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NOVEL CARBON NANOTUBE/COPPER HYBRID NANOCOMPOSITES FOR STRUCTURAL AND MULTIFUNCTIONAL APPLICATIONS

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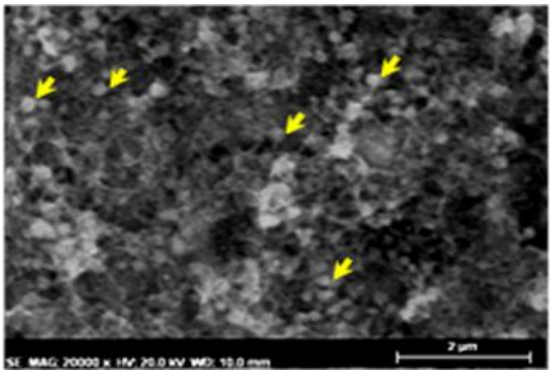
1. INTRODUCTION

Due to the extraordinary properties of carbon nanotubes (CNTs), nanocomposites of higher structural and functional properties compared to the matrix can be obtained in spite of the small amount of additions in the matrix [1]. However, the mechanical properties of nanocomposites are in the range of 10-20% less than those of the fiber reinforced composites [2]. In order to utilize the nanocomposites in the structural and functional applications, it is necessary to develop hybrid composites combined with micro fibers and CNTs. Here, to incorporate CNTs into the fiber reinforced polymeric composite, electrophoretic deposition (EPD) process has been utilized [3]. Especially, highly conductive and strong organic/metallic nano-hybrids were manufactured using CNTs and copper (Cu) nanoparticles [4,5].

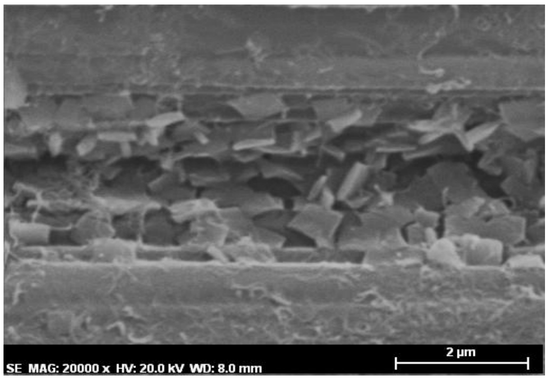
2. METHOD AND RESULTS

In the cathodic EPD process, positively charged CNTs are deposited on the carbon fiber surface. In addition to the CNT-deposition, ionized Cu from the copper anode plate is also attracted to the carbon fiber cathode and is simultaneously deposited together with CNTs. Such concurrent deposition creates a formicary-like nanoscaled junction structure [6]. For the anodic EPD process, negatively charged CNTs are deposited on the thermally vaporized Cu-coated carbon fiber surface. During the process, the coated Cu layer is corroded and partially exfoliated from the carbon fiber. Therefore, CNTs embedded Cu nanoplatelet structures are constructed [7]. Both formicary-like and platelet-type CNTs/Cu nanohybrids provide highly conductive and strong networks. Utilizing the nanohybrids, carbon fiber composites were manufactured and the enhanced electrical/mechanical properties were achieved.

Fig. 1 shows the SEM images of carbon fabric surfaces deposited by the cathodic and anodic EPD processes. Fig. 1(a) shows the surface of the carbon fabric after simultaneous deposition of CNTs and Cu particles. In this process, both CNTs and Cu particles were deposited at the same time and large-scale hybrid structures were observed. Finally, three-dimensionally formicary-like CNT/Cu hybrid nanostructures form on the surface of the fiber. When the anodic EPD process was applied after the thermal evaporation of Cu, numerous CNTs/Cu hybrid platelets were obtained as shown in Fig. 1(b).



(a)

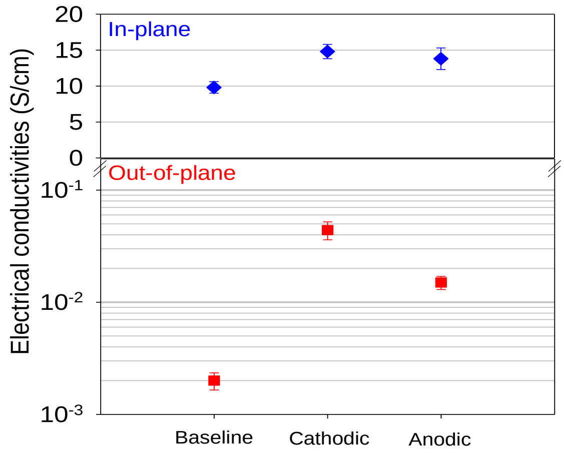


(b)

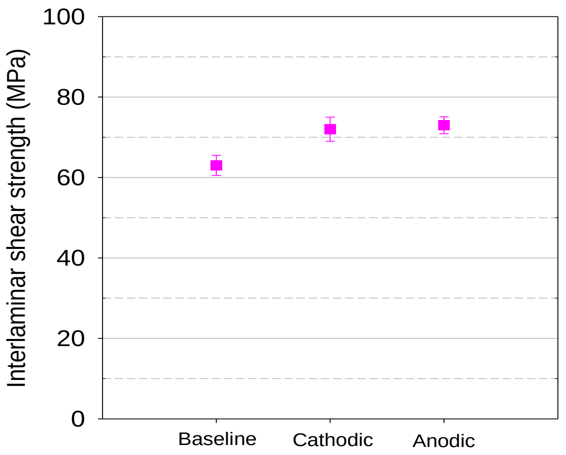
Fig 1. SEM images of carbon fiber surfaces by (a) cathodic and (b) anodic EPD

Fig. 2 shows the results of electrical conductivities and interlaminar shear strength of the CNTs/Cu deposited carbon fabric composite. The electrical conductivity in the in-plane direction of the composites was improved by

50% and 40% for the cathodic and anodic processes, respectively. However, in the thickness direction of the composites, the highly resistive epoxy resin is arranged in series with carbon fibers, resulting substantially reduced electrical conductivity. Furthermore the electrical conductivity in the thickness direction increased 2,000% and 650% as compared to the unmodified carbon fabric composites. This is due to the enhanced electrical network by the CNTs/Cu hybrids between the carbon fabric layers.



(a)



(b)

Fig 2. (a) Electrical conductivity and (b) interlaminar shear strength of CNTs/Cu embedded carbon fabric-epoxy composite

To examine the influence of the CNTs/Cu hybrid structures on matrix-dominated properties, the interlaminar shear strength was evaluated using the short-beam test method (ASTM D2344). Once the CNTs/Cu hybrids were introduced, the shear strength increased by 15~16% because the CNTs/Cu hybrids effectively prevents and delays the onset of crack propagation at the fiber/matrix interface. Furthermore, the crack propagation can be effectively blocked and deviated by the reinforcing networks. The results clearly indicate that CNTs/Cu hybrids are effective reinforcements to enhance the matrix dominant properties of the fiber composites.

3. CONCLUSION

In this work, the novel formicary-like and platelet CNTs/Cu hybrid nanostructures have been developed by applying the EPD process, which can establish a mechanically strong and highly conductive hybrid network. Utilizing the CNTs/Cu nanohybrids, carbon fabric-epoxy composites were fabricated using VARTM process, and their electrical and mechanical properties showed remarkable enhancement resulting from the multi-scale hybridization.

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