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# A homogeneous Ni–P coating with a unique scalelike structure deposited on VGCNFs by an electroless deposition method

Ju Hyung Kim[a], Jae Deuk Kim[a], Hoon Mo Park[b], Sang Bok Lee[c], Jin Woo Yi[c], Seung Il Jung[a,*]

[a] Future Industry R&D Center, DH Holdings Co., LTD, 705-32 Yeoksam-Dong, Kangnam-Gu, Seoul, 135-080, Republic of Korea
[b] Research & Development Division, Hyundai Motors, 460-30 Sam-dong, Uiwang-si, Gyeonggi-do, 437-815, Republic of Korea
[c] Composite Mateirals Research Group, Korea Institute of Materials Science, 797 Changwondaero, Changwon-si, Seongsan-gu, 641-831, Republic of Korea

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A unique scalelike structured Ni–P alloy coated vapor-grown carbon nanofibers (VGCNFs) were fabricated by an electroless deposition method following pre-treatment of activation. The coating was found to be homogeneous and mesoporous. The scalelike structure gives the composite material a very high surface area of 74.2 $m^2/g$, significantly higher than the only reported scalelike structured Ni–P/CNFs catalyst. Hence, it is suggested to have great potential in wide applications, especially catalysts. A relatively low level of phosphorus content was discovered, which result in a mixture of amorphous and crystalline in the initial state. Moreover, our results show that the Ni–P coating and VGCNFs have an interaction effect on the oxidation temperature of each other.

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## 1. Introduction

Nanoscale carbon materials have been used as reinforcement for a variety of composite materials due to their unique structure and excellent properties such as high tensile strength, good chemical stability, and high thermal and electrical conductivities. The composites are believed to possess a combined property of the isolated components, or even show a synergistic performance [1].

To fabricate such composites, wettability is a very important factor, which determines the quality of bonding between the constituents and thereby greatly affects the final properties of the composites [2]. Metal coatings or deposition on the surface of CNTs or CNFs is considered to be effective for improving their wettability [3]. Metals–CNTs composite has also been reported for application as catalysts, batteries, field emission and so on [1,4,5]. Recently another potential application of metal–CNT composites for hydrogen storage has attracted a lot of attentions. Metals such as Ni, Cu, Pd, Pt, and Ru, can act as catalysts to dissociate $H_2$ into hydrogen atoms due to spillover effect which are then chemisorbed on the CNTs/CNFs, thereby enhance the hydrogen storage capability [6–10]. However, the high price of precious metals such as Pd, Pt, and Ru makes them difficult for commercial applications. Therefore it would be more interested to investigate low-cost metals such as Ni and Cu.

Methods such as thermal evaporation [11,12], wet impregnation [13,14], and electrodeposition [15,16] have been used to deposit nickel on CNTs/CNFs. However, thermal evaporation requires sophisticated equipment, wet impregnation lacks for good control of the particle size, and electrodeposition needs additional electricity and electrodes [17]. In contrast, the electroless deposition method with easy-manipulation and low-cost is a promising technique [18,19]. A high specific surface area would greatly enhance the reactivity of the composites, thereby improve the performance in various applications.

In this respect, we report on an electroless deposition method for preparation of Ni–P alloy coated CNFs composites with high surface area. It was found that the Ni–P coatings had a unique scalelike structure. To the best of our knowledge, Xie et al. is the first and only group who reported Ni–P coatings with a scalelike structure, which resulted in a high surface area of 57.3 $m^2/g$ [20].

## 2. Experimental

Commercial available VGCNFs with a diameter of 150 nm and length of 10–20 μm, provided by Showadenko Co., Japan, were used in this study. The specific surface area calculated by BET method was 13 $m^2/g$. The VGCNFs were first dispersed in ethanol, filtered, and washed by distilled water. The activation of VGCNFs was then performed by stirring and dispersing the VGCNFs in a solution of

* Corresponding author. Tel.: +82 70 70936023; fax: +82 2 2083 1336.
*E-mail addresses:* sijung@donghee.co.kr, vincerosi@gmail.com (S.I. Jung).

