Phosphorus-doped multiwalled carbon nanotubes

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Multiwalled carbon nanotubes doped with phosphorus atoms have been synthesized using a solution of ferrocene and triphenylphosphine by Spray Pyrolysis method. These nanotubes exhibit a special bamboo type growth probably due to the direct formation of iron phosphate catalytic nanoparticles during the growth process. High resolution electron microscopy, X-ray photoelectron spectroscopy, X-ray diffraction analysis and other techniques were employed in this study.

Since the discovery of carbon nanotubes (CNTs), intrinsic structural and electronics properties have attracted a great deal of research interest because of its potentials applications as in nano-electronic devices, structure-reinforcing materials, catalysis, and as sensitive materials of chemical sensors for detection of a broad class of gases [1]. Designing nanotube-based nanoscale materials and devices requires the controllable modification of the physical and chemical properties of carbon nanotubes. In this sense, doping carbon nanotubes allows feasible tailoring of their electronic band structures and the other related properties. Particularly, carbon nanotubes doped with impurity atoms such as nitrogen, boron and phosphorus atoms have been increasingly attracted the attention of numerous research groups [2,3].

In this work, MWCNTs doped with phosphorous atoms have been synthesized by the Spray Pyrolysis method using a solution of ferrocene ($Fe(C_5H_5)_2$) and triphenylphosphine ($P(C_6H_5)_3$) in toluene (C_7H_8). The concentration of ferrocene was fixed in 2.0 wt %, while the concentration of triphenylphosphine was varied from 0.15 to 0.30 wt % as a phosphorous source of atoms, the oven temperature was kept constant at 850^{o}C. The advantage of this method is the capability to produce high yields of relatively clean nanotubes, via the atomization of a solution released from a glass liquid container through a preheated quartz tube. A carrier gas is also required, and for this purpose an Ar atmosphere was used with a flow rate of 1800 sccm. Low and high resolution TEM images of the as grown nanotubes showed a kind of compartmentalized morphology, probably as a result from a poisoning of the catalytic iron particles due to the presence of phosphorus known as a catalytic activity reduction of transition metal catalysts. X-ray diffraction and XPS confirmed the presence of iron phosphate as catalytic nanoparticles at different phosphorus concentration. Preliminary results obtained by EDX elemental mappings confirm the presence of phosphorus atoms essentially bonded to the iron particles instead of being in between the tubes walls. XPS measurements confirm this result. Raman spectroscopy was also used in this study.

References

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