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Improvement of Growth Yield of Multi-Walled Carbon Nanocoils by Mesoporous Materials and Sn Amount

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Multi-walled carbon nanocoils (MWCNCs) have been successfully synthesized by catalytic chemical vapor deposition (CVD) using Fe-Sn catalyst supported on mesoporous materials. Fe was supported on mesoporous materials in the ethanol solution of iron acetate, and Sn was deposited on the Fe-supported mesoporous materials using vacuum evaporation to form Fe-Sn nanoparticles. Zeolite and MCM-41 were used as a mesoporous material, and the length of Sn wire evaporated and reaction time were varied in the experiment. It was shown that zeolite with its smaller pore size worked better for MWCNCs growth than MCM-41 did. It is believed that the size of Fe-Sn catalyst nanoparticle was larger than that of the pores of zeolite and the catalyst nanoparticle stayed outside the pore, instead of entering into it. This makes carbon adsorption on catalyst nanoparticle easier during MWCNC synthesis. Evaporation of Sn for the formation of Fe-Sn catalyst resulted in a higher growth yield of MWCNCs than the previous catalyst supporting method that uses the acid solution of both Fe and Sn. Transmission electron microscopy observation revealed that MWCNCs grown have multi-walled graphitic layers (ca. 19 layers) with a hollow structure in the center of the tubes.
Key words: Multi-Walled Carbon Nanocoils, Catalytic Chemical Vapor Deposition, Zeolite, MCM-41, Scanning Electron Microscopy

1. INTRODUCTION

Carbon nanotubes (CNTs) have attracted intense attention since their discovery by Iijima in 1991 [1]. CNTs are a form of crystalline carbon by rolling graphene sheet into a tubule with various chiralities. A single graphene sheet that is rolled into a tube is called single wall CNTs (SWCNTs) whereas multi-walled CNTs (MWCNTs) are formed by rolling more than two sheets of graphene. CNTs exhibit many interesting properties including high mechanical strength [2], capillary properties [3] and excellent electronic properties [4]. Due to these remarkable properties, CNTs are a potential material in applications such as nanoelectronics [5], quantum computing [6], gas sensors [7-9] and field emission materials [10].

On the other hand, a helical carbon structure which is called helical carbon nanotube (HCNT) or multi-walled carbon nanocoil (MWCNC) was successfully fabricated in 1994 [11]. It was postulated that helical shape of CNTs is formed when heptagonal and pentagonal rings are inserted into the structure of CNTs [12]. The other growth mechanisms of MWCNCs were also reported elsewhere [13, 14]. Pan *et al.* reported that MWCNCs have higher electric field emission efficiency than CNTs due to its three-dimensional structure [15]. Hence, this outstanding structure of MWCNCs with the combination of CNTs and carbon nanocoils (CNCs), an amorphous helical carbon nanofiber, are highly demanded for wide applications including superconductors [16, 17], advanced reinforcement fillers in nano-composites [18], mechanical resonant sensors [19] and electromagnetic nano-transformers or nano-switches [20]. After the first synthesis of MWCNCs in 1994, there are a lot of works toward high-yield MWCNCs synthesis [21-26]. However, high-yield synthesis of MWCNCs still remains unsolved.

CNTs have been produced using arc discharge [27], laser ablation [28], chemical vapor deposition (CVD) with and without plasma assist [29-32]. Among these synthesis techniques, CVD has advantages: a versatile method; materials formation under the melting point; simple in experiments; and ease of scale-up. To our