

# Electron Beam Induced Deposition of Cobalt for Use as Single-Wall Carbon Nanotube Growth Catalyst

M. H. Ervin and B. M. Nichols  
U. S. Army Research Laboratory, 2800 Powder Mill Road,  
Adelphi MD 20783-1197

EBID of metals has been developed for a number of applications including circuit edit, mask repair, and nanostructure fabrication. Unfortunately, EBID typically deposits poor quality metal composed of nanocrystallites of metal in a carbonaceous matrix. However, this composition is actually advantageous for use as a catalyst for carbon nanotube (CNT) growth where the catalyst size affects the resulting nanotube diameter. Previous workers have established that the deposit composition and the size of the nanoparticles can be affected by deposition conditions such as beam current<sup>1</sup> and energy<sup>2</sup>. CNT growth has been demonstrated using EBID catalyst, with the resulting nanotubes having diameters of 20-50 nm<sup>1,3</sup> which indicates that they are multi-wall CNTs. Here we deposited cobalt, using cobalt tricarbonyl nitrosyl as the precursor, and then oxygen plasma ashed the deposits to expose the cobalt nanoparticles for the growth of CNTs using a CVD process. The cobalt deposits resulted in multi-wall CNTs growing vertically from the main deposits, but single-wall CNTs were seen in the areas surrounding the intentional deposits due to incidental deposition during SEM navigation (Fig. 1). Deposits made using increasing doses (and fluences) were found to vary from unobservable (in the SEM), to a visible deposit with SWCNTs only (Fig. 2.), to deposits having MWCNTs. Future work is required to optimize the EBID, plasma ashing, and growth processes for the desired CNT growth.

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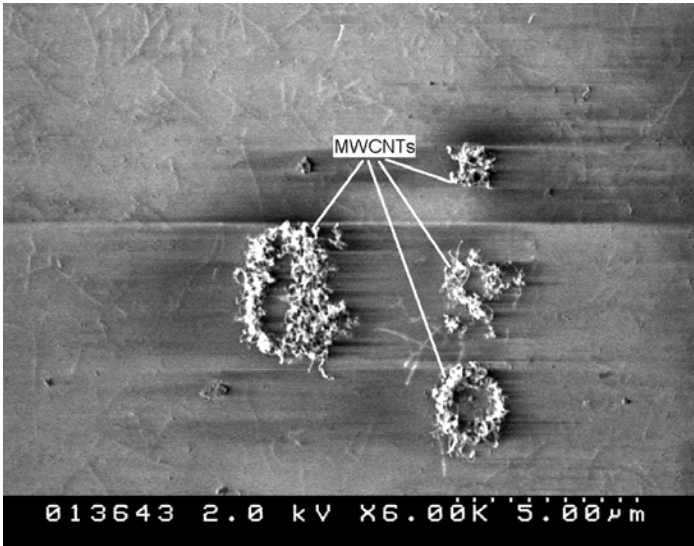


Figure 1. SEM image showing vertically grown MWCNTs at the patterned EBID deposits and SWCNTs growing along the surrounding sample surface where residual cobalt was deposited during imaging for navigation purposes. No CNTs are seen several microns away where the sample was not imaged in the presence of the precursor.

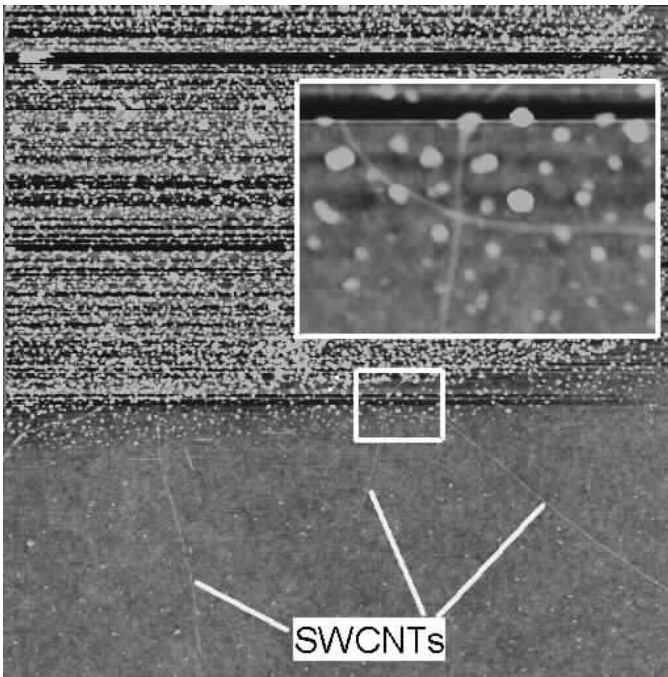


Figure 2. AFM image of an EBID deposit which produced only SWCNTs. The inset is a blow-up of the marked area in the image showing 1-2 nm diameter SWCNTs growing out from the deposit. The deposit was made using a 10 kV/~200 pA beam rastered over a 10 x 10 micron area for 3 minutes. The local gas pressure is unknown, but the gas flow from a 24 gauge needle in close proximity to the deposition site resulted in a chamber pressure of 4E-5 torr.