# Synthesis of Si/C Nanocomposites Using Triple Thermal Plasma Process

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**Abstract:** To solve Si's volume expansion in terms of energy storage, we synthesized Si/C nanocomposites using the triple thermal plasma system. In the nanocomposites, structurally stable carbon surrounds Si surface. We experimented with different injection locations of Si powder. We investigated the location that is suitable for synthesizing Si/C composites. The results showed that high-temperature Si injection enabled carbon to attach to the surface.

## 1. Introduction

Si has a theoretical capacity about 10 times higher than graphite. However, Si faces challenges such as more than 300 % volume expansion during electrochemical reactions, creating a short-circuit hazard. To solve this problem, the study investigated whether the volume expansion of Si could be controlled by attaching carbon to its surface. Si/C nanocomposites were synthesized using thermal plasma to pyrolyze $CH_4$, a carbon precursor. Thermal plasma is effective for the synthesis of nanoscale materials due to its high temperature and variety of active species.

## 2. Methods

The triple thermal plasma system used $N_2$ as the plasma-forming gas at a flow rate of 15 L/min per torch. 20 L/min of $CH_4$ was injected through an injector in the co-flow direction, the same direction as the torch. Si powder was injected in the counter-flow direction, opposite the $CH_4$ flow. Si was injected at a 0.5 g/min rate with 10 L/min of $H_2$ as the carrier gas.

The effect of Si-injected temperature on Si/C nanocomposite synthesis was investigated. Si was injected at 350 mm and 1050 mm below the $CH_4$ injector as a reference. The nanocomposites captured in the filter zone were subjected to analysis.

## 3. Results and Discussion

Numerical simulations show that the Si injection temperature of 350 mm is about 3400 K. The $CH_4$ pyrolysis reaction time at 350 mm is insufficient for the carbon precursor to grow into a solid state. In addition, a temperature of about 3400 K makes little difference to the vaporization temperature of Si. This may cause the Si powder to react with the carbon precursor in the gaseous state without vaporizing. On the other hand, the Si injection position of 1,050 mm is about 1,700 K. This makes phase change of Si powder impossible. The carbon at 1,050 mm had enough growth time to become solid after $CH_4$ pyrolysis. The composite is synthesized from a mixture of solid carbon powder and Si powder.

The XRD pattern shows Si, graphite, and SiC crystalline phases when Si was injected at 350 mm. In contrast, at 1,050 mm, only Si and graphite crystalline phases are observed. This suggests that the vaporization of Si at 350 mm and its reaction with carbon promotes SiC synthesis at higher temperatures. Raman spectrum shows that at 1,050 mm, the $I_D/I_G$ ratio is low, indicating that relatively defect-free carbon is synthesized. This finding implies that the $CH_4$ pyrolysis process allows solid carbon to grow into a crystalline structure.

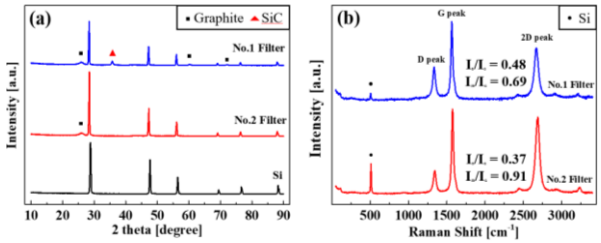


**Fig. 1**. (a) XRD patterns, (b) Raman spectrum of composites under experimental conditions.

## 4. Conclusion

This study synthesizes Si/C nanocomposites using triple thermal plasma and utilizes them as battery materials. We examined the effect of Si powder injection positions on the synthesized nanocomposites. Carbon generated after $CH_4$ pyrolysis is attached to the surface of Si. The longer the Si stays in the high-temperature region, the more phase change can occur, forming SiC. In addition, it has been demonstrated that sufficient reaction time is required to grow $CH_4$ into crystalline solid carbon.

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