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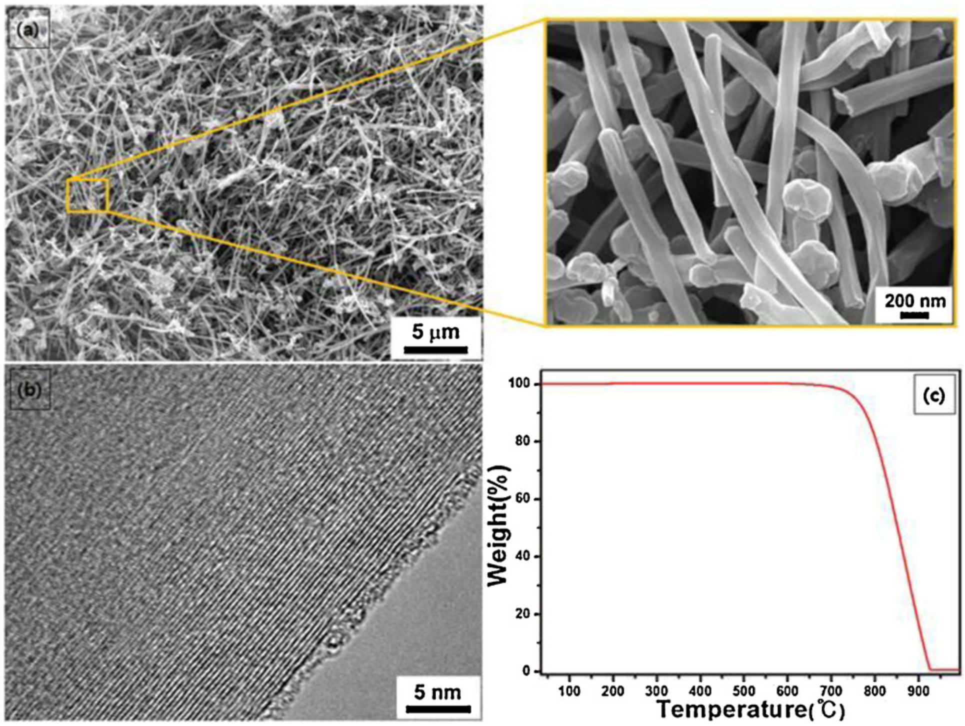


**Fig. 1.** (a) SEM image of VGCNFs with the low magnification, the inset represents the high magnified image of the tagged area, (b) TEM image with the high magnification, and (c) TGA data of VGCNFs, respectively.

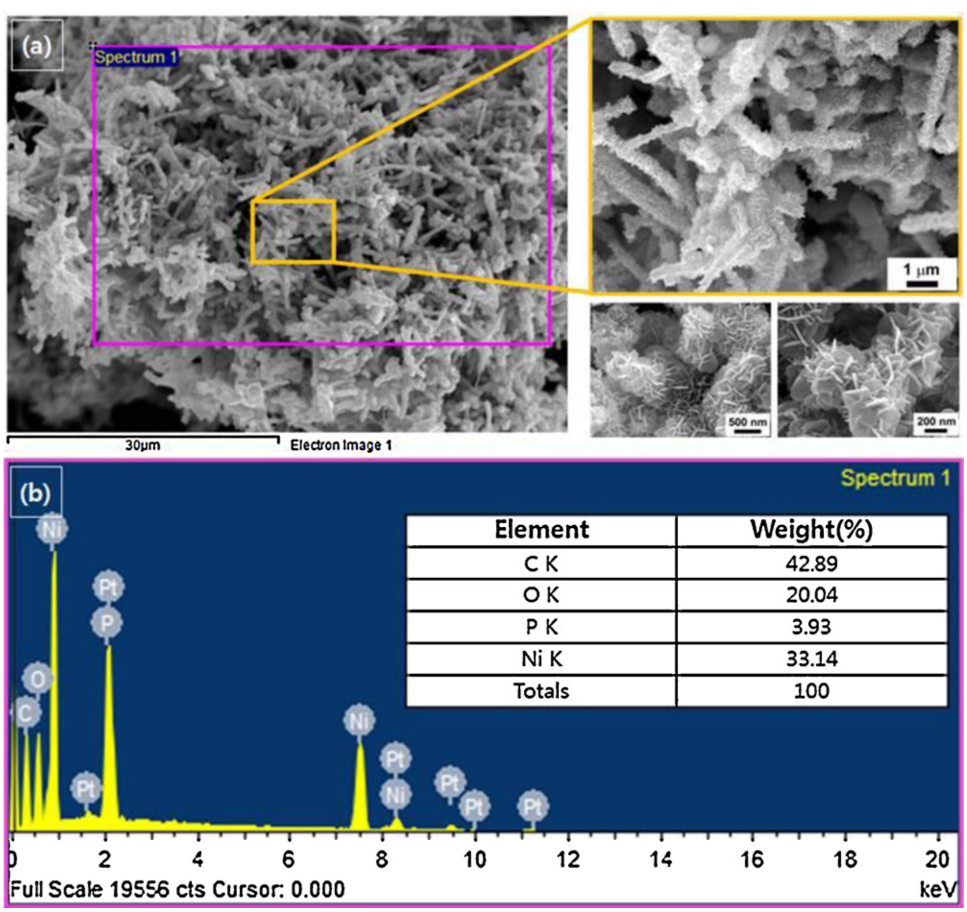


**Fig. 2.** (a) SEM image of Ni–P alloy coated VGCNFs with the low magnification, the insets represent the high magnified image of the tagged area, (b) is EDX spectrum of the marked area of Fig. 2(a).

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