Electrode Performance of “Neodymium Oxide-containing Tungsten” in Argon Gas Atmosphere

Ar ガス雰囲気下における ”Nd-W” の電極性能

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Abstract

The performance and the erosion mechanism of neodymium-oxide containing tungsten were performed for the development of an alternative material of thorium oxide-containing tungsten that has been used as a cathode of a plasma torch and so on. Under an argon atmosphere, the neodymium oxide-containing tungsten as a cathode of DC arc provides lower erosion rate than the thorium oxide-containing tungsten of the conventional cathode material. Lower erosion rate is attributed to lower surface temperature of the cathode which was measured by the high-speed camera with bandpass filters. Lower melting point of neodymium oxide than that of thorium oxide leads to lower surface temperature of the cathode. Experimental results show that neodymium oxide-containing tungsten can be used as an alternative to thorium oxide-containing tungsten.

プラズマトーチなどの陰極電極として使用されている、酸化トリウム入りタングステンの代替材として、開発された酸化ネオジウム入りタングステンについて、直流アーク用の陰極電極として使用し、代替材として性能評

価及び、消耗のメカニズム解析を行った。
アルゴン雰囲気下では、直流アーク用の陰極電極として酸化ネオジウム入りタングステンを使用した場合、従来材の酸化トリウム入りタングステンよりも低い消耗挙動を示した。
バンドパスフィルタを用いた高速度カメラによる電極表面温度の測定により、消耗量が低くなる原因は、電極の表面温度の低下によるものと推測され、電極温度を低下させている要因は、酸化ネオジウムの融点が、酸化トリウムよりも低いためと考えられる。
実験の結果より、酸化ネオジウム入りタングステンは、酸化トリウムタングステンの代替材となりうることが分かった。

1. Introduction

In large industrial applications, strong demands are required on materials to improve production capacity and efficiency. Improvement of damage and loss of function of a component, surface modifications or coating technologies are often applied [1]. Plasma spraying is one of several methods of coating. Plasma spraying involves generating a plasma jet using a plasma spray gun with a tungsten cathode. The coating material, such as metal or ceramic, is heated to close to melting, accelerated in the plasma jet, and sprayed onto the base material. Thorium oxide-containing tungsten is generally used for the cathode electrode. However, thorium is radioactive; therefore, a material that does not contain thorium and has better erosion resistance than thorium-containing tungsten is required [2].

In the present study, we used neodymium oxide-containing tungsten as an slternative for thorium oxide-containing tungsten. Neodymium oxide-containing tungsten contains no radioactive substances, and can be used in plasma torches as the cathode for the DC arc. We evaluated the performance and erosion mechanisms by measuring the surface temperature of the electrode. We used a bandpass filter (BPF) optical system that transmits only specific wavelengths.

2. Experimental

In this study, we used a DC arc generator in the laboratory of Kyushu University. The DC arc generator used in the experiment is shown in Fig.1.

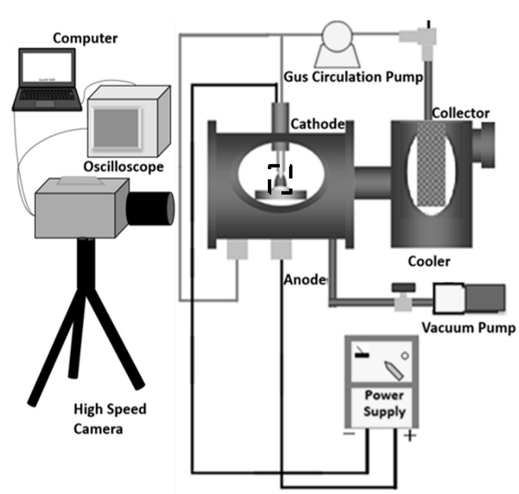

Fig. 1 DC arc generator

The cathode electrodes tested were all diameter 6 mm, processed to a tip angle of 60°. Four materials were used: tungsten, neodymium oxide-containing tungsten, thorium oxide-containing tungsten, and lanthanum oxide-containing tungsten. A metal mass of molybdenum was used for the anode electrode, and an arc was generated between the cathode electrodes under an argon atmosphere, at a current of 100 A. The distance between the electrodes was 10 mm and the flow rate of the shielding gas was 10 L/mm.

A broad spectrum of thermal radiation wavelengths is emitted from the electrode. Therefore, we combined a high-speed camera and an appropriate BPF optical system and observed only specific wavelengths (Fig. 2).

