シャッタースパッタリング触媒上の単層カーボンナノチューブ成長における画像解析

Image Analysis for SWNT Growth on Shutter Sputtered Catalyst

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[Introduction] Carbon Nanotubes (CNTs) have been used in remarkable ways since their discovery in 1991 by Sumio Iijima. Properties such as high thermal conductivity, good mechanical strength, and electrical conductivity are what make CNTs attractive[1]. Some of their applications include water filtration, vehicles, energy storage, and now there is great potential in the biomedical field for CNTs as composites in tissue engineering, therapeutics carrier across the blood-brain barrier, cancer treatment, and much more[1]. The issue that comes with Single-Walled Nanotubes (SWNTs) however is Ostwald ripening of catalyst and low CNT production. It is difficult to control gas parameters for hydrogen and argon, and can be dangerous in a smaller lab, so acetylene without dilution gas is used. One study to lessen the effects of Ostwald ripening and produce “uniform and dense CNPs” did catalyst reduction at a lower temperature, then exposed to a higher one for annealing in argon gas[2]. The method proposed here is, utilizing shutter sputtering[3] of Iron on a th-SiO2/AlO substrate, followed by thermal chemical vapor deposition (CVD) for annealing[4]. Shutter sputtering allows greater particle adhesion to the substrate due to wavelength and energy changes, which allow for smaller catalysts to grow and greater possibility of long SWNTs. We compare the effects of Ostwald ripening on catalysts formed on a Fe shutter sputtered substrate annealed at 730°C and another at 760°C, in order to identify the correlation between size and distance of catalyst particles for SWNT growths through Atomic Force Microscopy (AFM) image analysis.

[Methods] A th-SiO2 substrate was shutter sputtered with iron (0.8nm) for 21.53 seconds and aluminum (30nm) for 19 minutes and 24 seconds in a gaseous environment of O2 10^{-3} Pa and Argon 0.8 Pa. The substrate was then annealed in thermal CVD at 760°C, which when cooled was then analyzed through the AFM. The same process had been done before by a previous student but at 730°C and the AFM images were analyzed to be used as a comparison.

[Results] The 730°C AFM image shows many catalysts with green centroids and Voronoi edges, while the 760°C catalysts are less and blurrier but also have green centroids with the Voronoi edges. The distance among the particles was also observed and distributed in histograms. Radii distribution for both annealings produced a right-skewed distribution. Voronoi area distribution for 730°C annealing was normal while 760°C annealing was not.

[Discussion] In order to find the relationship between distance and size of the catalysts, catalysts of [1-20nm] radii were identified for 730°C annealing and [5-50nm] for 760°C. Ostwald ripening causes large catalysts to form, forming a vacuum of space around. Using the Voronoi functions in MATLAB the areas of the ploy shapes, which include the vacuum of space around the catalyst, were found and could be compared to the distribution of the distance between catalysts. It can be observed that the 730°C catalysts, Fig.1, have clearer identification vs the 760°C. For 730°C the mean Voronoi area was about 400nm^2 with a mean radius of around 3nm. For 760°C the Voronoi area distribution had a decline with a mean radius of around 7.5nm.

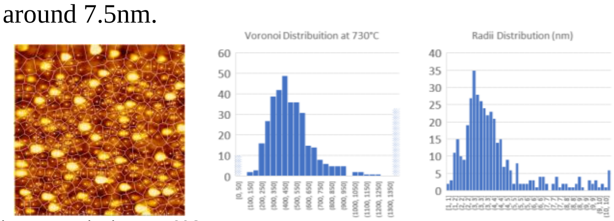

Fig. 1 Voronoi Edges at 730C

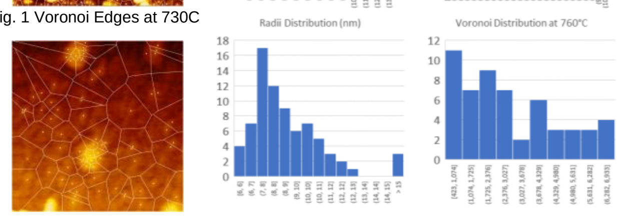

Fig. 2 Voronoi Edges at 760C

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