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多相交流アークにおける Li-Mn 複合酸化物ナノ粒子の生成機構
Formation Mechanism of Li-Mn Composite Oxide Nanoparticles in Multiphase AC Arc

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1. Introduction

Attractive material processing with thermal plasmas have been proposed for the nanoparticle synthesis. This is because thermal plasmas offer unique advantages such as high enthalpy, rapid quenching, and so on.

Spinel-type $LiMn_2O_4$ is one of promising cathode materials for lithium-ion batteries. Recent works revealed that thermal plasma is suitable for mass-production of $LiMn_2O_4$ nanoparticles [1], while more efficient method is required for its industrialization. In the present study, a multiphase AC arc (MPA) with high energy efficiency is focused.

The purpose of this study is to synthesize $LiMn_2O_4$ nanoparticles by MPA. Another purpose is to investigate formation mechanism by elucidating the temperature field.

2. Experimental setup

The MPA was generated among 6 electrodes by phase-shifted AC power supplies. The driving frequency was varied from 60-180Hz. A powder mixture of Li_2CO_3 and MnO_2 was introduced into the plasma at a feed rate of 0.7 g/min. Molar ratio of Li to Mn was adjusted at 1:1. Synthesized nanoparticles were analyzed by X-ray diffraction (XRD) and transmission electron microscopy (TEM).

High-speed camera with appropriate band-pass filters were utilized to visualize Li vapor. Excitation temperature of was estimated by the relative intensity ratio method.

3. Results and Discussion

XRD patterns of nanoparticles produced by MPA at each frequency condition are shown in **Fig. 1**. Results indicated that the Spinel-type $LiMn_2O_4$ and layered rock-salt type $LiMnO_2$ was synthesized as major product, while Li_2CO_3 was also observed as minor product. The results also showed an increase in the fraction of $LiMnO_2$ and a decrease in the fraction of $LiMn_2O_4$ and Li_2CO_3 as the frequency was increased.

Figure 2 shows the visualized temperature fields at different frequencies. Higher frequency leads to suppressed temperature fluctuation. This is because the arc fluctuations become smaller as the frequency is increased. The reason for the decrease of by-product fraction at higher frequency can be explained by suppressed temperature fluctuation at higher frequency.

4. Conclusion

Nanoparticles of Li-Mn composite oxide were successfully synthesized as major product by the MPA. Thermal plasma synthesis enables to produce attractive electrode materials for lithium-ion battery at high-productivity.

References

[1] H. Sone et al., Jpn. J. Appl. Phys., **55**, 07LE04, (2016)

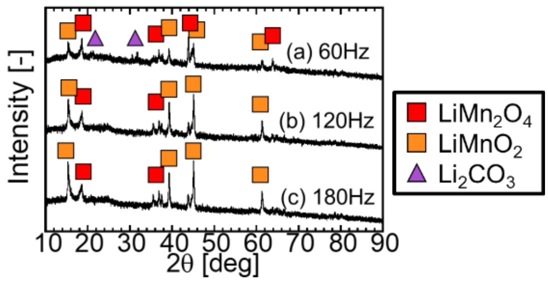

Fig. 1 XRD spectrum chart of produced nanoparticles at frequencies of (a) 60 Hz, (b) 120 Hz, and (c) 180 Hz.

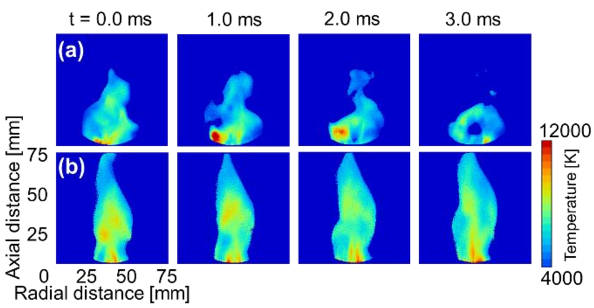

Fig. 2 Visualized temperature distributions at different frequencies; (a) 60Hz and (b) 180Hz.