

Supplementary Information

Low-Temperature Annealing of Nanoscale Defects in Poly-crystalline Graphite

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A. Surface Pore Characterization Image J

In this study, we performed quantitative characterization of surface pores using the public domain software Image J. ImageJ is a Java-based image processing program developed at the National Institutes of Health and the University of Wisconsin. The software can analyze 8-bit, 16-bit and 32-bit images and support image stacks. It performs image processing functions such as logical and arithmetical operations between images, Fourier analysis, as well as geometric transformations such as scaling, rotation, and flips.

In this section, we describe the steps to analyze the surface pores with Image J. Images were generated with a scanning electron microscopy (SEM), consecutively taken every 60um on the surface of both untreated and treated samples. Following parameters were employed in SEM imaging.

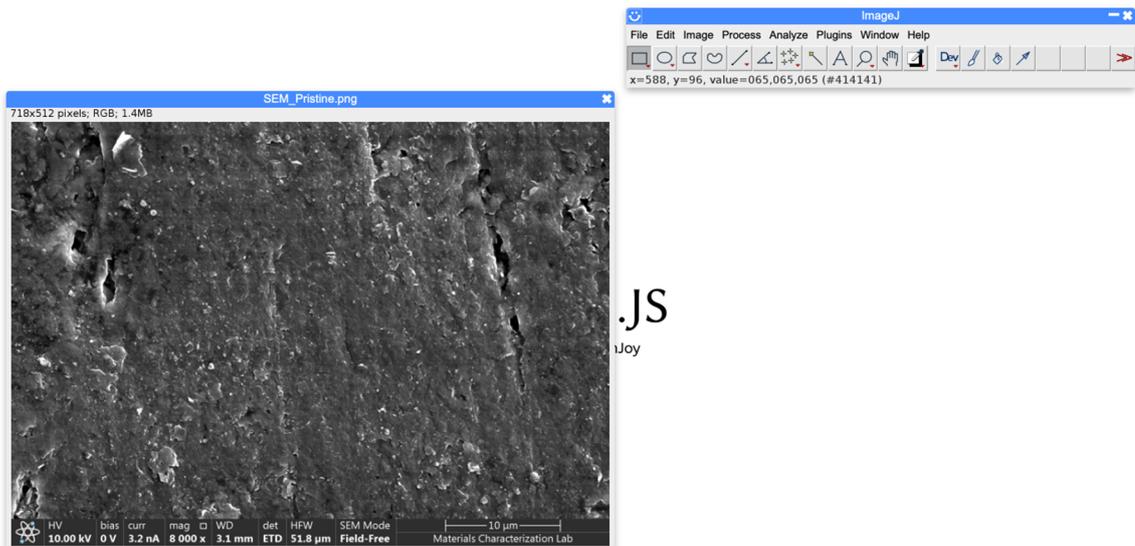
Voltage: 10 kV

Current: 3.2 nA

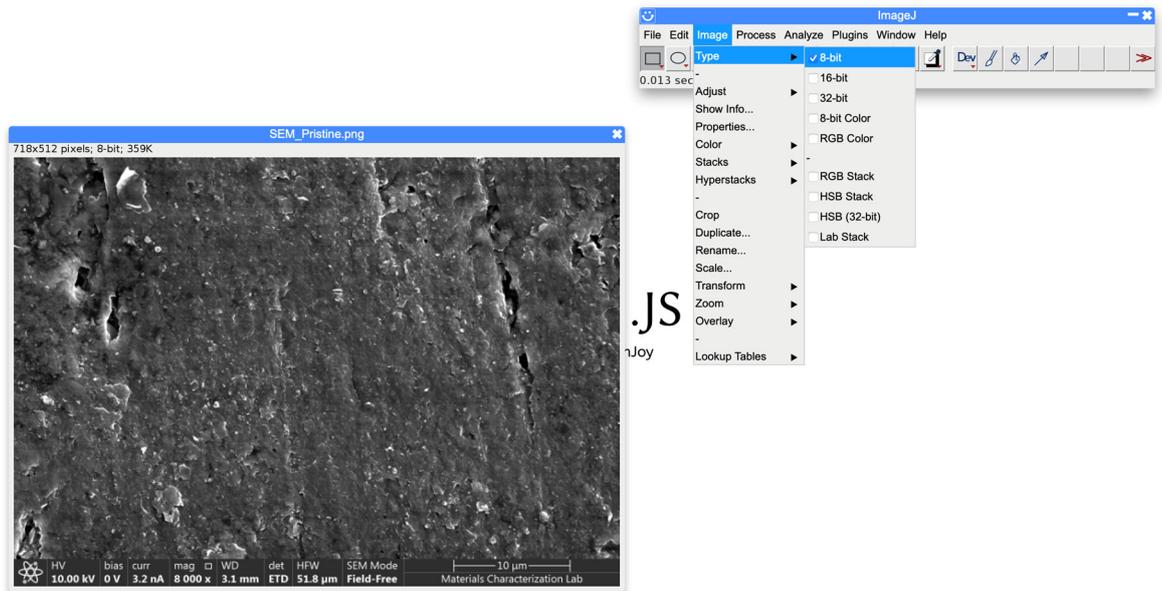
Magnification: X8000

