it should try to use other alloying elements substitution of Pt-Ir alloy. Doping rare earth element such as Y is an important approach to improve properties and reduce cost at the same time.

Studies have shown that the grain of Pt doped with Y is obviously refined [3,4]. Chen et al. [3,5] showed that Y concentrations of 0.23wt% and 0.5wt% remarkably increase Vickers hardness and tensile strength at room temperature, but reduce elongation rate. The Y doped in Pt can enhance high temperature strength[3,6]. Moreover, Xie et al. [7] investigated the electrical contact performance of Pt-25Ir alloy and found that the welding resistance, arc erosion resistance was obviously increased due

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to the adding of 0.5wt% Y. To the best of our knowledge, there is no report on the microstructure and the electrical contact performance of the Pt-10Ir alloy doped trace Y.

In this study, therefore, the Y was selected as the additional element in Pt-10Ir binary alloy for refined microstructure and reduced costs. The influence of Y on as-cast microstructure, arc erosion morphology and material transfer of Pt-10Ir was researched.

2. Experiments

The Pt-10Ir and Pt-10Ir-1Y alloys were prepared by high frequency induction melting with platinum (99.95%), iridium (99.95%) and yttrium (99.90%) under vacuumed condition. Cast samples, which were fabricated into a cylindrical rod-shape zirconia crucible, were solidified by air cooling. Microstructure analysis of the polished as-cast samples (finished with 0.5µmdiamond paste) was observed by optical microscopy (LEICA DM4000M, German). The electrical contact samples were obtained by annealing and cold drawn or rolling. Afterwards, they were assembled on the contact material test system (JINFENG JF04C, China) undergoing test (breaking DC arcs) under different conditions as listed in Table 1.

| Test voltage/ V | 24 |
|-----------------|----|
| Load current/ A | 15 |
| Contact gap/ mm | 1  |
| Contact force/ N| 0.2|
| Load type       | resistive load |

After finishing the predetermined number of operations, the morphology of arced spot with the tested contacts were observed by scanning electron microscopy (HITACHI S-3400N, Japan). The mass of materials was determined by electronic balance (METTLER TOLEDO AB135-S, Switzerland).

3. Result and Discussion

3.1 Microstructure

The microstructures of cast Pt-10Ir and Pt-10Ir-1Y contact materials were observed by optical microscopy, and the images are shown in figure 1(a)–(b).

![OM images of cast alloys: (a) Pt-10Ir alloy; (b) Pt-10Ir-1Y alloy.](image)

In figure 1, the microstructure of Pt-10Ir cast has significantly different grain size. There is seriously alloying elements segregation in some grain, which is characterized by cystiform-dendritic...
structure. The microstructure of Pt-10Ir-1Y is principally irregular cell crystal. By contrast, the cast microstructure became more uniform and more fine by addition of Y.

3.2 Material Transfer

Usually, the erosion of anode or cathode contacts is different because of the two contactor material’s different physical properties, or the different amount of the input arc energy and heat-flow density when the circuit turn on or turn off. For the dispersity of speed direction during material separating from contacts, one part of the erosion contact transfers to the surrounding space, one part of it deposits on the self surface, and another part of it transfers to the surface of the other contact, as shown in figure 2. If the looses and obtainment of the contact materials is off-balance, there would be increases or decreases of the contact weight.

Due to the limitations of existing analysis methods, the degree of contact erosion is often characterized by the variation of contact weight amount \( \Delta m \) after multiple operations. \( \Delta m > 0 \) means the net increase in contact material, otherwise weight reducing. The \( \Delta m \) calculated from measured results of Pt-10Ir and Pt-10Ir-1Y for cathode and anode are shown respectively in figure 3.

| Material transfer schematic[8]. |
|---------------------------------|

| Figure 2. |
|----------|

| Figure 3. Contacts weight changes after 10000 operations. |
|----------------------------------------------------------|

It can be observed from figure 3 that the material transfer of anode of Pt-10Ir is increases with increasing of the operations. The trend of cathode is the opposite of the anode, and the variation range of cathode is obviously larger than that of the cathode. Researchers have proved that the material
transfer direction is dependent on the arc duration in the metallic and gaseous phases\cite{9}. For Pt-10Ir, it means the gaseous phase arc duration plays a main part under the current experimental condition when cathode loss and anode gain take place. For Pt-10Ir-1Y, it shows that the expected cathode loss and anode gain is reversed with cathode gain and anode loss. This phenomenon indicates that the addition of Y changes the arc behavior of Pt-10Ir alloy. That is, the metallic phase arc is dominant leading to the anode gain.

3.3 Erosion Morphology

Arc energy transfers heat to the contact pairs, thus resulting in the surface damage of the contacts. The surface profiles on each sample surface measured with a scanning electron microscopy are shown in figure 4 and 5.

![Figure 4](image1)

**Figure 4.** The morphology of Pt-10Ir contact surface after 10000 operations (a) cathode (b) anode.

![Figure 5](image2)

**Figure 5.** The morphology of Pt-10Ir-Y1 contact surface after 10000 operations (a) cathode (b) anode.

Figure 4 shows the typical SEM photomicrographs of the eroded surfaces of the Pt-10Ir contacts. It is seen from figure 4(a) that the interior of the eroded cathode surface presents a reaction appearance where a large variety of small shallow spots are superimposed and interlaced one another. Only a very small area around the spot becomes molten due to concentrated Joule heating. Figure 4(a) shows the interior of the eroded anode surface which is characterized by molten pool and the splashing droplets around it. Since the anode molten pool is induced by electron bombardment due to the electric field, the
material heat up and melt, meanwhile, the molten droplets are splashed into strip-like metallic particles on the anode surface. Their results indicate that the arc is short-arc. It is found from figure 5 that the eroded surface of Pt-10Ir-Y1 is quite similar to figure 4. It means that arc of Pt-10Ir-Y1 is also short-arc under aforementioned conditions. The addition of Y (1wt%) does not significantly affect the arc type of Pt-10Ir.

4. Conclusions

1) By comparisons in microscopic structure, it was shown that the shape and distribution of the crystals are refined due to the doping of Y.
2) The transfer direction of Pt-10Ir whose arc behavior is dominated by gaseous phase arc is from the cathode to the anode. On the contrary, material transfer of Pt-10Ir-Y1 is from the anode to the cathode. This is due to the Y effects the arc behavior.
3) The arc erosion observed in this study is obviously caused by anode arcs. Y is not without significant influence upon the erosion morphology of Pt-10Ir.

5. References

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