Supporting Information

Engineering the Activity and Lifetime of Heterogeneous Catalysts for Carbon Nanotube Growth via Substrate Ion Beam Bombardment

A. E. Islam[1,2,‡], P. Nikolaev[1,2,‡], P.B. Amama[3], S. Saber[4], D. Zakharov[5], D. Huffman[1,2,6], M. Erford[7], G. Sargent[1,2], S. L. Semiatin[1], E. A. Stach[5], and B. Maruyama[1,]*

[1]*Materials and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio 45433*

[2]*Biological and Nanoscale Technologies, UES, Inc., Dayton, Ohio 45432*

[3]*Department of Chemical Engineering, Kansas State University, Manhattan, Kansas 66506*

[4]*School of Materials Science and Engineering, Purdue University, West Lafayette, Indiana 47907*

[5]*Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, New York 11973*

[6]*Department of Physics, Wright State University, Dayton, Ohio 45435*

[7]*Southwestern Ohio Council for Higher Education, Dayton, Ohio 45403*

[‡]*These authors contributed equally.*

Section S1: Calculation of ion beam dose

The measured current in the ion gun: I_1 [Amps]

The spot area of ion beam: A ~ 0.09 [cm^2]

The number of Ar^+ ions injected per unit area per sec, $N_1 = I_1/qA$ [cm^{-2}-sec^{-1}]

where, $q = 1.6 \times 10^{-19}$ [Coulomb] is the charge of electron.

The Ar^+ ion dose = N_1 x The duration of ion exposure [cm^{-2}]

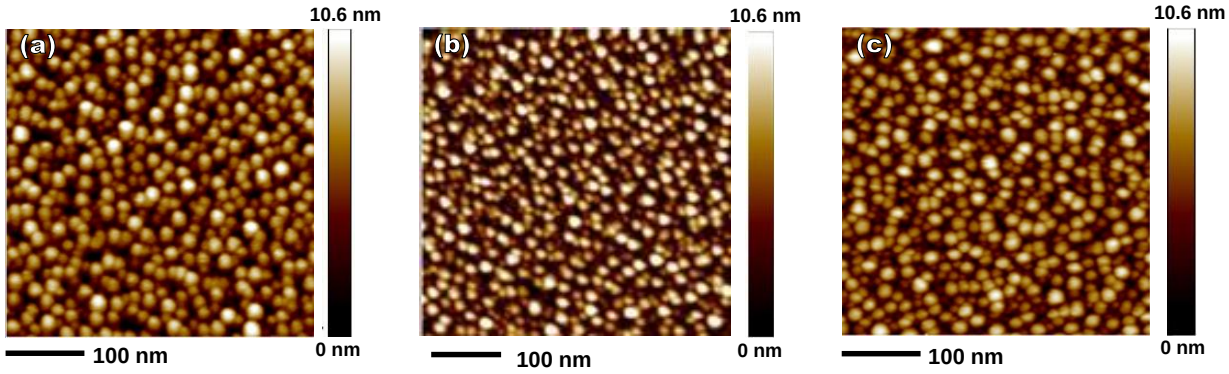

Figure S1. AFM topography of Fe nanoparticles formed on sapphire surfaces with increased degree of damage: Sapphire surfaces were damaged using Ar^+ ion accelerated at (a) 3 kV, (b) 5 kV, and (c) 6 kV at a fixed dose of 2.1×10^{20} cm^{-2}. To form these nanoparticles on damaged sapphire surfaces, Fe film of ~ 1 nm was coated on the surfaces, which was followed by a 10 min hydrogen anneal at 585 ^{0}C. Catalyst particles show a reduction in size (with lower surface roughness) and increase in areal number density with increasing damage, as summarized in Figures 3(d) and 3(f).

