TUNGSTEN ELECTRODES CONTAINING THREE TYPES OF RARE EARTH OXIDES①

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ABSTRACT Three types of tungsten electrodes containing three rare earth oxides, namely Y_2O_3, La_2O_3, and CeO_2 and one with Y_2O_3 and CeO_2 were prepared, in which the total contents of rare earth oxides are 2.2 % in mass, and the characteristics of these electrode materials were studied. By TIG welding, the welding characteristics including arc starting, arc static properties and electrode consumption of these electrodes were also analyzed. The results suggest that the electrodes added three rare earth oxides are more favorable for processing than that added two rare earth oxides. All the electrodes activated with two or more rare earth oxides are more superior to W-ThO_2 in operating, and the electrode combined with Y_2O_3 and CeO_2 shows the best properties when it is used at a heavy current for a long time. The analyses of the results of electrode consumption indicates that the rim forming during arcing is one of the important reasons for electrode's heavy erosion, and the increased Y_2O_3 content in electrodes is beneficial to retard the formation of rim, and leads to the improvement of consumption resistance of the electrodes.

Key words rare earth oxides tungsten electrode welding rim $Y_2O_3 + La_2O_3 + CeO_2$

1 INTRODUCTION

With increasing demands to the property of welding electrode and better knowledge of Th-W electrode material's radioactivity, some studies have been done on the replacement of rare earth oxides to ThO_2 in recent years. Tungsten materials added with single rare earth oxides, W-CeO_2, W-La_2O_3, and W-Y_2O_3 have already been developed[1-6]. The research[7] shows that they have their respective characteristics according to the type of rare earth oxide added. Although some of their properties are better than those of ThO_2-W electrode, they still have a few defects in their working and processing properties. That is why single rare earth tungsten materials can not replace W-ThO_2 materials on a large scale. In our recent researches[8-11], we carried out the studies on the processing and working properties of rare earth tungsten materials co-added with CeO_2, La_2O_3, and Y_2O_3. The results show that the rare earth tungsten materials added with two combined additives have superior hot emission ability and longer time operating stability over those rare earth tungsten materials added with single rare earth oxide additives. Especially, those electrodes which have lower CeO_2 but higher Y_2O_3 contents exhibit the best operating characteristics. Because of their higher Y_2O_3 content however, which results in forming second phase particles resisting materials deformation, they are relatively difficult for processing. In order to improve the processing properties of co-added rare earth tungsten materials and secure their operating characteristics at the same time, the processing and operating properties of the rare earth tungsten materials activated with three rare earth oxides are compared.

2 MATERIALS PREPARATION AND PROCESSING PROPERTY

2.1 Materials preparation method

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Firstly, the combined rare earth nitrate solution and WO_3 powder were mixed. Then after drying, the combined W-Rare earth oxides powder was attained. Through a series of processing activities such as doping, pressing, pre-sintering, sintering, swaging, and chain wire drawing, several types of co-activated rare earth tungsten electrodes were finally achieved, whose diameters are 1.0, 1.6, 2.0, 2.4 and 3.2 mm respectively. Their chemical compositions are shown in Table 1. The Th-W electrode is purchased as a reference electrode.

Table 1 Chemical compositions of test electrodes(%)

Electrode No.	Oxides		
	La_2O_3	Y_2O_3	CeO_2
981	0.6 ~ 0.8	0.6 ~ 0.8	0.6 ~ 0.8
982	0.3 ~ 0.5	1.2 ~ 1.4	0.3 ~ 0.5
983	0.8 ~ 1.0	0.8 ~ 1.0	0.3 ~ 0.5
12	0	1.5 ~ 1.7	0.5 ~ 0.7
Th-W	2.0 % ThO_2 (Compared specimens)		

2.2 Processing property

Though the analyses of powder reduction, raw rod sintering and rod processing, added with three combined rare earth oxides are shaped more easily. Also, their forming working temperatures can be lower than that of the tungsten electrodes added with two combined rare earth oxides and their particle size does not vary significantly with their compositions after powder reduction. According to our previous research, the order of rare earth oxides' ability to increase processing difficulty was Y_2O_3, La_2O_3, and CeO_2, from heavy to slight. The processing property of three co-activated rare earth tungsten materials, due to the comprehensive role of the three types of rare earth oxides, is obviously better than that of the two co-activated rare earth tungsten materials.

3 OPERATING PROPERTY

3.1 Experimental methods

The arc starting property, voltage-current relationships and consumption characteristics were tested and compared. Direct current electrode negative, high frequency spark, electrode diameter 3.2 mm, cooper water-cooled anode, electrode tip angle 45°, arc gap 3 mm, electrode stick-out length 6 mm were used throughout all experiments. The power system comprises ZS500 SCR welding power supply, GNP-300 welding controller and TSIA100/0.5 adapter.

