PRODUCTION OF CNT FORESTS BY A SIMPLE LAYER BUILDING METHOD ON A CONDUCTIVE SUBSTRATE

Anna Szabó[1], Lilla Nánai[1], Zsejke-Réka Tóth[1], Klára Hernádi[1]

[1]*Department of Applied and Environmental Chemistry, University of Szeged, H-6720 Szeged, Rerrich Béla tér 1, Hungary*
e-mail: szabo.anna@chem.u-szeged.hu

Abstract
The carbon nanotubes (CNTs) play an important role in nanotechnology research today because the CNT have outstanding properties. Many substrates can be used to fabricate carbon nanotube forests (CNT forests); however, it is important that the desired structure is achieved on a conductive substrate, and for these reasons, carbon nanotube forests have been synthetized on a titanium substrate in this research. Environmental protection is highly discussed nowadays, therefore it is necessary to be able to produce CNT forests with less energy investment and cost-effectively. For these reasons, we used dip-coating method, which is a simple process and without heat-treatments step to save energy in achieving the forest structure. Therefore, this research uses a dip-coating method to form a catalyst layer on the surface of the substrate, and to investigate the effect of heat-treatment of the substrate to produce CNT forests directly on the titanium substrate.

Introduction
The CNTs are used in different aera today due to their prominent properties. One type of CNTs is 3D-structured vertically aligned carbon nanotubes (VACNT), often referred to in as CNT forests, which have outstanding electrochemical properties. This structure was first produced in 1996 by a Beijing research team [1]. Nowadays, it is important to produce CNT forests on a conductive substrate, such as aluminum [2], copper [3], and titanium [4] substrates are often used in researched. In addition, it is possible to form a catalyst thin film on the substrate surface with several layer building methods such as spin-coating [5], spray-coating [6], PLD [4], and dip-coating [2], however, it is increasingly important to use a simple method to make forest structure more cost effective. Another important factor is to produce CNT forests directly on the surface of the substrate without the oxide support layer [7], which requires better catalyst adhesion for many substrates and allows the production of CNT forests in fewer steps. In this research, we would like to produce CNT forests on a titanium substrate using a simple layering method such as dip-coating. Then we want to investigate whether it is possible to directly achieve the CNT forest structure on the titanium substrate without the absence of the support oxide layer, and whether the heat-treatment phases used during the layer construction are necessary to fix the catalyst layer on the substrates.

Experimental
During the syntheses, a titanium substrate was used, for which layer building was a simple process, which was dip-coating. The catalyst was Fe- and Co-nitrate mixed in absolute ethanol at a concentration of 0.11 M and the catalyst ink ratio was Fe:Co = 2:3. The substrate was heat-treated in different phases, before and after the catalyst construction, and in some cases an Al-nitrate layer was built on the surface of the substrate due to the formation of the support oxide layer. The samples containing catalyst layer were synthesized by the quartz reactor already containing the sample in a pre-heated tube furnace at 700°C and synthesized at this temperature. The role of the carrier gas in the system was to provide a nitrogen as well as an oxygen free

environment, hydrogen was used to reach the reduction environment, and the carbon source was ethylene.

Results and discussion

In the research, a thin layer was formed on a titanium substrate by dip-coting method based on the parameters described in the experimental section. Before the catalyst layer building, the substrate was subjected to heat-treatment in some cases, to observe whether a native oxide layer formed on the substrate surface during heat-treatment is necessary to achieve the desired structure, and an alumina-oxide layer was also built on the substrate surface to see how these parameters affect the growth of CNT forests.

In addition, in all cases the structure characteristic of the CNT forest appeared on the substrate, even in the case when the heat-treatment did not take place after the substrate or the catalyst. This may be due to the fact that the synthesis took place at high temperatures and it was possible for the iron- and cobalt-nitrate in the reactor to decompose to oxide at the beginning of the synthesis, after which carbon detachment on the catalyst particles may occur. However, in cases where alumina-oxide was present on the substrate surface, the height of the CNT forests was significantly higher and the carbon nanotube forests did not appear uniformly on the substrate, while without support oxide, the CNT forest structure appeared more ordered on the substrate. In the sample without heat-treatment, the height of the CNT forests was only 5 µm, and it should be taken into account that if without heat-treatment is applied at all, in that case the production can be made more cost-effective.

Conclusion

Summarizing it can be concluded that it was possible to produce CNT forests with a simple catalyst layer building method. Also, there is no need for the presence of a support oxide layer on the surface of the substrate, could be produce CNT forests directly on the substrate. In addition, there is no need for a heat-treatment phase to stabilize the catalyst thin film on the surface of the substrate, thus making the production of carbon nanotube forests more cost-effective.

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