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Effect of Anode Jet on Nanoparticle Production by Ar-H_2 Arc

アルゴン-水素アークによる金属ナノ粒子生成におけるアノードジェットの影響

Tasuku Shimizu, Liang Feng, Manabu Tanaka, and Takayuki Watanabe

清水　佑, 梁　風, 田中　学, 渡辺隆行

Department of Environmental Chemistry and Engineering, Tokyo Institute of Technology
4259 G1-22, Nagatsuta, Yokohama, Kanagawa 226-8502, Japan
東京工業大学大学院総合理工学研究科　〒226-8502　横浜市緑区長津田町4259番地G1-22

Anode jet is plasma flow, which occurs from raw material on anode under certain special conditions. The anode jet is important phenomenon because it is one of factors which enhance metal evaporation for preparing metal nanoparticle in hydrogen plasma metal reaction. The parameters involved with anode jet are arc current, hydrogen concentration, shield gas flow rate and so on. The anode jet's features were observed by high speed camera and emission spectroscopy to investigate this phenomenon effect on enhancement of metal evaporation.

1. Introduction

Thermal plasma can prepare nanoparticles with high productivity, because it has high temperature, rapid quenching rate and high reactivity by radicals. Ohno and Uda developed hydrogen plasma metal reaction (HPMR) for the purpose of nanoparticle synthesis by using DC arc [1]. Metal evaporation rate is increased by adding hydrogen gas in argon gas. Dissociated hydrogen in arc plasmas dissolves into molten metal and enhances the vaporization of metal when the hydrogen atoms are emitted from the molten metals. However, this explanation is not enough because the particular metal's evaporation is enhanced selectively when metal mixture is used [2].

The anode jet is the plasma flow, which occurs from raw material of anode, while the plasma stream from cathode is the cathode jet. We found the anode jet by HPMR when nickel was used as raw material. The operating parameters involved with anode jet are arc current, hydrogen concentration, shield gas flow rate, anode material and so on [3].

The objective of this study is to investigate the relationship between hydride formation and selective metal evaporation, and the effect of anode jet on the enhancement of metal evaporation in nanoparticle synthesis.

2. Experimental

2.1 Experimental setup

Figure 1 shows a schematic illustration of experimental setup for nanoparticle production. The setup consists of a power supply, an arc chamber, a particle collector, and a gas circulation pump. 50 g nickel ingot as raw material was placed on the water-cooled copper anode. Ar and Ar-H_2 arc was

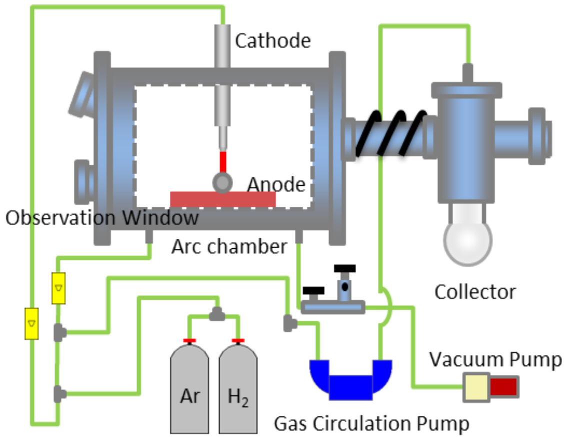

Fig.1. Schematic of the experimental setup.

used for the evaporation of the raw material. Typical operating conditions are as follows: current: 50-200 A, voltage: 20-40 V, total pressure: 101 kPa, shield gas flow rate: 0-40 Nl/min, H_2 concentration: 0, 30, 50vol%.

2.2 Plasma analysis

The behavior of anode jet was observed by high speed camera (Photron, SA WTI). The vaporized species from the molten metal were identified by spectroscopic diagnostics with a spectrometer (Horiba Jobin Yvon, iHR-550) and a CCD detector (Horiba Jobin Yvon, Synergy). The weight difference of the raw material was measured after treatment to estimate the evaporation rate of the raw material.

3. Results and Discussion

The behavior of anode jet was observed in HPMR over 30% hydrogen with nickel substrate. Fig.2 shows arc images for different plasma gas conditions by high-speed camera.

In order to analysis the size of anode jet, 5,000 images which correspond to 500 ms are superposed.

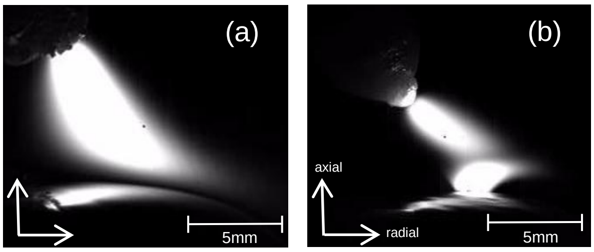

Fig.2. High-speed camera images of (a) 100%-Ar arc (b) 30%-H_2 arc.