3.2 Arc starting characteristics

According to the voltage of preliminary arc ignition, we tested every electrode 30 times per voltage value and increased the voltage value at a step of 1 V. The test criteria are: arc ignition within 1 s is considered successful, starting arc within 10 s but out of 1 s is considered retarded success, and not being able to start arc until 10 s is considered failure. The testing results are shown in Fig.1. It is shown that the arc starting characteristics of co-activated electrodes is better than that of the ThO_2-W electrode. There are no significant differences among No.982, 983 and 12 electrodes, whose characteristic are better than that of No.981 and ThO_2-W electrodes. No.982 electrode is the best among the three.

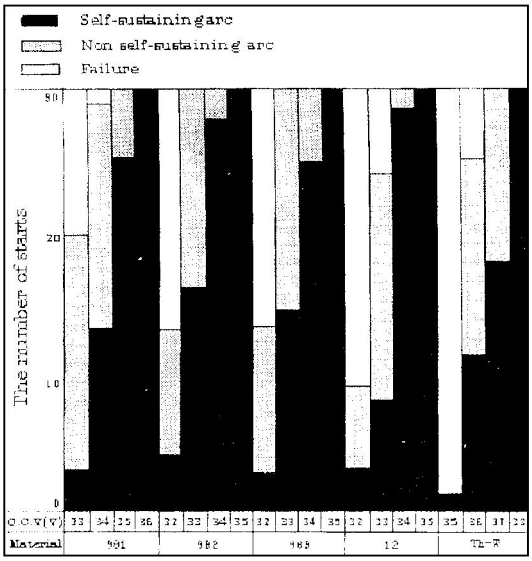

Fig.1 Arc-starting characteristics evaluated by open circuit voltage tests

3.3 Are static characteristics

While the arc current value is 40, 60, 80, 100, 120, 140, 160, 180, and 200 A, the corresponding arc voltages are measured and the voltage-current relationship curves are drawn in Fig.2.

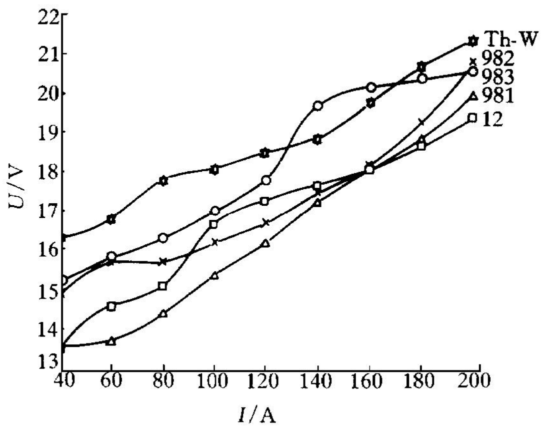

Fig.2 Voltage-current relationships for various electrodes

It can be seen from Fig.2 that the arc voltage of co-activated electrodes is lower than that of the ThO_2-W electrode (except a few points of No.983 electrode), which indicates that the hot emission ability of co-activated rare earth tungsten electrode is better than that of ThO_2-W electrode. It can also be seen from Fig.2 that, while the welding current is medium or small, the arc voltage values of No.981, 982 and 12 electrode are of no significant differences; while the welding current is below 160 A, the curve of No.981 is the lowest of all, which indicates its superior hot emission ability; while the current value is above 160 A, No.12 electrode shows the best hot emission ability and arc stability. Hence, increasing Y_2O_3 content is one of the effective ways to improve the electrode arc stability in the case of heavy currents and long time operation.

3.4 Electrode consumption property

The five electrodes were tested under the condition of DC 240 A, arcing time 20 min and Argon flow rate 10 L/min. By using DP-100 optical analytical balance, the mass decreases after arcing was measured and the results are shown in Table 2.

Table 2 Electrode consumption

Electrode No.	Before loading/g	After loading/g	Mass lose/mg
981	10.4300	10.4250	5.0
982	10.3802	10.3763	3.9
983	8.7902	8.7717	18.5
12	10.2648	10.2636	1.2
Th-W	12.0872	12.0680	19.2

It can be seen from Table 2 that ThO_2-W electrode has the worst consumption property, No.981, 982, and 12 electrodes have good consumption resistance while No.12 electrode is the best among the three. Electrodes' microstructures are shown in Fig.3. We believe that the rim formation at the tip of electrode during arcing (as shown in part "*A*") is one of the important factors that result in serious electrode corrosion.

It can be seen from Fig.3 that there is a big rim at the tip of No.983 electrode, which exhibits the microstructure of dendrite. But this phenomenon is not observed in the case of No.12 electrode. Some researches[11,12] indicate that, at an appropriate area on the surface of electrode tip, the rim is formed due to a series of processes including melting, evaporating, oxidation decomposition and deposition of tungsten. The rim formation reflects the electrodes' working temperature, the higher the temperature, the greater the rate of tungsten evaporation and oxidation, the easier the rim formation. The rim formation limits the self-regulation function of welding arc, which leads to over-heating and serious corrosion of electrode tip. At the same time, the electrodes without rim do not produce over-heating and thus, their corrosion is less severe.

