Ni and Fe catalysts for synthesis of carbon nanotubes by thermal chemical vapor deposition using SiO_2 and Al_2O_3 as support layers

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Catalytic thermal chemical vapor deposition (CVD) method, using a mixture of methane and hydrogen at atmospheric pressure on a horizontal tubular quartz furnace, has been our choice to study the growth of carbon nanotubes (CNTs). Thermally oxidized n-Si (100) wafers have formed the SiO_2 substrate. Dc magnetron sputtering on the same type of silicon wafers has produced the Al_2O_3 substrate. Thin metal catalyst films (1-10 nm) of iron and nickel are deposited onto SiO_2 and Al_2O_3 support substrate by electron beam evaporation. Catalyst layers break up into clusters by annealing before the start of the CVD process. Here we show the influence of the catalytic metal-substrate interaction on CNTs growth by comparison of the Ni/SiO_2, Ni/Al_2O_3, Fe/SiO_2, and Fe/Al_2O_3 systems under different process length of time. We also present an evaluation of the CNTs growth rates and the aspect ratio for each system. The oxide layers are analyzed by atomic force microscopy (AFM). High resolution scanning and transmission electron microscopy and Raman spectroscopy characterize the as-synthesized products. The results show markedly differences among the studied systems that strongly affect the CNTs growth. A new kinetic model of CNT nucleation and growth is developed where the energetic aspects of the process are shown to be essential.