Design of Nitrogen DC Arc for Industrial Production of Nano-Powders

Masayuki Maekawa, Shen Zhengtong, Manabu Tanaka and Takayuki Watanabe
Faculty of Engineering, Department of Chemical Engineering, Kyusyu University
maekawa.masayuki.934@s.kyushu-u.ac.jp

Functional nano-powders synthesis by DC arc system have been developing. One of hinder for the development of mass production of nano-powders by DC arc is a cathode lifetime. Cathode property is greatly affected by a doping rare earth oxide. The effect of different rare earth oxides doped in tungsten-based cathodes on arc temperature distribution was investigated.

The electrode surface temperatures were measured successfully by combination of line and continuum emissions with two-color pyrometry. The effect of melting point of doped oxide, and the work function of doped oxide on current density led to the difference arc temperature between cathodes dope with different kinds of rare earth oxide.

Figure 1 presents the schematic illustration of an experimental apparatus of DC arc system which consists of a power supply, an arc chamber, a particle collector, a gas circulator and a system for observing emissions from the DC arc. Tungsten-based cathodes doped with rare earth oxides of Ce_2O_3, ThO_2, La_2O_3, and Y_2O_3 with concentration of 2-5wt% were used and compared. The cathode diameter was 6 mm. The electrode gap distance was fixed at 10 mm. Arc currents ranged from 100 A to 200 A.

Figure 2 shows the arc temperature distribution maps of W-2wt%Ce_2O_3, W-2wt%La_2O_3, W-2wt%Y_2O_3, and W-2wt%ThO_2 cathodes in N_2 50vol%-Ar atmosphere with current of 200A. Figure 3 shows the arc temperature distributions of W-2wt%Ce_2O_3, W-2wt%La_2O_3, W-2wt%Y_2O_3, and W-2wt%ThO_2 cathodes different cathodes in axial direction in N_2 50vol%-Ar atmosphere with current of 200 A. The cathode of W-2wt%Y_2O_3 has the highest arc center temperature. The W-2wt%ThO_2 cathode has a higher arc center temperature than those of W-2wt%Ce_2O_3 and W-2wt%La_2O_3 cathodes. This is because the cathode tip temperature (3,000 - 4,500 K) can reach the melting point of the rare earth metal oxide after arc ignition for rare earth oxide doped W-based cathodes [1]. The melted rare earth oxide then diffuses along the tungsten grain boundaries from cathode inside to the cathode tip surface due to the temperature gradients. Cathode tip surface is covered by melted rare earth oxide. Therefore, the low work function of rare earth oxide results in the low effective work function of cathode.

The current density with the W-2wt%Y_2O_3 cathode was highest due to the lowest work function of Y_2O_3 (2.0 eV) than those of ThO_2 (2.6 eV), Ce_2O_3 (3.2 eV), and La_2O_3 (3.1 eV) based on the Richardson-Dushman equation. Hence, the arc with W-2wt%Y_2O_3 cathode had the highest arc center temperature. Small area of melted layer of ThO_2 at covered W surface causes by higher melting point of ThO_2 (3,323 K) than those of Ce_2O_3 (2,523 K) and La_2O_3 (2,577 K). Constricted current attachment at the cathode tip leads to the higher arc center temperature (20000 K) and steeper temperature gradient of W-2wt%ThO_2 than W-2wt% Ce_2O_3 and W-2wt% La_2O_3.

The effect of melting point of doped oxide, and the work function of doped oxide on current density led to the difference arc temperature between cathodes dope with different kinds of rare earth oxide.

The arc temperature controllability is helpful to the development for the mass production of nano-powders.

References
[1] Sakura N., et al., Jpn. J. Appl. Phys. 59, 116001 (2020)

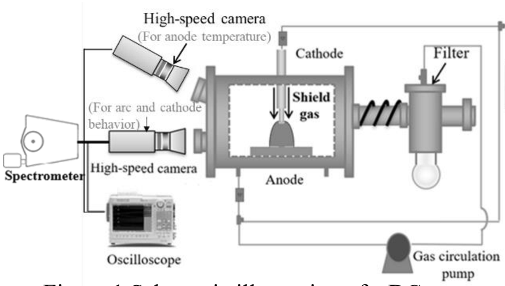

Figure 1 Schematic illustration of a DC arc system.

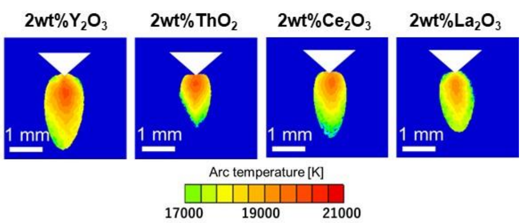

Figure 2. Arc temperature distribution maps in N_2 50vol%-Ar arc.

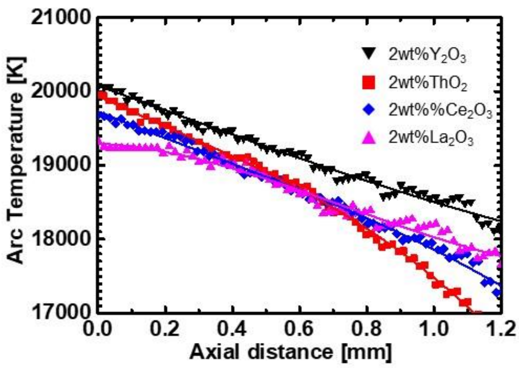

Figure 3. Arc temperature distributions in axial direction.