Some researches[1,8-10] show that the electrode working characteristics depend on the relationship between the migration rate and evaporation rate of rare earth oxide on the surface of the electrode. The rare earth oxide's long time existence on the electrode surface can efficiently low-

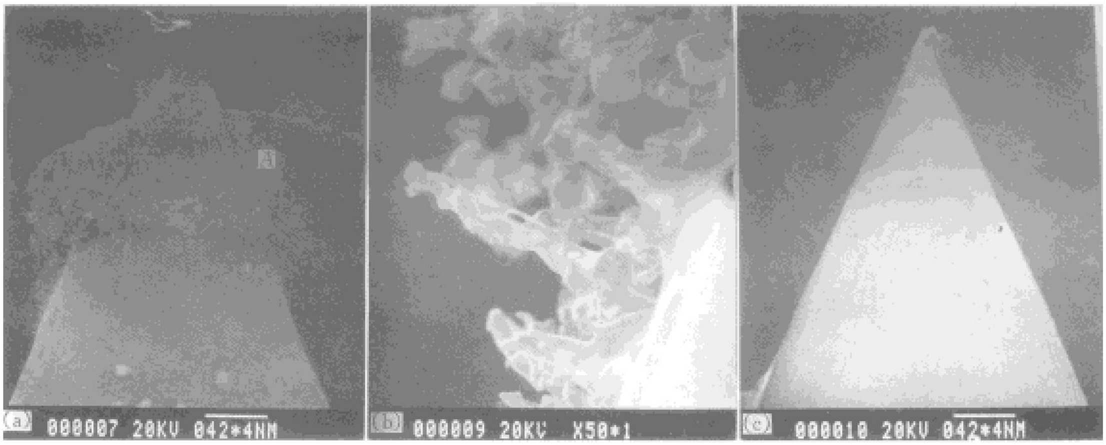

Fig.3 Appearance of an electrode tip after heavy loading
(a) —No.983 electrode; (b) —Part "A" in (a); (c) —No.12 electrode

er the electrode's work function, improve the electrode's hot emission ability and decrease the electrode working temperature, which can resist the rim formation and relieve the electrode corrosion. It can be concluded from the results and analyses of the experiments above that Y_2O_3 in large amounts in the electrode can decrease the corrosion, which can lead to great improvement for welding arc stability and heavy load and long time corrosion resistance.

4 CONCLUSIONS

(1) The processing properties of the rare earth tungsten electrode materials activated with three rare earth oxides are better than that of the rare earth tungsten electrode materials activated with two rare earth oxides.

(2) While the welding current is medium or small, the three-co-activated electrodes with lower Y_2O_3 content have superior hot emission ability and arc stability. While the welding current is heavy, Y_2O_3 can improve the electrode corrosion resistance.

(3) The rim formation during arcing is one of the important factors leading to serious electrode corrosion. High contents of Y_2O_3 can retard the rim formation effectively and thus, improve the electrode corrosion resistance.

(4) No.982 electrode is better than No.12 electrode in terms of comprehensive properties.

REFERENCES

1 Sadek A A, Ushio M and Matsuda F. Metallurgical Transactions A, 1990, 21A(12): 3221.
2 Ushio M, Sadek A A and Matsuda F. Plasma Chemistry and Plasma Processing, 1991, 11(1): 81.
3 Matsuda F, Ushio M and Hasegawa K. EP0651065, 1993.
4 Matsuda F, Ushio M and Hasegawa K. EP0651066, 1993.
5 Yang Yang, Zhou Meiling and Li Hanguan. J of Central-South Institute of Mining and Metallurgy, (in Chinese), 1993, 24(1): 69.
6 Nie Zuoren, Zhou Meiling, Zhang Jiuxing *et al*. Materials Review, (in Chinese), 1997, 11(5): 19.
7 Nie Zuoren, Zhou Meiling, Zhang Jiuxing *et al*. J of Beijing Polytechnic University, (in Chinese), 1998, 24(2): 28.
8 Nie Zuoren, Zhou Meiling, Zhang Jiuxing *et al*. Rare Metal Materials and Engineering, (in Chinese), 1998, 10.
9 Chen Ying, Nie Zuoren, Zhou Meiling *et al*. Rare Metal Materials and Engineering, (in Chinese), 1998, 10.
10 Zhou Meiling, Nie Zuoren, Chen Ying *et al*. Rare Metal Materials and Engineering, (in Chinese), 1998, 10.
11 Matsuda F, Ushio M, Fujii H *et al*. Journal of the Japan Welding Society, 1988, 6(2): 9.
12 Fan Xiaowu, Nie Zuoren, Chen Ying *et al*. Rare Metal Materials and Engineering, (in Chinese), 1998, 10.

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