Strengthening Mechanism of Silicon Carbide Green Body via Cellulose Nanofiber Addition

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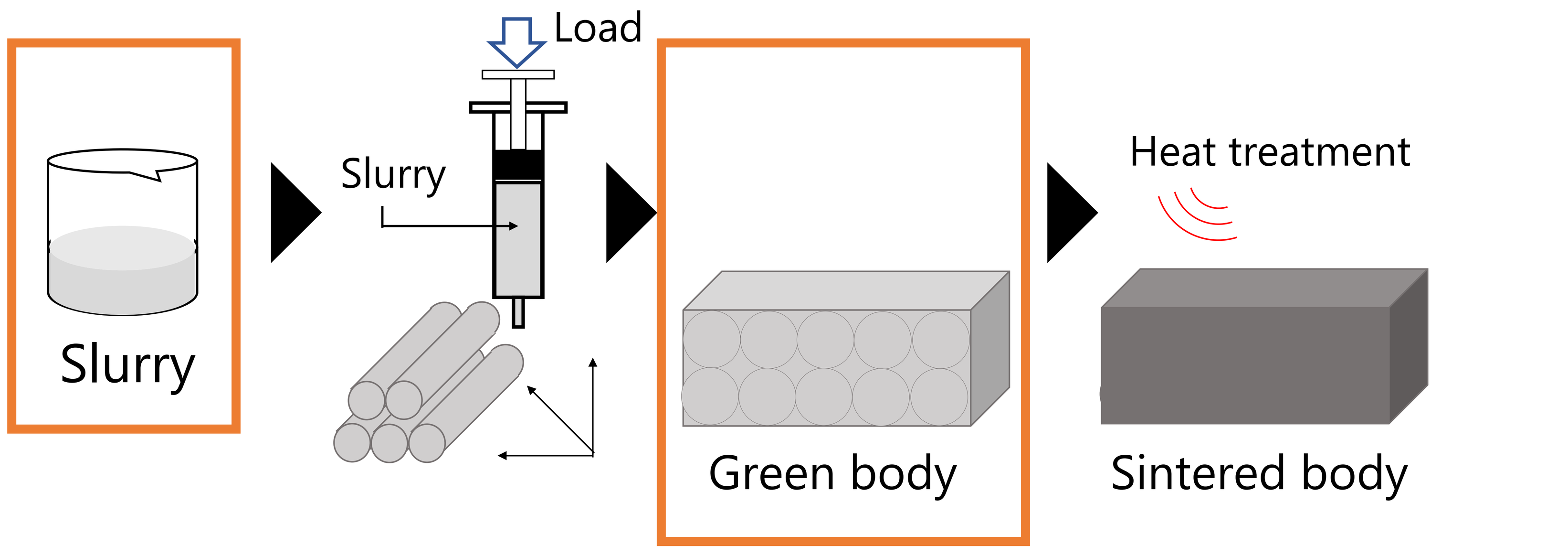
1. Introduction

Robocasting for ceramics



Ceramic slurry

- ☐ Shear thinning
- ☐ Yield stress

⇨ Robocasting requires the slurry which shows Bingham-pseudoplastic behavior.

Ceramic green body

- ☐ Low strength
- ☐ Brittleness

⇨ The green body can easily collapse by shocks. (ex. Transportation from a modeling stage to a furnace)