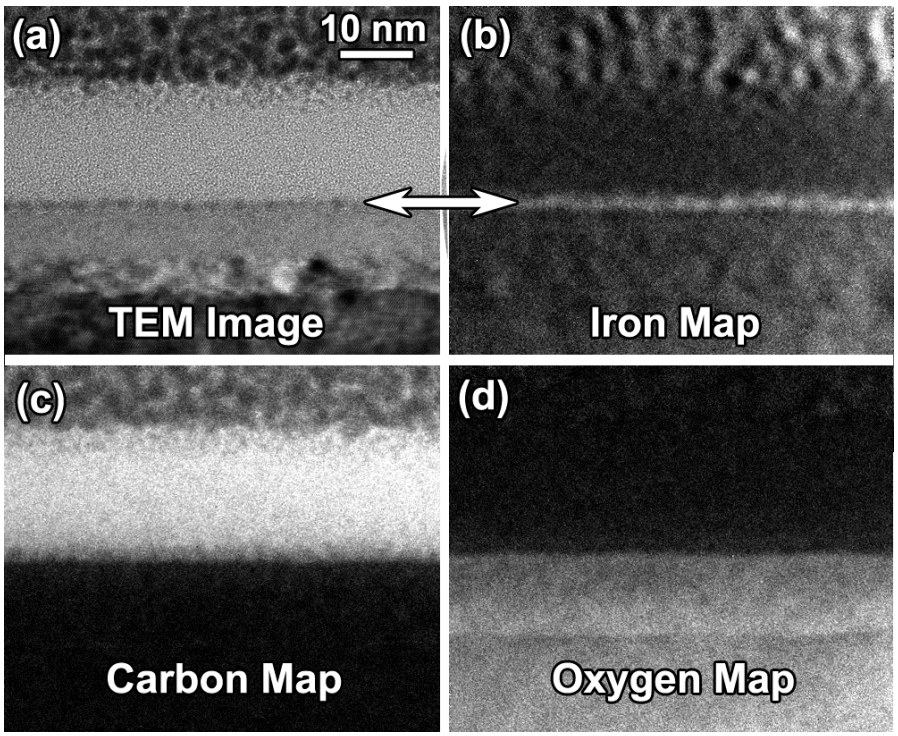

Figure S2. Method of identification of materials in different regions in Figure 5 using energy filtered maps: (a) TEM image of ion beam bombarded sample (same as that in Figure 5) with corresponding energy filtered maps for (b) iron, (c) carbon, and (d) oxygen. White double headed arrow shows iron layer on images (a) and (b).

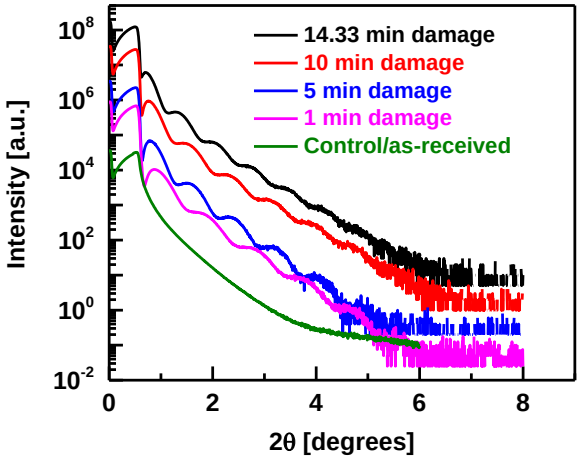

Table: Extracted damage depth after sapphire surfaces are bombarded for different durations using a Ar^+ ion beam at a rate of $2.4x10^{17}$ ions/cm²/sec with an acceleration voltage of 5 kV.

Duration of ion exposure [min]	Total ion dose [ions/cm²]	Damage depth [nm]
14.3	$2.1x10^{20}$	12.8
10	$1.4x10^{20}$	11.3
5	$0.7x10^{20}$	10.9
1	$1.4x10^{19}$	9.4
0	0	0

Figure S3: X-ray reflection (XRR) patterns obtained from ion beam damaged sapphire substrates for different damage duration at a fixed rate of $2.4x10^{17}$ Ar^+ ions/cm^2/sec and for a 5 kV acceleration voltage. The table in the right presents the damage depths for different durations of ion exposure.