Here are the steps to analyze the number of pores and average size with Image J

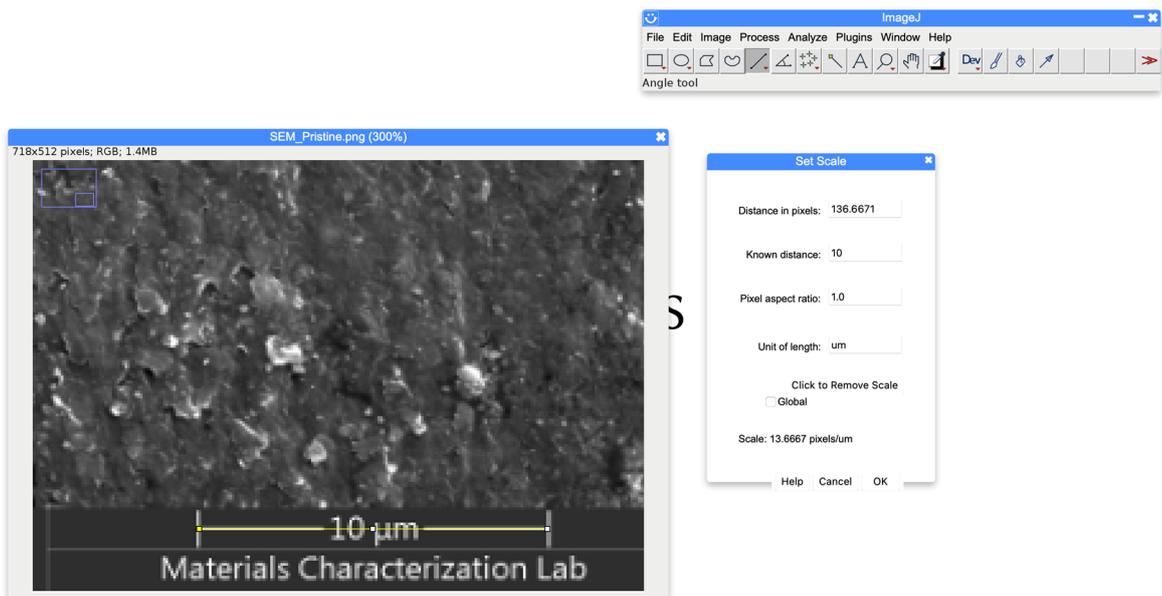
1. Load the file to Image J



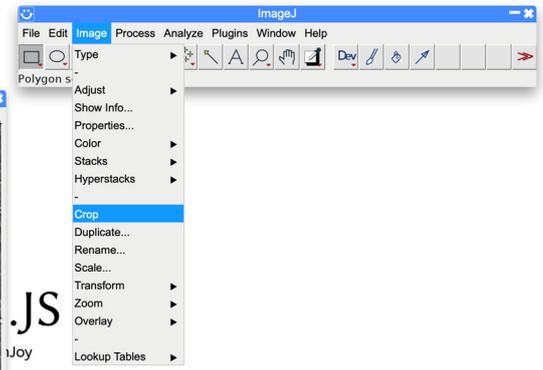
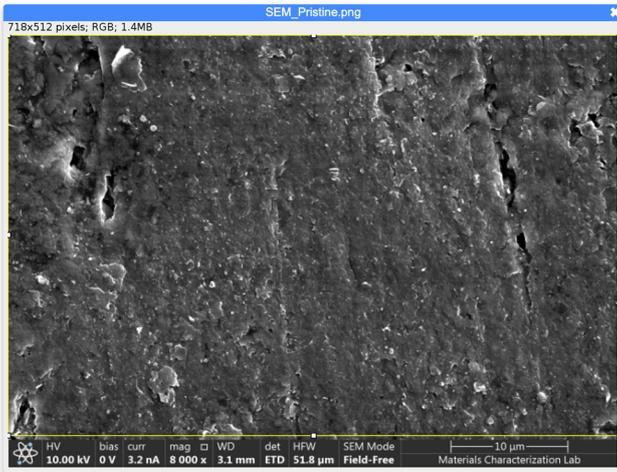
2. Convert the image to grayscale



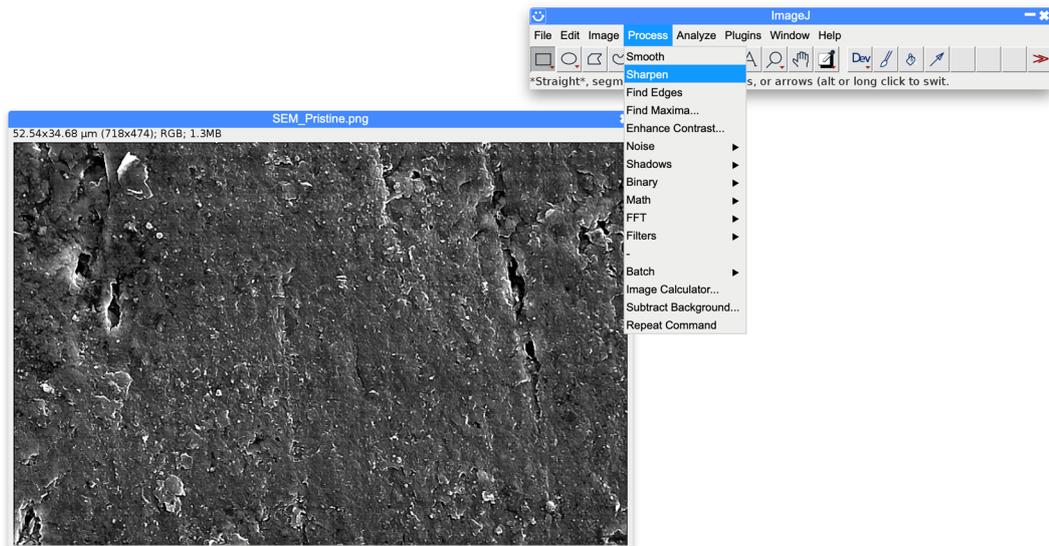
- Use the scale bar on the image to set the distance on image per pixel
Go to “Analyze” – “Set Scale” Put correct distance and unit from the given scaling bar



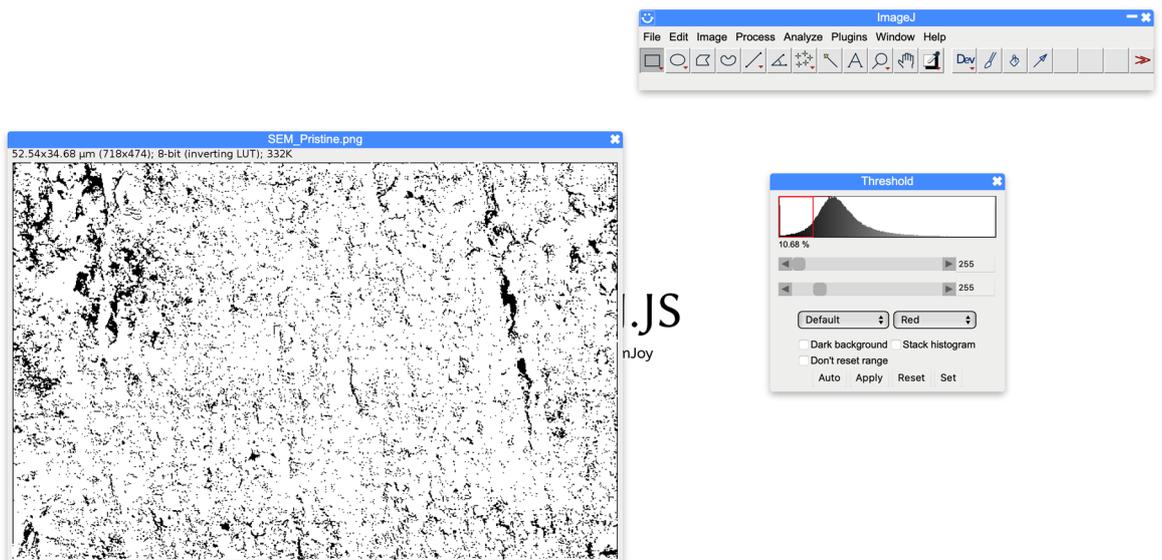
- Crop the bottom end of the image to get rid of microscopic information
Watch for the uniform cropping size