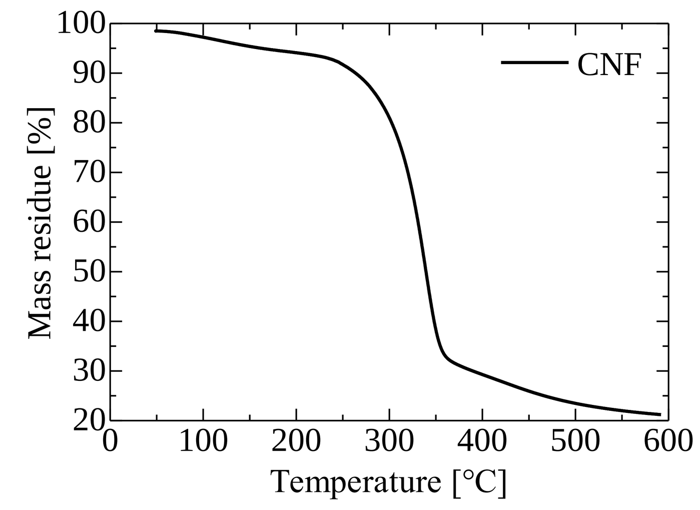
ABSTRACT

This study has reported the enhancement of a SiC green body by CNF slurry addition to the SiC slurry for robocasting. Three-point flexural strength of the green body containing CNF was about 1.5 times higher than that without CNF. The enhancement was caused by an increase in the number of hydrogen-bonding site. On the other hand, the strengthening mechanism changed to an increase in the number of non-polar groups site after annealing.

Reinforcement

Cellulose nanofiber (CNF) aqueous slurry

- ☐ shows **Bingham-pseudoplastic behavior**.
- ☐ forms **rigid CNF sheet** after drying at room temperature through hydrogen-bonding.
- ☐ Desorption of bound water begins at 250℃, and pyrolysis occurs at more than 300℃ drastically.



TGA of CNF sheet[1]

Objectives

1. **Enhancement of the green body by the CNF addition.**
2. **Proposing a mechanism of the enhancement by the CNF addition.**

2. Methods, Results and Discussion

Raw materials

- Silicon Carbide (SiC) powder (solid loading of 40 vol%)
- Boron carbide and Carbon powders (sintering additives)
- Water and 2 wt.% commercial CNF aqueous slurry (dispersion medium)
- Anionic dispersant

