

Catalysis of CVD Carbon Nanotube Growth by Cobalt Ion Implantation of Silicon

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The use of carbon nanotubes as new materials for solid state electronics applications is widely desired and discussed, but lack of control of the placement of CNTs on the silicon surface has limited the fabrication of functioning devices. We believe that CCVD (catalytic chemical vapor deposition) using catalyst aggregates that are fixed in the silicon surface may provide a route to better placement control of this versatile material.

We have modified our previously reported catalytic chemical vapor deposition conditions¹ to allow for the deposition of multi-walled carbon nanotubes on silicon wafers that have been ion implanted with cobalt. Reactive ion etch using CF₄ was used to expose the peak Co concentration, ca. 4 x 10¹⁶ ions/cm². Annealing this surface *in vacuo* at 700°C for 10 minutes produced cobalt-rich catalyst islands that were characterized by SEM, AFM and EDX spectroscopy, and were comparable to literature results for annealing of iron (Fe) ion-implanted wafers.²

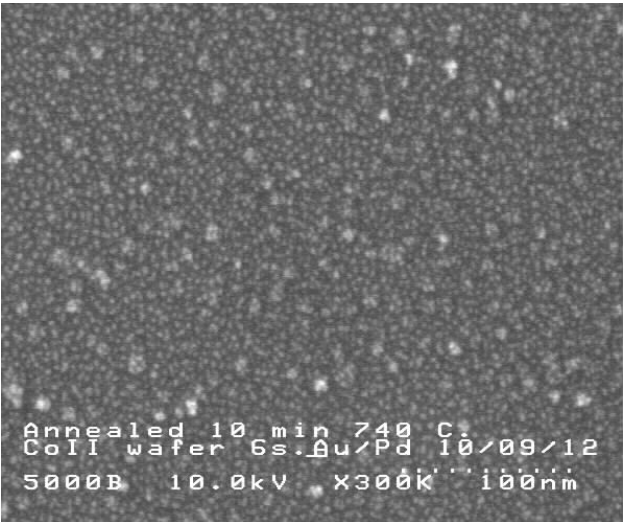


Figure 1. SEM of annealed cobalt ion-implanted silicon wafer surface, showing Co-rich catalyst islands.

After annealing, CVD growth was conducted, using acetylene as the precursor. Substrate temperature, total reactor pressure and growth time were varied systematically, but typical conditions were 700-750°C, at 0.5-1.0 torr total pressure, for a growth time of 30 minutes. Substrates treated in this manner appeared unchanged by the naked eye, but Raman spectroscopy revealed the presence of the D- and G-bands typical of multi-walled CNTs. SEM and AFM analysis confirmed the presence of a low density of short nanotube segments on the surface, as can be seen in figure 2. CNTs grown by this process are fairly uniform with a diameter distribution in the range of 10-30 nm. While most CNTs were short segments, some aspect ratios >1000 were also

observed. Tube length and density of surface coverage were studied as a function of acetylene pressure and deposition time.

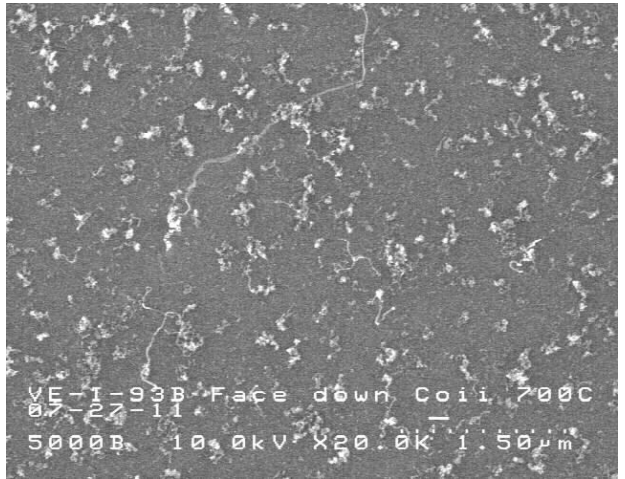


Figure 2. SEM of nanotubes grown on cobalt ion-implanted Si wafer at 700°C and 0.75 torr of acetylene.

(1) Smart, C.J.; Pearce, M.A.; Oh, S.P.; Hudson, R.; Alles, A.; Kaur, S.; Belli, S.L., *ECS Transactions*, **2011**, Vol. 35(25), pp. 13-21.
(2) Choi, Y.; Sippel-Oakley, J.; Upal, A. *Appl. Phys. Lett.*, **2006**, Vol. 89(15), 153130.