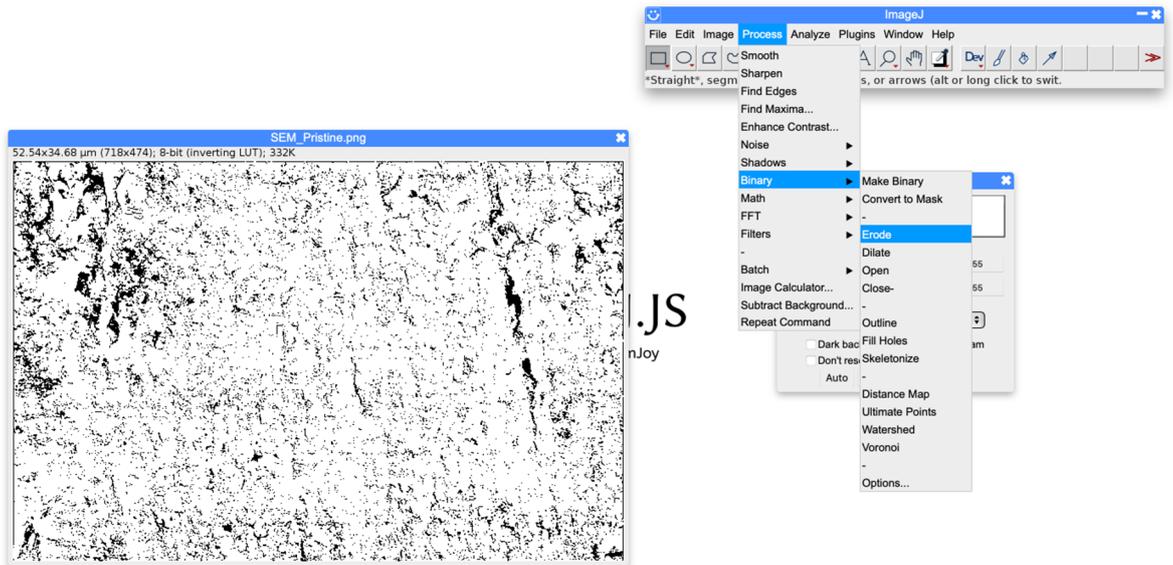
5. Go to “Process” – “Sharpen” to increase the sharpness of the image