It is enough to estimate time-averaged anode jet area because the arc fluctuation frequency was 100 Hz (10ms).

The quantitative anode jet area was evaluated from these superposed images. The size of anode jet is changed according to shield gas flow rates in 30%-H_2 arc. Effect of shield gas flow rate on anode jet area is shown in Fig.3. The anode jet area decreases with increasing shield gas flow rate until 10 Nl/min. Because the cathode jet flow is enhanced with increasing the shield gas flow by thermal pinch effect. In contrast, the anode jet area increases with increasing shield gas flow rate higher

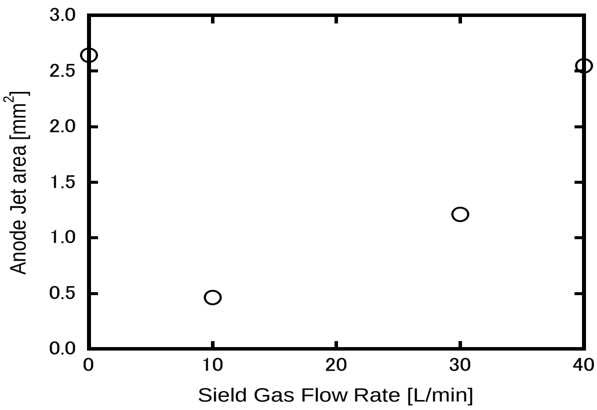

Fig.3. Effect of shield gas flow rate on anode jet area.

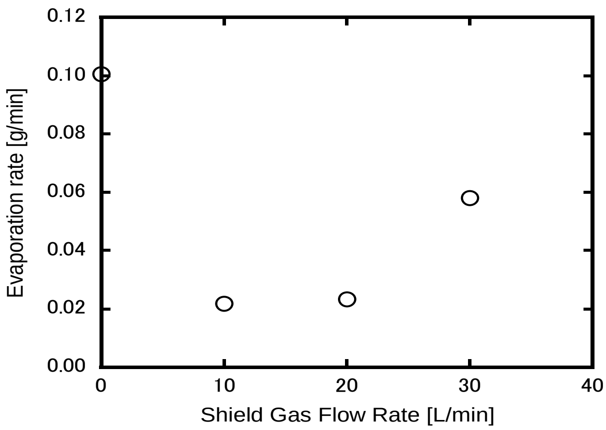

Fig.4. Effect of shield gas flow rate on evaporation rate.

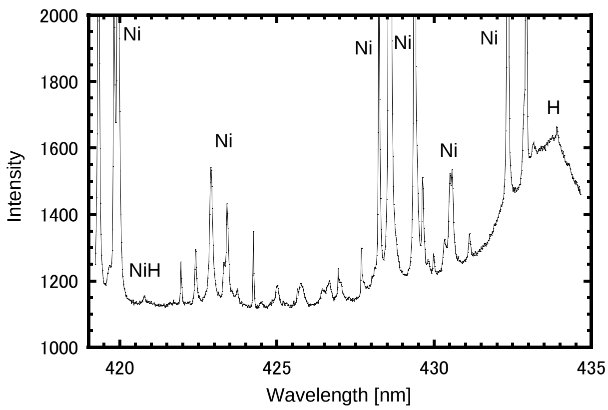

Fig.5. Emission spectrum of Ar-H_2 arc.

than 10 Nl/min. This is because the anode spot shift which leads to longer arc length. Consequently the anode jet flow became stronger due to smaller momentum of cathode jet in axial direction.

The effect of shield gas flow rate on evaporation rate of nickel is presented in Fig.4. The evaporation rate has the same tendency with the anode jet area. This result indicates that the evaporation rate is significantly affected by the anode jet. The anode jet can improve metal nanoparticles generation.

The spectroscopic measurements of the vaporized species in anode jet region were carried out to investigate the evaporation behavior. Fig.5 shows the atomic emission of nickel in 30%-H_2 arc. The nickel hydride peak was observed at 420.7 nm, which is observed only in anode jet region. It is necessary to understand the effect of the anode jet on the enhancements of hydride formation and metal evaporation in future.

4. Conclusions

The effect of shield gas flow rate on the anode jet phenomenon was investigated. The anode jet behavior is influenced by momentum of cathode jet in axial direction. Moreover the nickel hydride peak was observed in anode jet region by spectroscopy. The reason for enhancement evaporation in HPMR may be related to the formation of metal hydride. At last, controlling anode jet phenomenon is the best way to improve nanoparticle generation.

References

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