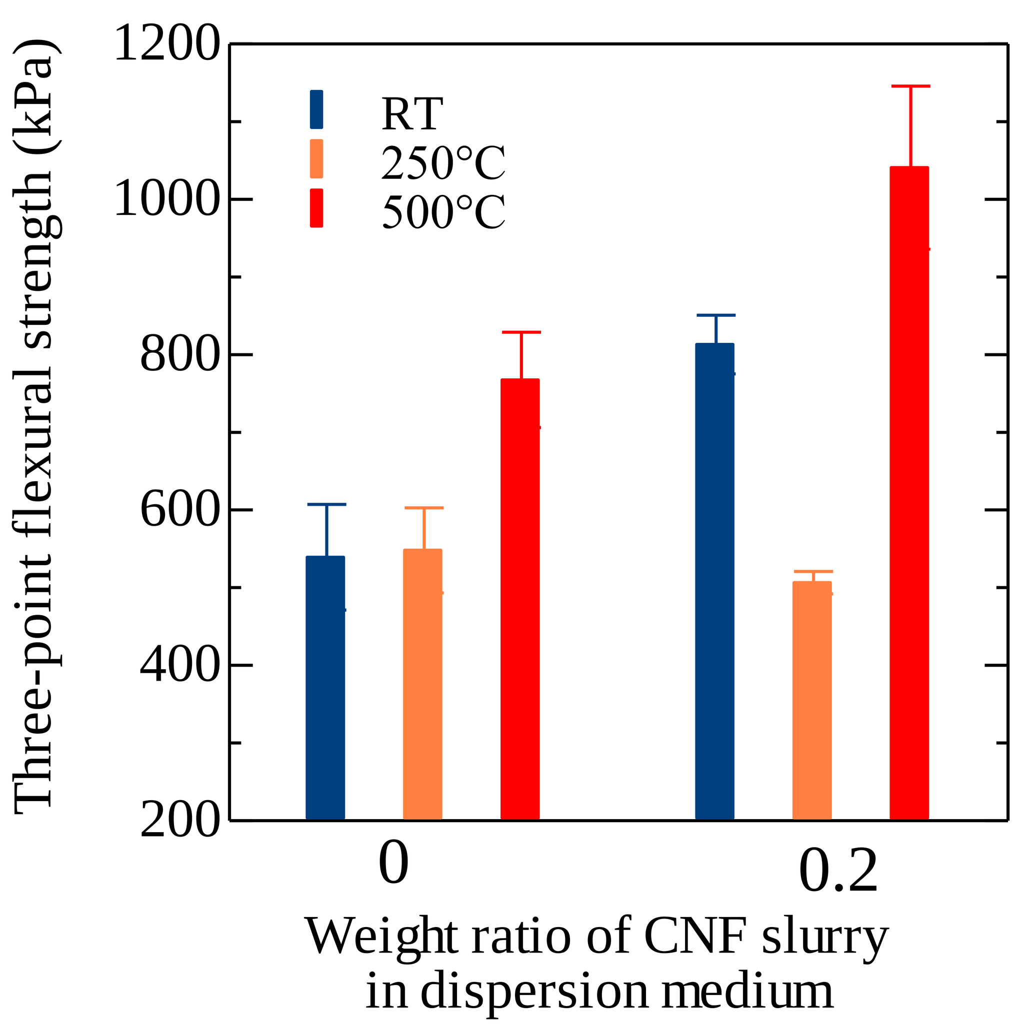
Specimens

- Different weight ratio (water-to-CNF slurry) in the dispersion media (100:0 and 80:20)
- Room temperature (RT) drying for a day.
- Annealing at 250℃ or 500℃ to investigate the strengthening mechanism.

Evaluation

- Three-point flexural test. (crosshead speed of 0.5 mm/min, support span of 30 mm)
- Three-point flexural test after heat treatment.
- Microstructural observation of the green bodies and CNF.

Flexural strength of green bodies



Flexural strength σ_T^i

Composition of CNF i = 0 or 0.2
Annealing temperature T = RT, 250 or 500

$\sigma^{0.2}_{RT} > \sigma^{0}_{RT}$

CNF strengthened the SiC green body.

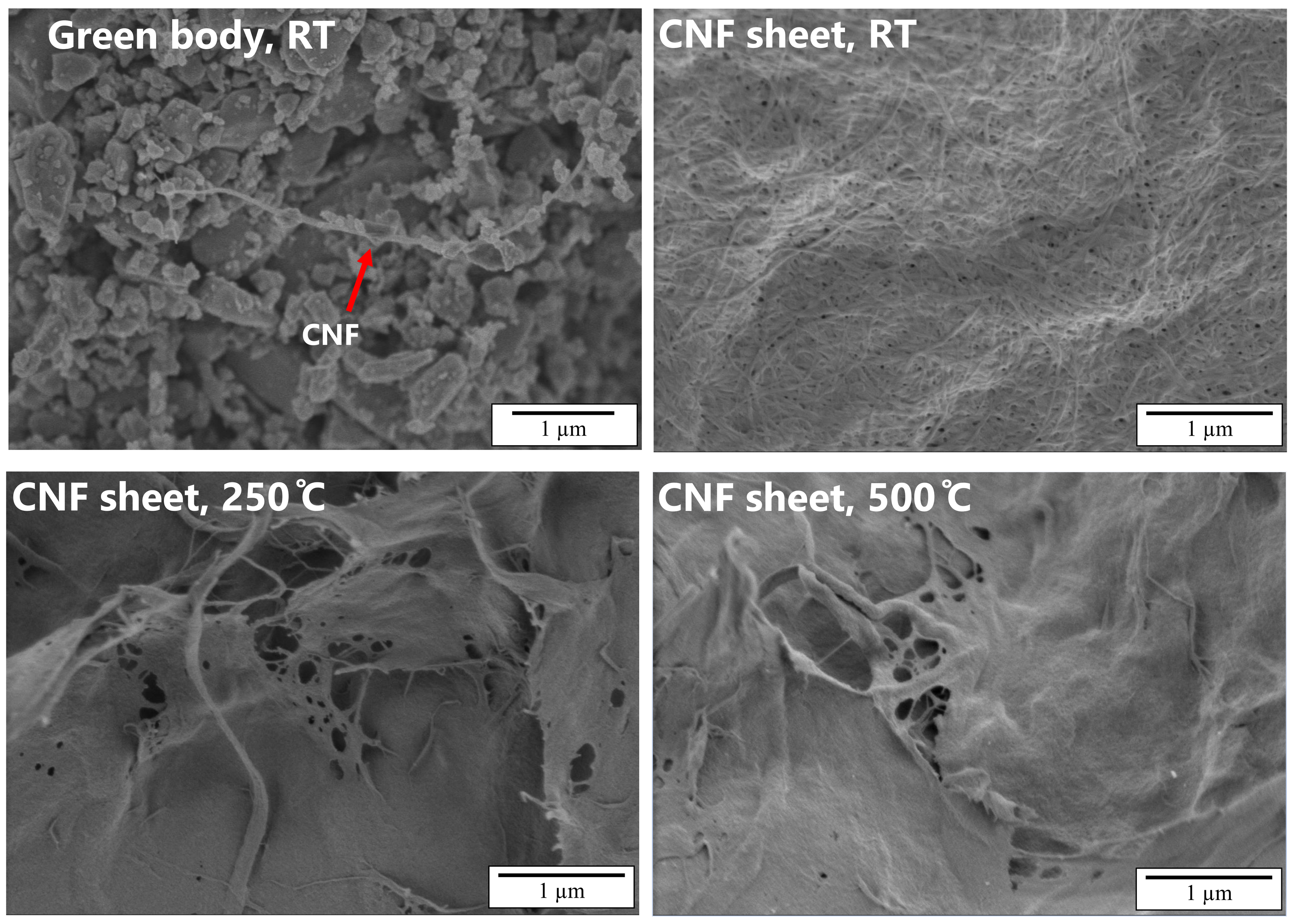
$\sigma^{0.2}_{RT} > \sigma^{0.2}_{250} \cong \sigma^{0}_{RT}$

