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Formation mechanism of Silicon Nanoparticles with Carbon coating in Induction Thermal Plasma with Controllable Temperature Distributions

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1 Introduction

Silicon is a promising anode material for lithium ion batteries due to high charge storage capacity of 4200 mAh/g, which is approximately 10 times higher than commercial graphite. However, crystalline silicon shows a 400% volume expansion during lithiation and delithiation and leads to serious electrode failure mechanisms, which has severely reduced its promise for applications.

Application of carbon coating on silicon nanoparticles (SiNPs) is believed as a useful way to prevent electrode pulverization, and provides continuous electronic conduction pathways during cycling. A reliable and effective synthesis method for such structure is proposed in this research on the basis of induction thermal plasma. The formation of carbon coating is influenced significantly by temperature distribution in reaction chamber as well as SiNPs. Therefore, the plasma properties are modified through the composition of plasma sheath gas, and the effect on products will be investigated.

2 Experimental

The experimental setup mainly consists of torch, chamber and filter. Plasma is generated with a RF power supply at 4MHz and 17.5 kW. The ratio of tangential and radial flow rates (T/R), which compose plasma sheath gas, varies from 0.5 to 1 to understand the effect on plasma properties as well as products. Silicon raw powders with a diameter of 5 μm are injected at 800 g/min with Ar carrier gas.

Methane is chosen as carbon source and injected into chamber to form carbon coating, and the flow rate varies from 1.28 to 1.92 L/min. Particles were characterized by XRD, TEM and EDS mapping.

3 Results and Discussion

Morphology of particle with special conditions is shown in **Fig. 1**. Prepared SiNPs marked with brown circles can be observed in all cases while SiC marked with the hexagonal symbols can only be obtained in the case of T/R=0.5. Taking into account of the formation mechanism of SiC [1], possible reason is the effect of T/R values on the plasma temperatures. As the tangential gas flow rate is higher, the temperatures in the zones of CH_4 injection will be lower and the decomposition of CH_4 molecules will be suppressed. Therefore, the formation of SiC is ignored with T/R value of 1.

Core-shell structure can be identified with EDS mapping results as shown in **Fig. 2**. Carbon coating is prepared successfully in this work with various T/R values, while the shell thickness of T/R=1 is much thinner than the lower case. This further proves the conclusions obtained with TEM images, and reveal the temperature distribution can be affected by sheath gas significantly.

4 Conclusion

The value of T/R has a significant effect on the temperature distribution as well as the products, and the component of products is tunable in the current work which is meaningful for practical applications.

References

[1] X. Zhang et al., Powder Technology. 371 (2020) 26–36.

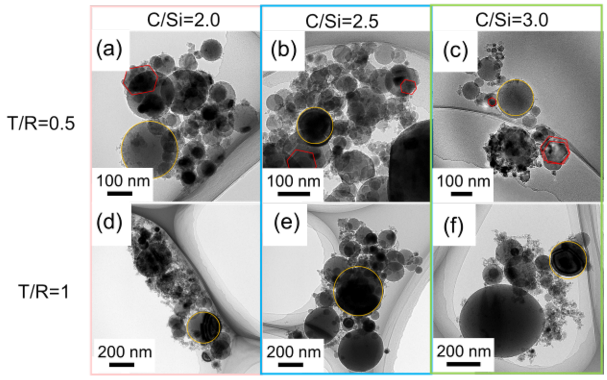

Fig. 1 TEM images of particles at changed C/Si and T/R.

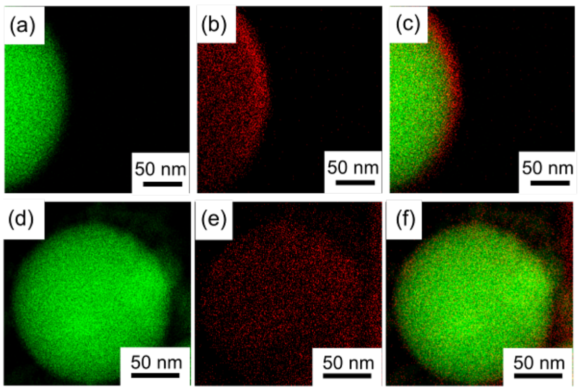

Fig. 2 EDS mapping results at C/Si ratio of 3: (a-c) show the results at T/R=0.5; (d-f) are results with T/R=1. Green and red mean silicon and carbon, respectively.