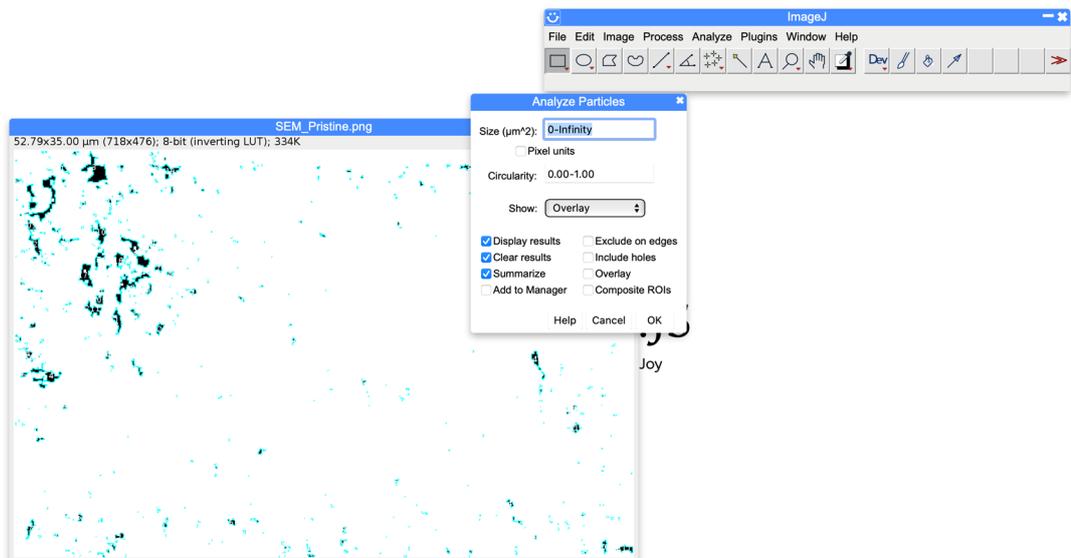
6. Go to “Image” – “Adjust” – “Threshold” (Threshold adjustment will allow bypassing only adjusted darker locations on the image)



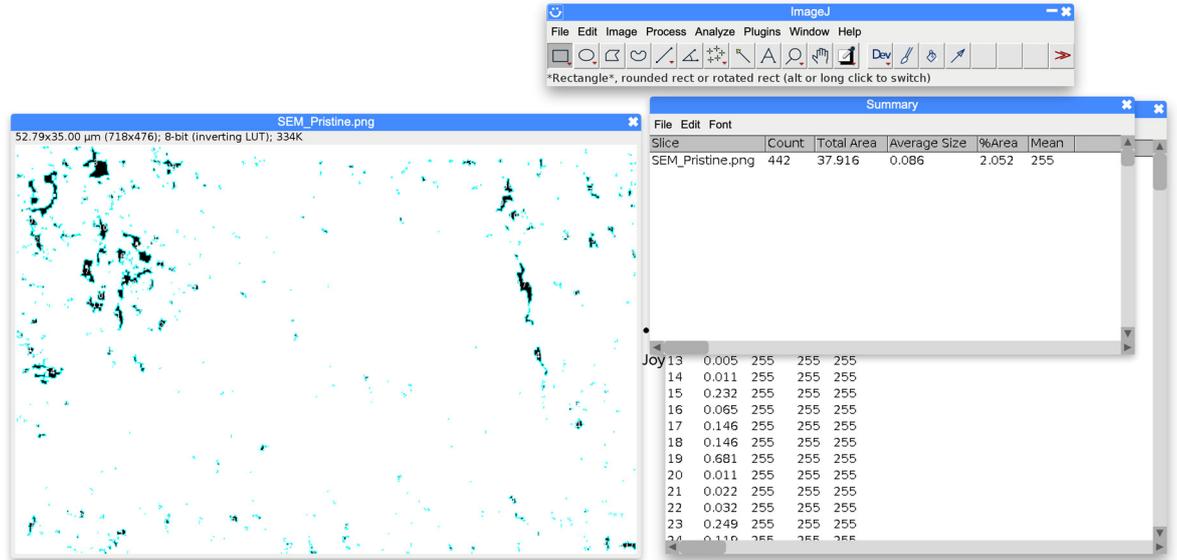
7. Apply “Erode” to filter out small noises



8. Go to “Analyze” – “Analyze Particles”
Select “Display results” and “Summarize”



9. The number of pores, total area, and average size of the pores are given in the summary
As set in the set scale, the unit of area is μm^2



B. Raman Spectra for As-received and Electron Wind Force Annealed Specimens

Raman spectra were obtained from the as received specimen as well as electron wind force treated at current densities below 25.2 A/mm^2 . Figure S1 shows the acquired data. This is the current density range for which only marginal changes in electrical resistivity were observed.

