Synthesis of Iron Nitride Nanoparticles using DC Thermal Plasma

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Abstract: Transition metal nitrides(TMN) are the most promising materials for energy storage devices, such as supercapacitors and batteries. Among them, Iron nitride(Fe_2N) has significant potential as an electrode substitute. In this work, Fe_2N nanoparticles were synthesized using nitrogen thermal plasma. To reveal the optimal synthetic environments, the influences of heat insulation and additional quenching gas were investigated.

1. Introduction

Transition metal nitrides(TMN) have a wide bandgap, flat and adjacent potential similar to lithium-metal, high capacity, superior conductivity, ideal chemical stability, and tunable structure. From this perspective, Iron nitride(Fe_2N) is the best electrode for electrochemical energy storage devices due to its brilliant electrical conductivity, high capacity, environmental friendliness, low resistance, economic and natural abundance [1].

Fe_2N was synthesized using nitrogen non-transferred arc plasma. The thermal plasma synthesis method is an eco-friendly dry method using micro-sized iron powder directly as a precursor without organic solvent compared to the conventional wet synthesis method. A hollow-type cathode increased the reactivity between the injected iron powder and dissociated nitrogen. The torch provides high temperature medium above 10,000 K, and the injected iron powder is vaporized, and dissociated nitrogen promotes the nitridation of vaporized iron. They rapidly condensed by the sharp temperature gradient(10^4-10^6 K/s) of the plasma jet and produced as nanoparticles.

2. Methods

Table 1 shows experimental conditions for synthesizing Fe_2N nanoparticles. Input power for discharge was fixed at 10 kW(80 A, 126 V), and the reactor pressure was maintained in the atmosphere. In Run 1, additional nitrogen gas was injected as the quenching gas. The influence of heat insulation following the condensation rate was investigated in Run 3.

Table 1. Experimental conditions for synthesizing Fe_2N nanoparticles using DC thermal plasma.

Parameters	Run 1	Run 2	Run 3
Plasma forming gas	50 L/min N_2		
Carrier gas for precursor	5 L/min N_2		
Heat insulation tube	-	-	Located
Feeding rate of Fe powder	300 mg/min	300 mg/min	910 mg/min

The synthesized Fe_2N nanoparticles were analyzed through X-ray Diffraction(XRD), Transmission electron microscope(TEM), Energy Dispersive Spectroscope(EDS), and Thermogravimetric Analyzer(TGA).

3. Results and Discussion

Figure 1 presents XRD patterns of the synthesized nanoparticles in Runs 1-3. The crystalline Fe_2N peaks were observed in Run 3 where the heat insulation tube was inserted.

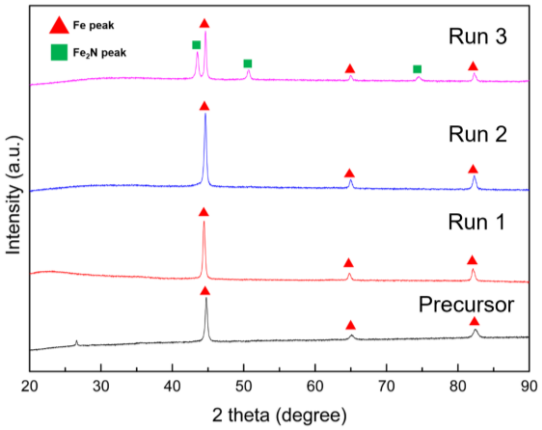

Fig. 1. XRD patterns of iron precursor and nanoparticles synthesized Runs 1,2, and 3.

The morphology of synthesized Fe_2N nanoparticles was spherical, the outer layer was thinly coated with nitrogen. They have a broad size distribution between 30 nm to 200 nm. Through TGA analysis, synthesized Fe_2N has a similar degradation trend with Fe_2N coated with nitrogen rather than complete Fe_2N particles [2].

4. Summary and Future Plan

Fe_2N nanoparticles were synthesized using nitrogen thermal plasma. The torch provides a sufficient temperature for the vaporization of iron, and the dissociated nitrogen reacted with the vaporized iron. It suggests that Fe_2N synthesized only with nitrogen is used as the plasma forming gas without an additional nitride source. The synthesized nanoparticles are observed to be Fe_2N in nitrogen-coated form by TEM and TGA analysis.

Additionally, Vibrating sample magnetometer(VSM) analysis will be conducted to analyze the magnetic properties of the synthesized Fe_2N nanoparticles.

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References

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