# Suppressing the formation of impurity carbons during carbon nanotube deposition by thermal chemical vapor deposition process

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Carbon nanotubes (CNTs) have a great potential as materials for electronic devices such as field effect transistors, field emitter arrays, sensors, etc. Among several routes to synthesis of CNTs, chemical vapor deposition (CVD) seems to be the most adequate to fabricating electronic devices using CNTs in terms of self-alignment, selective growth, and low temperature synthesis. However, many problems is still to be solved before realizing the CNT electronic devices, including high purity synthesis, oriented growth, uniformity control (atomic structure, morphology, distribution, etc.), etc. In particular, the purity of CNTs has a strong effect on their electrical properties so that the impurity particles have to be stringently controlled for practical applications to electronic devices. This study investigated how to minimize carbonaceous particles co-deposited during the CNT synthesis by optimizing the compositions of growth gas mixture. Thermal CVD was used to synthesize CNTs on glass substrates with a thin layer of Fe-Ni-Co alloy catalyst. The substrates were heated by infrared lamps through a quartz window, while a gas mixture of CO and $H_2$ was fed into the chamber. In the CNT synthesis for gated field emitter arrays, we observed the formation of electrically conducting paths between the cathode electrodes and gate electrodes with the in-between insulating layer of $SiO_2$, which were incurred by deposition of amorphous carbon on the insulator walls. Here, the presence of carbon impurities were examined by Raman spectroscopy, X-ray induced photoelectron spectroscopy, and electric conductivity measurements. In addition, a substantial amount of carbonaceous particles were co-deposited with CNTs during the CVD process. To minimize the quantity of impurity carbons, the gas ratios of CO to $H_2$ were optimized. We also studied the effect of adding dilution gases of He, $N_2$, Ar (to the gas mixture of CO to $H_2$) on the purity of as-grown CNTs. The dilution of the growth gas mixture substantially changes the amount of carbonaceous particles in the CNTs as well as elimination of conducting paths between the electrodes. It seems that the addition of dilution gases change the heat exchange characteristics between gas molecules as well as between gas molecules and solid surface. The growth mechanism will be discussed in detail in terms of such a modification of heat exchange properties depending upon the dilution gases.