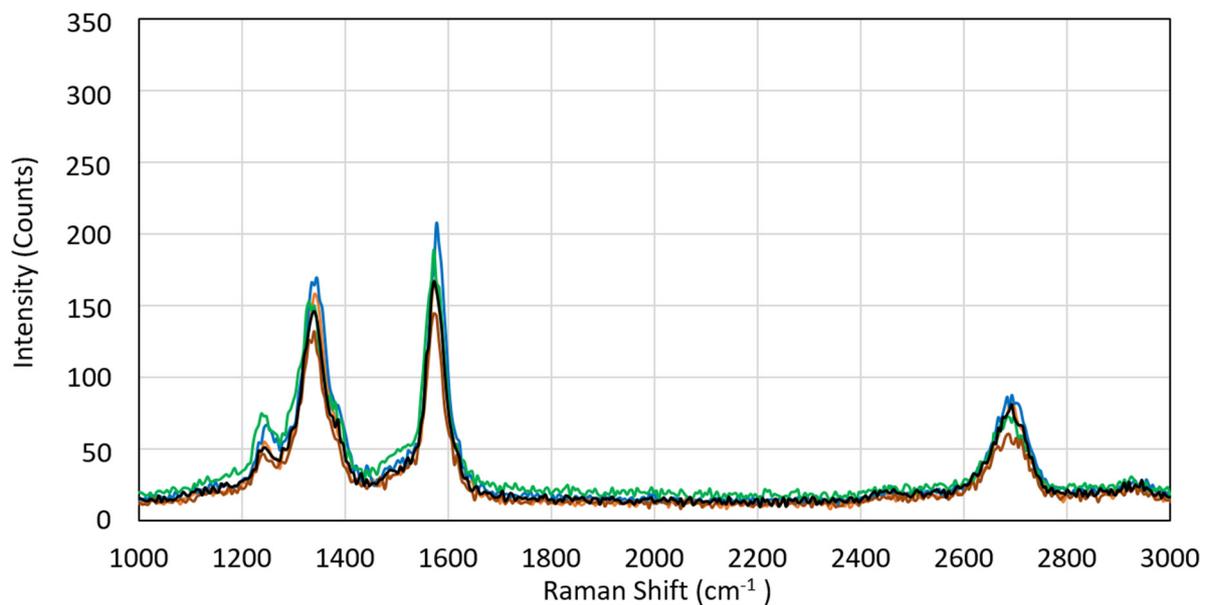


Figure S1. Raman spectra acquired at current density range of $0\text{-}25.2 \text{ A/mm}^2$.

Figure S2 shows the Raman spectra at current density range of $25.2\text{-}44.5 \text{ A/mm}^2$. The electrical resistivity was observed to be fairly constant in this range.