CNF did not work as reinforcement after annealing at 250℃.

$\sigma^{0}_{500} > \sigma^{0}_{RT}$, $\sigma^{0.2}_{500} > \sigma^{0.2}_{RT}$

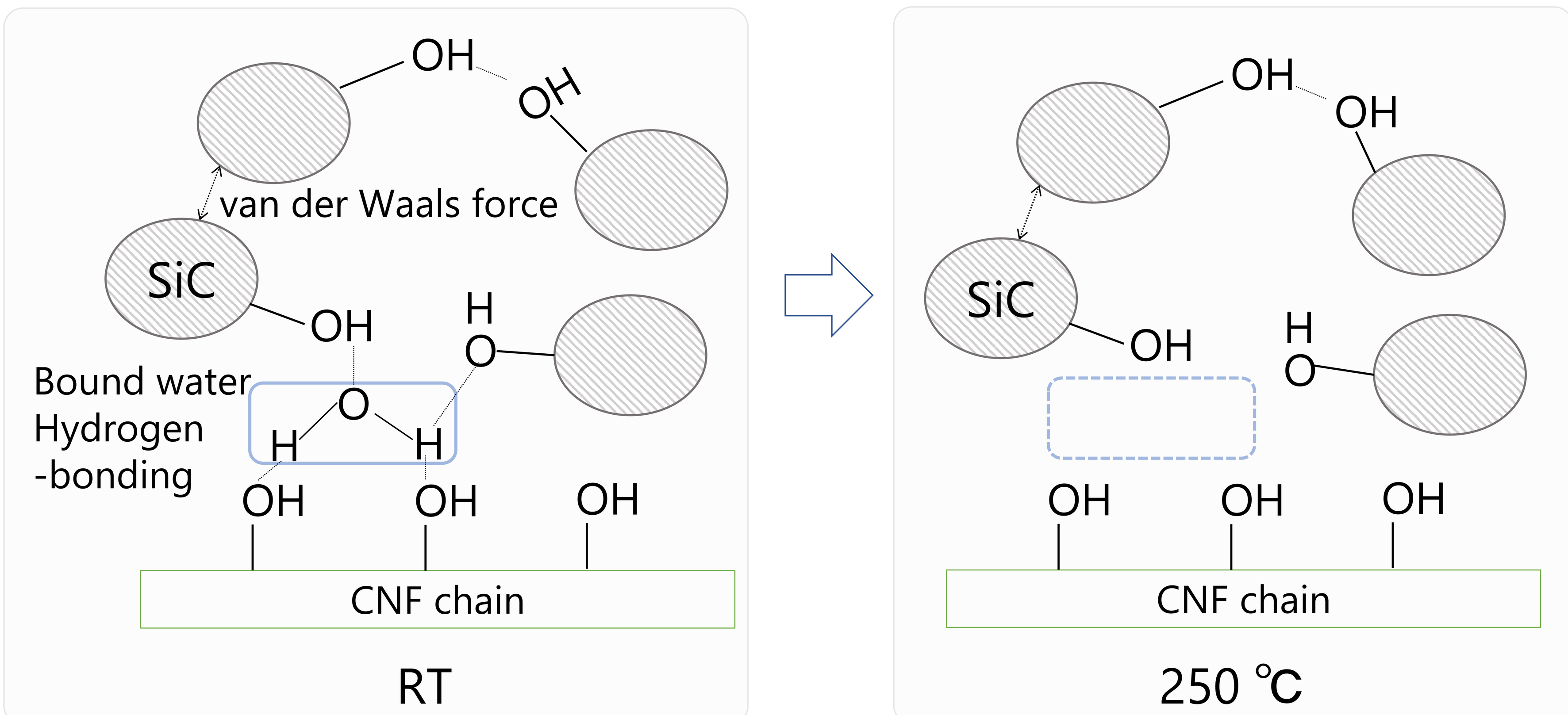
The strength depended on the effect of annealing on the particles.

