SELF-ASSEMBLED SURFACE STRUCTURES CAUSED BY ARGON ION BOMBARDMENT OF RETICULATED VITREOUS CARBON (RVC)

Rebecca J. Chacon[1] and Charles E. Hunt[2*]

[1)]Chemical Engineering and Materials Science, University of California, Davis CA 95616 USA
[2)]Electrical and Computer Engineering, University of California, Davis CA 95616 USA
Corresponding Author: Phone (530)752-1958, Fax 530-752-8428, hunt@ucdavis.edu

In our previous work[1-4], a method for surface treating Reticulated Vitreous Carbon (RVC) was outlined. Argon-ion bombardment of carbon surfaces has been shown to create modifications at the surface level. These modifications result in the improvement of field emissive properties, namely the onset of field emission at lower fields and higher current density compared to other carbon materials.

In the current work, thirty-four samples of RVC were surface treated under various conditions of argon-ion beam voltage, beam current and duration. Surface treatment duration varied from 3.5 minutes to one hour in length. The resultant self-assembled surface features, observed by Scanning Electron Microscopy (SEM), demonstrate improved field emission both by being geometrically-beneficial emission sources as well as because of induced modifications in sp^2- and sp^3-bonds at the surface. Examples of the types of structures formed by ion irradiation are seen in Figure 1(A-F) which show variations in a few of these structures over the duration of irradiation. Language falls short of completely describing the observed structures (such as carbon cones, whiskers and nanotubes.) Generally, with increased irradiation time we have noticed increases in feature sizes as well as overall feature density, seen best at 2000x magnification (Figure 1(A-C)). In many of samples, there is the tendency for self-assembly to proceed along ridges not appearing to be part of the overall initial strut morphology of the RVC. Such a ridge formation is seen in Figure 1 (A,D).

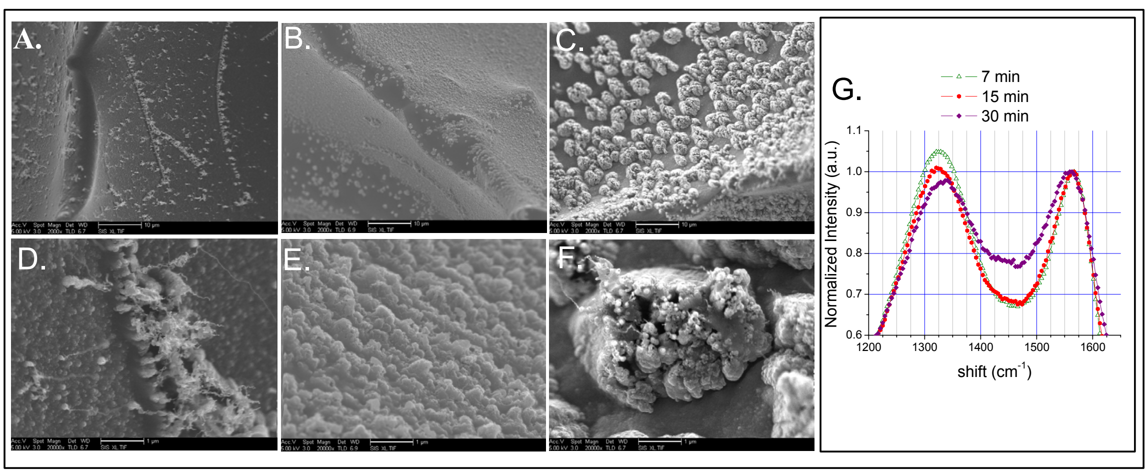

Figure 1: SEM images of RVC irradiated for 7min (A,D), 15 min (B, E) and 30 min (C,F) shown at 2,000x (A-C) and 20,000x magnification (D-F). Samples irradiated at 200mA beam current and 1,200V beam voltage. Raman spectra for similar time duration samples irradiated at 100mA beam current and 1,200V beam voltage is provided as figure G.

1-4244-1134-3/07/$25.00©2007

Raman Spectroscopy demonstrates the change in bonding characteristic at the surface as seen in Figure 1(G) which compares (normalized to the G band) samples irradiated at 1200V and 100mA for differing times. The change in the intensity and position of the "D" (disorder) band due to the type of clustering seen in Figure 1(A-F) is evident, with the trend being an increase in the D peak, and typically a narrowing of the FWHM as well. Cases which do not follow this trend are being investigated.

