Synthesis of carbon nanotube-biochar composites by plastic pyrolysis and biomass gasification

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Polymer plastics, such as packing materials, play a crucial role in people's life. Most plastic waste in Singapore is ended with landfills, while only 4% is recycled (Oh, 2021). The natural degradation cycle of plastic took more than centuries. Singapore is an island country and cannot afford to provide a large area of land for the landfill in the long term. Hence, it is urgent to find new solutions to deal with waste plastics. One possible route is to convert waste plastic into high-value carbon nanotubes (CNTs) by the chemical vapor deposition (CVD) process.

Biochar is a low-cost and carbonaceous material derived from organic matter through pyrolysis or gasification in an oxygen-limited environment. The waste biomass, such as horticultural waste, was generally used as the precursor of biochar. It was demonstrated that there was a feasibility of using biochar as a support for catalyst (Luo et al., 2022). Owing to the porous structure of biochar, metal particles can be effectively dispersed over its surface, facilitating the synthesis of CNTs during the CVD process.

The CNTs-biochar nanocomposites have been widely studied in recent years as adsorbents, phase change materials, anodes for battery, and electrocatalysts for oxygen reduction reaction (ORR), etc. In most of the previous studies, CNTs-biochar nanocomposites were synthesized by assembling commercial CNTs to biochar. Specifically, Zhang et al. (2019) found that it was possible to produce CNTs-biochar nanocomposites by directly growing CNTs on the biochar through the microwave-assisted CVD method using methane.

Herein, this work intended to synthesize CNTs-biochar nanocomposites through CVD process using the vapor from plastic pyrolysis on biochar. The woody biochar used in this study was obtained from gasifying horticultural pruning waste at 750 °C. The produced biochar was manually ground, and the particle size was sieved below 125 μm. Five grams of sieved biochar was well mixed with 2.755 g of $Ni(NO_3)_2 \cdot 6H_2O$ in 120 ml aqueous solution and sonicated for 1 hour. The solution after sonication would be transferred to a 200 ml hydrothermal autoclave and placed in a 150 °C oven for 24 hours. After that, the Ni/biochar precursor would be washed with DI water and centrifuge three times. The precursor would be calcinated in an inert atmosphere (N_2) for 1 hour at 800 °C. After that, the 10 wt% Ni/biochar catalysts were collected.

The experimental setup for this work is similar to our previous paper (Yao et al., 2021). A two-stage reactor was used. In the experiment, Ni/biochar catalyst (0.4 g) was placed in the lower stage, while the polystyrene (PS) (1.0 g) was placed in the upper stage. The forming gas (5% H_2 and 95% N_2) would reduce the catalyst before pyrolysis (at 800 °C for 1 hour). After that, the PS would be pyrolysis in an inert atmosphere (N_2) at 500 °C for 50 min while the temperature of the lower stage maintained at 800 °C. In the end, the system was cooling down in N_2 atmosphere and the produced CNTs-biochar composites were collected and characterized.

The yield of carbon deposition was 61.0 wt carbon deposition /w plastic %. It was relatively higher than our previous results (30.25 - 38.26 wt%) (Yao et al., 2021; Yao et al., 2022). Bamboo-shaped CNTs were successfully synthesized, and the scanning electron microscope (SEM) images are shown in Figure 1. It was observed that the CNTs were grown uniformly on the biochar. The predecessor of the small cluster was a Ni/biochar particle.

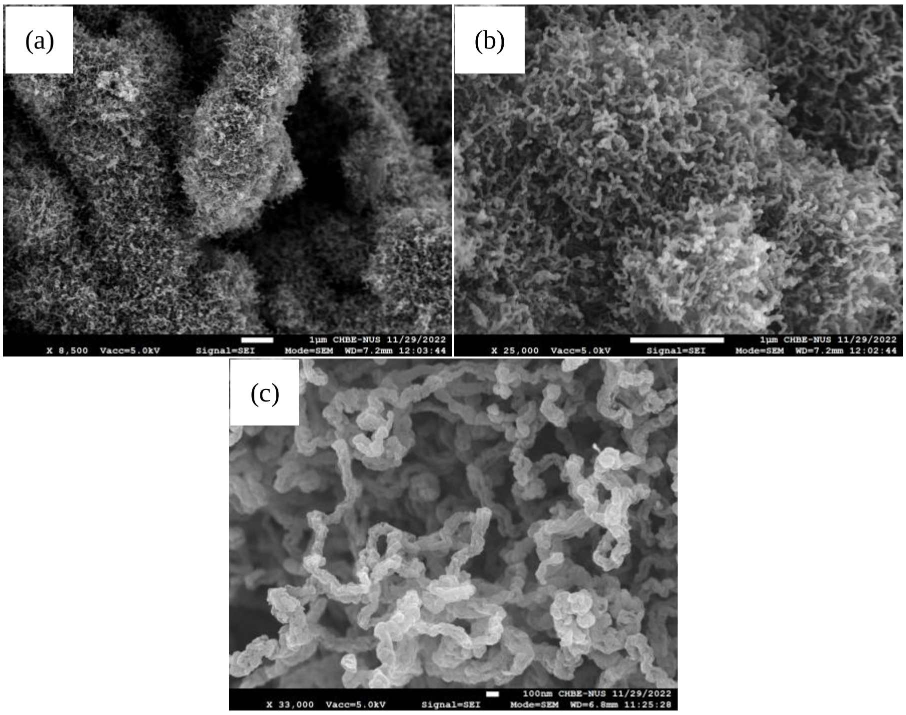

Figure 1. SEM image for CNTs-biochar composites in different magnifications.

This work successfully synthesized bamboo-shaped CNTs on Ni-doped biochar by CVD method at high temperature. It provides a concept for processing waste plastics and biomass into a high-value nanomaterial of CNTs-biochar nanocomposites. Moreover, the CNTs-biochar nanocomposites has the potential to be directly used in adsorption and electrochemical fields.

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