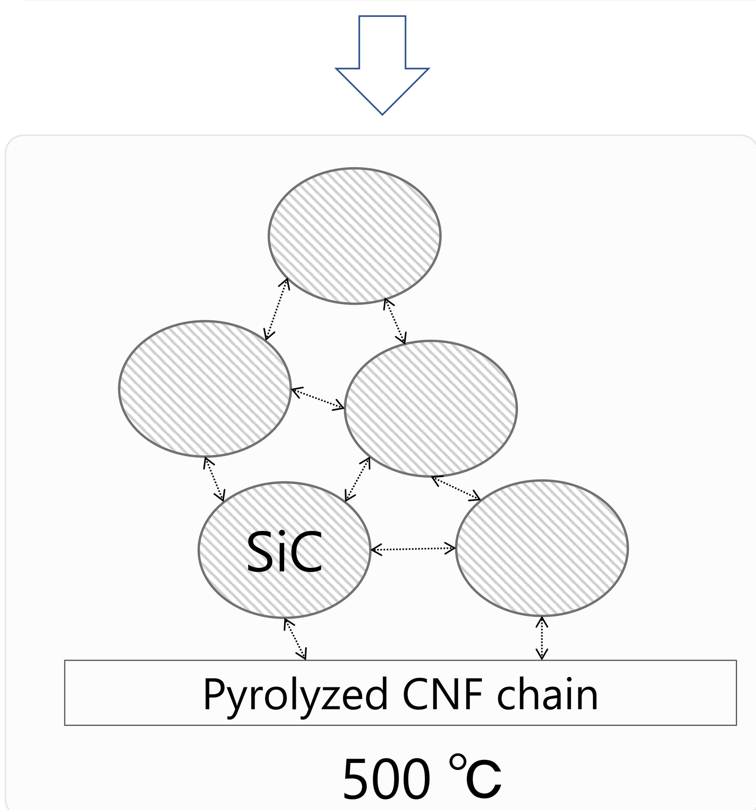
Microstructure of green body and CNF



- ☐ **CNF generated bonding sites between CNF and particles.**
- ☐ CNF sheet had dense fiber network structure.
- ☐ CNF network structure disappeared after annealing.
- ☐ Only the thick CNF bundle remained.
- ☐ Almost no difference in microstructure was observed between CNFs annealing at 250℃ and 500℃.

Proposed strengthening mechanism by CNF addition





(Room temperature)
CNF strengthens SiC green body by increasing the number of bonding sites through hydrogen-bonding.

(250℃)
CNF does not contribute to the matrix strength due to the loss of bound water.

(500℃)

- ☐ The partially-oxidized SiC particle surface is cleaned. Besides, non-polar groups (Si–C) are exposed[2].
- ☐ The residual pyrolyzed fiber bundle increases the number of bonding sites through van der Waals force.

Acknowledgement: JSPS KAKENHI (grant number: JP22J20100)

[1] T. Kanno et al., *Int J Adv Manuf Technol*, 125, pp.2055-2064 (2023).
[2] H. Kamiya et al., *Powder Technol*, 127, pp.239-245 (2002).