Temperature and Density Measurements of Lithium Vapor of Nanoparticle Precursors in Multiphase AC Arc

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Abstract: Multiphase AC arc (MPA) as an attractive thermal plasma system is a powerful tool for nanoparticle synthesis with high productivity due to its advantages of high energy efficiency, large plasma volume and long processing time. Temperature and density fields of metal vapors as nanoparticle precursors are important for controlling product properties. These field measurements using lithium self-absorption have been developed in this study.

1. Introduction

Lithium oxide composite nanoparticles have been investigated as cathode materials for lithium-ion batteries. The synthesis of nanoparticles by thermal plasma has attracted attention. Lithium oxide composite nanoparticles by RF thermal plasma have been reported [1].

Multiphase AC arc (MPA), one of the new methods for thermal plasma generation, has the advantages of high energy efficiency, large plasma volume, and long processing time. MPA has been studied with the aim of establishing a method for mass production of functional nanoparticles. In particular, knowledge of metal vapors as precursors of nanoparticles is needed, as they are important for the product properties.

In order to visualize the nanoparticle formation process, the temperature field has been successfully evaluated by measuring the emission of lithium vapor supplied as raw material. However, the fluctuations in the density field have not yet been elucidated. The line spectra of lithium atoms at 460, 610, and 671 nm were confirmed, and it was experimentally clarified that self-absorption occurred, especially at 671 nm [2]. The purpose of this study is to establish the method for measuring lithium atomic density using self-absorption.

2. Experimental Methods

The MPA generates thermal plasmas between electrodes by applying AC voltages of different phases to multiple electrodes. The plasma was generated by 6-phase AC under atmospheric pressure. The arc current was 87 A and the drive frequency was 180 Hz. Ar shielding gas flowed at 5 L/min per electrode.

The feedstock was fed from the center of the plasma, just below the electrodes. A mixed powder of Li_2CO_3 and MnO_2 was used as the feedstock, with a composition ratio of Li and Mn of 1:1. The feed rate was about 0.7 g/min.

Two high-speed cameras were installed at the same height facing each other for synchronous measurement of metal vapor in two directions. A 3-wavelength synchronous measurement of Li atoms was attempted using a system combining a high-speed camera and bandpass filters of 460±5 nm, 610±5 nm, and 671±5 nm for the line spectrum of lithium atoms.

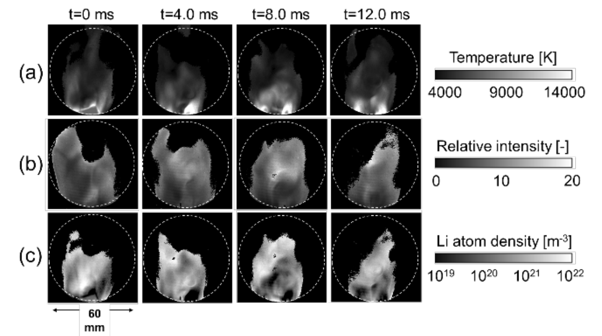

Fig. 1. Snapshots of (a) temperature and (b) relative intensity of 610 nm to 671 nm and (c) density distribution of Li atom.

3. Results and Discussion

Snapshots of the temperature, relative intensity ratio, and number density distribution of lithium atoms obtained by the high-speed camera are shown in Fig. 1. These figures indicate that the density of lithium atoms is mostly in the order of 10^{20} to 10^{21} m^{-3}.

The results were compared with those obtained by spectroscopy, which has higher measurement accuracy. The data were averaged over 150 ms in both cases, which is a sufficiently long and valid comparison since the AC period is approximately 5.5 ms. The results of the density measurements by emission spectroscopy and the high-speed camera were in good agreement. This confirms the validity of the density calculated from the high-speed camera observation.

4. Conclusion

The two-dimensional density distribution of lithium atoms was obtained by a high-speed camera using the luminescence and absorption phenomena of Li atoms.

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References

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