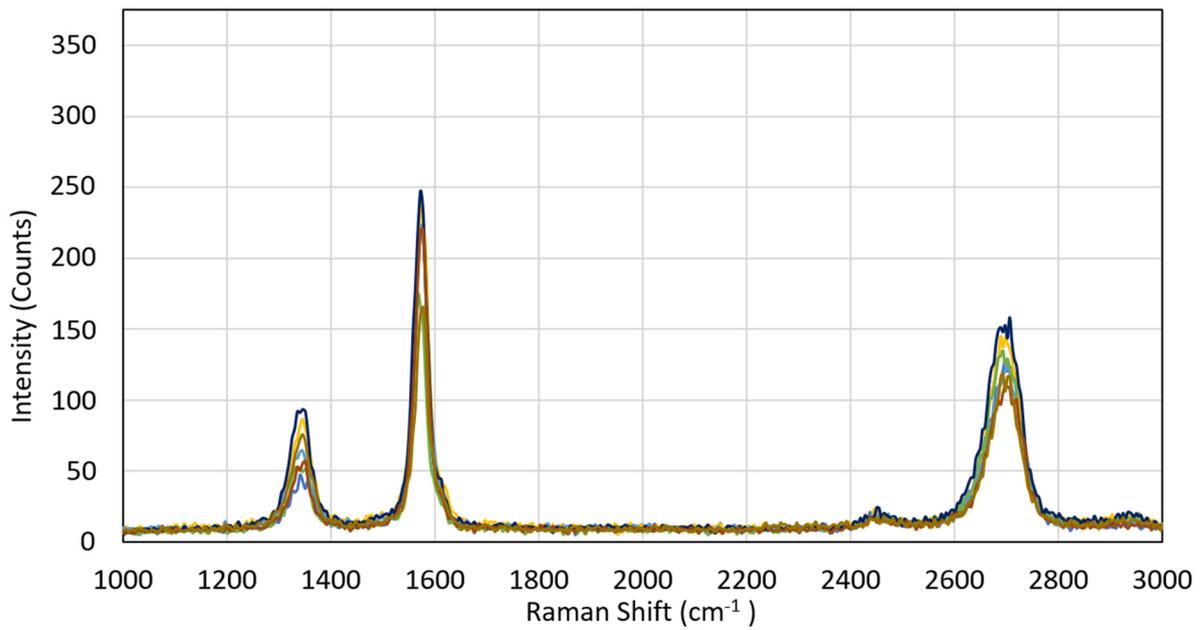


Figure S2. Raman spectra acquired at current density range of 25.2-44.5 A/mm².

C. Mechanical Properties of As-received and Electron Wind Force Annealed Specimens

Mechanical properties data showed significant scatter as shown in Figure S3 below. Therefore, at least 9 indentations were performed, and average values are reported in the study. Table S1 shows these average values.

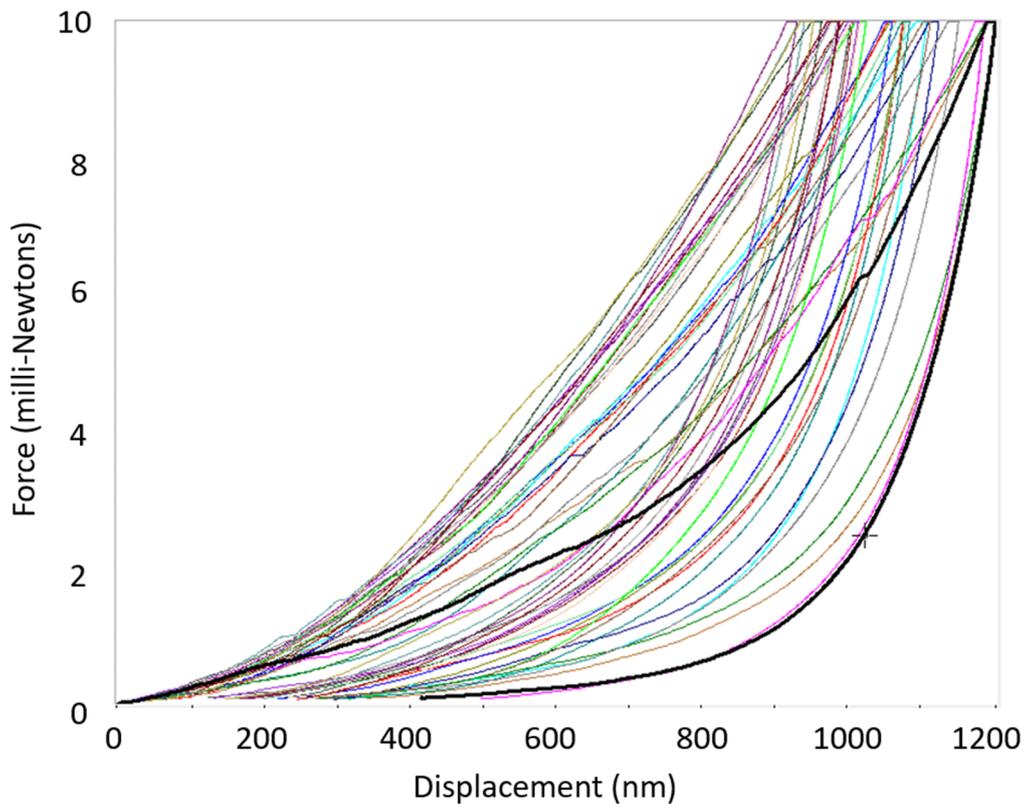


Figure S3. Juxtaposition of load-displacement curves for current density 0-25.2 A/mm².

Table S1: Average mechanical properties for different current density inputs.

Current density (A/mm ²)	Hardness (Standard deviation)	Reduced Modulus (Standard deviation)	Contact depth (Standard deviation)
0	0.38 GPa (0.14)	11.26 GPa (2.34)	1220.6 nm (287.6)
25.2	0.58 GPa (0.14)	11.79 GPa (1.01)	941.7 nm (134.9)
44.5	0.57 GPa (0.15)	11.8 GPa (1.1)	945.2 nm (145.5)