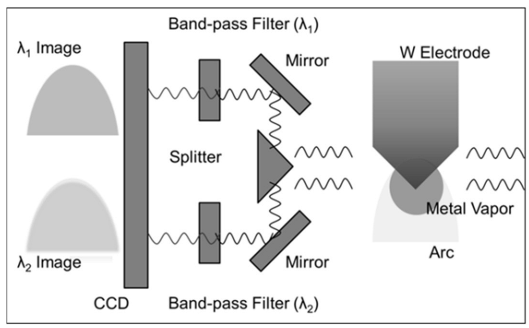

Fig. 2 Conceptual diagram of an optical system having a bandpass filter (BPF)

To measure the temperature of the cathode, the BPF wavelengths used were 785 ± 2.5 nm and 880 ± 5.0 nm. These observe only the heat radiation from the cathode without the interference from other emissions in the plasma gas. Based on the obtained relative intensity of the two wavelengths, the cathode surface temperature was calculated based on the two-color radiation temperature measurement method. Tungsten wear was calculated by measuring the cathode weight before and after the experiment.

3. Results and Discussion

3.1. Comparison of cathode electrode wear in argon atmosphere

The results showing cathode electrode wear in an argon atmosphere are shown in Fig. 3. When pure tungsten was used as a cathode electrode, wear tended to be about 10 times larger than in the oxide-containing Tungsten. This is because the work function of pure tungsten is 4.5 eV, but the work function of oxide-containing tungsten is lower than that of pure tungsten (Table 1).

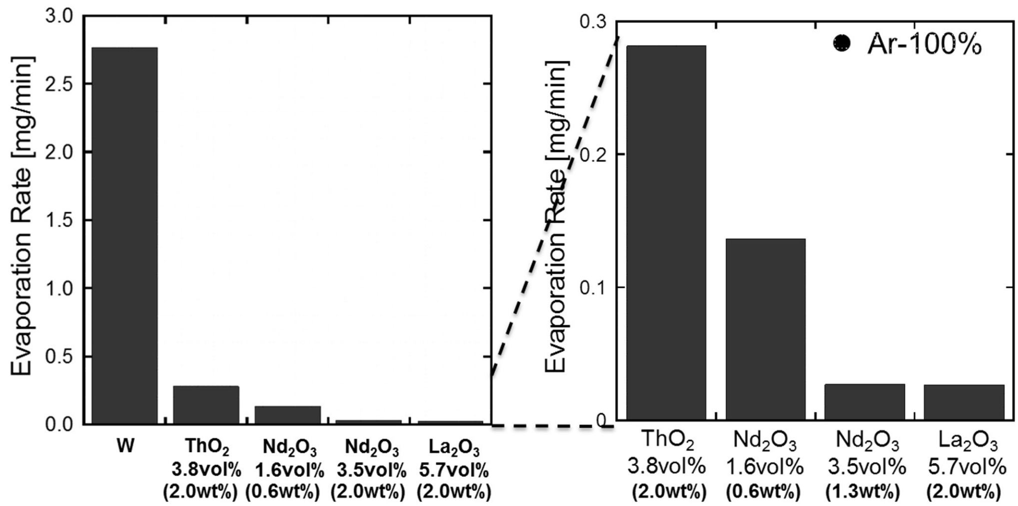

Fig. 3 Comparison of wear by cathode material

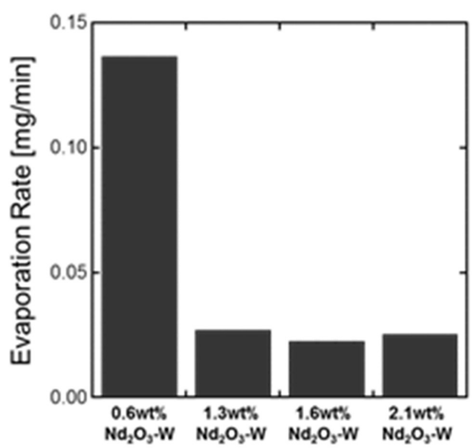

Fig. 4 Comparison of wear by oxide addition

Table 1 Work functions and melting points

電極種	Φ (eV)	M.P.(K)
W	4.5	3695
ThO_2	2.7	3323
Nd_2O_3	2.3−3.3	2506
La_2O_3	3.1	2490

Results showing wear of neodymium oxide-containing tungsten electrode for different addition amounts is shown in Fig. 4. As a result of changing the neodymium oxide content to 0.6, 1.3, 1.6, or 2.0 wt%, it was found that the wear amount increases at 0.6 wt%, and becomes constant at 1.3 wt% or more. When the amount of the additive added is 1.3 wt% or less, the performance is near to that of pure tungsten.