Field emission from the irradiated samples shows improvement in uniformity with increased surface structuring. Samples were subjected to an applied electric field and the resulting emission response is recorded in Figure 2(A-C). Details of the portions of each graph, at the region of emission onset, is provided in Figure 2 with a linear fit of the data (open symbols) seen as solid lines, as well as 95% prediction bands (dashed) containing virtually all data points. If 10^{-6} A/cm^2 is considered as the onset of emission, Figure 2 shows emission as requiring applied fields of 1.38, 1.80 and 1.60 V/µm for the 7min, 15min and 30min samples respectively. The RVC cathodes were then subjected to a continuous, applied field for an extended time, after which the emission tests were repeated (solid symbols). Emission onset was then observed to occur at 1.62, 1.59 and 1.60 V/µm in Figure 2(A-C), respectively.

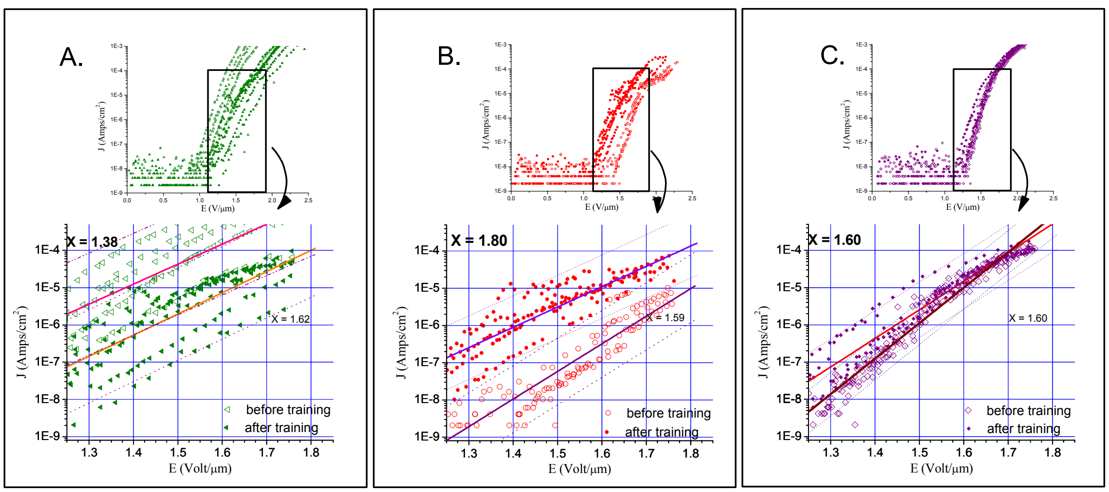

Figure 2 Current density versus Electric Field for (A) 7 minute, (B) 15 min and (C) 30 min irradiated samples at 1200V beam voltage and 200mA beam current.

The training time was not the same for each case, and so additional investigation is required. However, a rudimentary correlation between surface structure type and the onset of emission is seen. Generally, a lower field is required for clustered samples. More dense structures result in a more reproducible field requirement for the onset of emission.

1. R.J. Chacon, C. E. Hunt, "Emission Enhancement by Surface Modification of Reticulated Vitreous Carbon (RVC) ", *Digest of the 19th International Vacuum Nanoeletronic Conference*. P. 109 (2006)
2. C. E. Hunt, O. J. Glembocki, Y. Wang, S. M. Prokes, "Carbon Nanotube Growth for Field-Emission Cathodes from Graphite Paste using Ar-Ion Bombardment", *Appl. Phys. Lett., **86**, 163112 (2005)*
3. C. E. Hunt, A. G. Chakhovskoi and Y. Wang, "Ion-beam morphological conditioning of carbon field emission cathode surfaces", *J. Vac. Sci. Technology **B 23**(2) Mar 2005*
4. M. M. Cao, R.J. Chacon and C.E. Hunt, "A Field Emission Light Source using a Reticulated Vitreous Carbon (RVC) Cathode and Cathodoluminescent Phosphors", submitted to *IEEE Transactions On Industrial Applications, 2006.*