3.2. Analysis of cathode electrode surface temperature

The electrode surface temperature of thorium oxide-containing tungsten (2.0 wt%) and neodymium oxide-containing tungsten (0.6 wt%) in arc discharge was measured using a high speed camera and two kinds of BPFs of 785 ± 2.5 nm and 880 ± 5.0 nm (Fig. 5).

Neodymium oxide-containing tungsten generated a wider arc area than thorium oxide-containing tungsten. This is likely because the liquid film area of the additive covering the electrode surface is widened and the current density is lowered.

The variations of electrode surface temperature with current for each amount of oxide added are shown in Fig 6. The cathode electrodes surface temperature decreased as the amount of oxide added increased, and as the current decreased. Cathode electrode surface temperatures for neodymium oxide-containing tungsten electrode surface temperature were lower than those for thorium oxide-containing tungsten. This difference is caused by the liquid area covering the surface widening, because the melting point of neodymium oxide is lower than that of thorium oxide.

From this result, it is considered that the wear amount of neodymium oxide-containing tungsten was smaller than that of thorium oxide-containing tungsten because the surface temperature of the electrode was decreased by neodymium oxide.

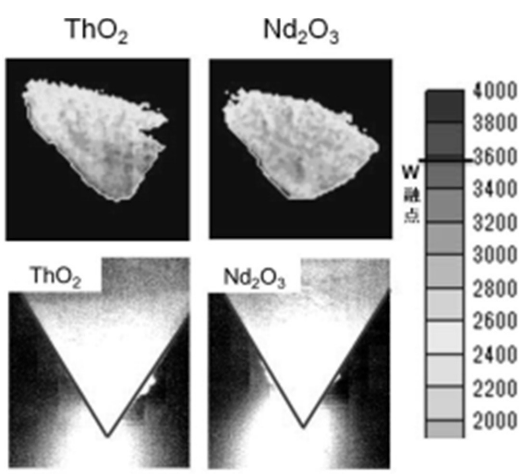

Fig. 5 Electrode surface temperature analysis results

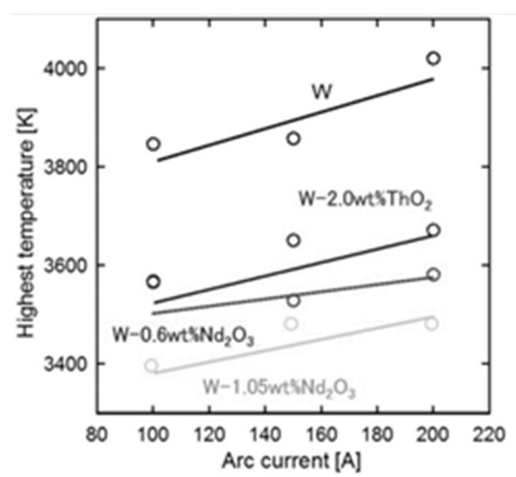

Fig. 6 Surface temperature of electrode by current value and additive amount

4. Conclusion

Under an argon atmosphere, neodymium oxide-containing tungsten used as a cathode for the DC arc showed lower erosion rate than the conventional thorium oxide-containing tungsten. The erosion rate is reduced by adding oxide, up to approximately 1.3 wt%, beyond which no substantial improvement was found. The erosion rate decreases because the surface temperature of cathode is lowered. This is because the melting point of neodymium oxide is lower than that of thorium oxide. Experimental results show that neodymium oxide-containing tungsten is an effective alternative to thorium oxide-containing tungsten.

References

[1] M. Heißl*, C. Mitterer*, T. Granzer**, J. Schröder**, M. Kathrein*** ”Substitution of Thoria Additions by Lanthanum-Oxide Doping in Electrodes for Atmospheric Plasma Spraying” 18th Plansee Seminar 2013

[2] K.fujii T.Watanabe ”Development of plasma electrode material forobtaining high durability”Plasma material sciences 153 committee,October 21,2015

[3] N.Sakura,T.kondo,M.Taanaka,T,Watanabe,Kyusyu,Univ. ”Visualization of metal vapor evaporated from tungsten-based cathode in DC arc by high-speed camerar ”