Determining the grain size of polycrystalline diamond

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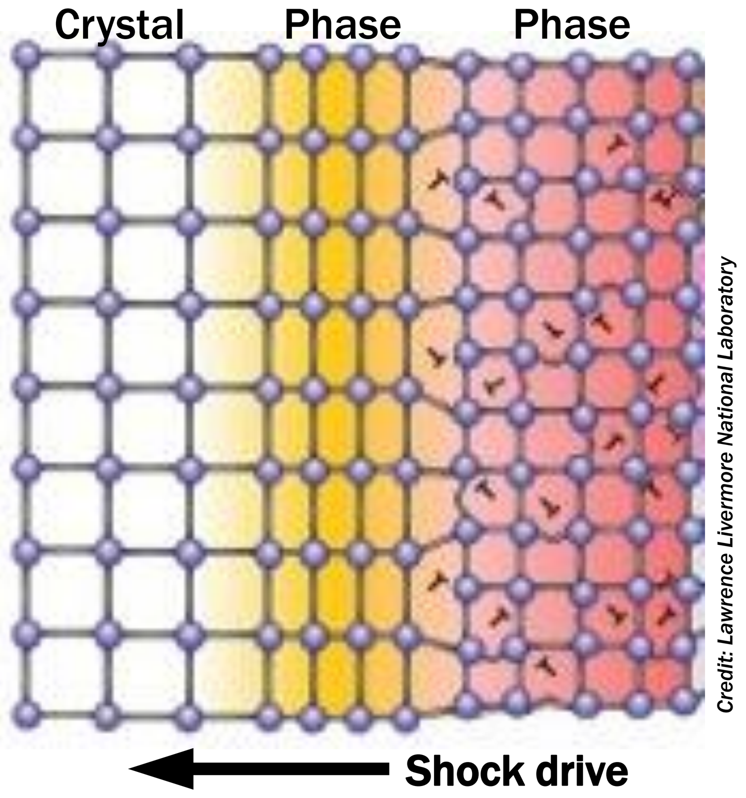
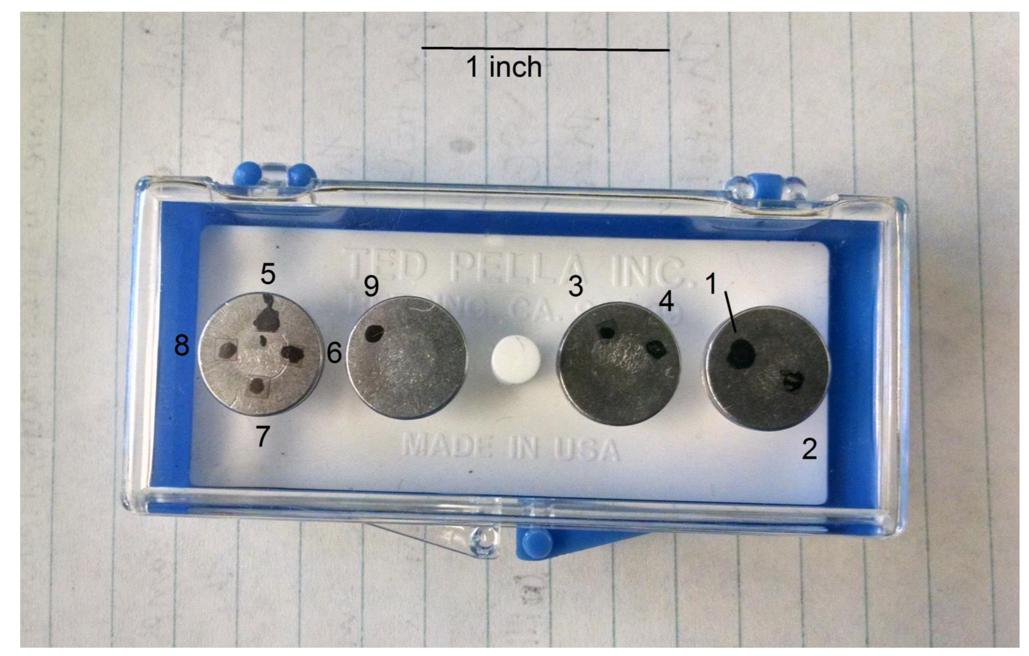
Introduction

The High Energy Density Sciences group at SLAC National Accelerator Laboratory studies materials in extreme conditions such as very high temperatures and pressures. We use shock waves produced by the Linac Coherent Light Source to compress polycrystalline diamond samples. Compressing these samples allows us to use x-ray diffraction to study the changes to the material's structure as it experiences high pressure conditions. As a result of the shock wave, the polycrystalline diamond samples undergo dynamic compression. Polycrystalline diamond is valuable to study because it can be formed into ablator capsules for use in inertial confinement fusion reactions.

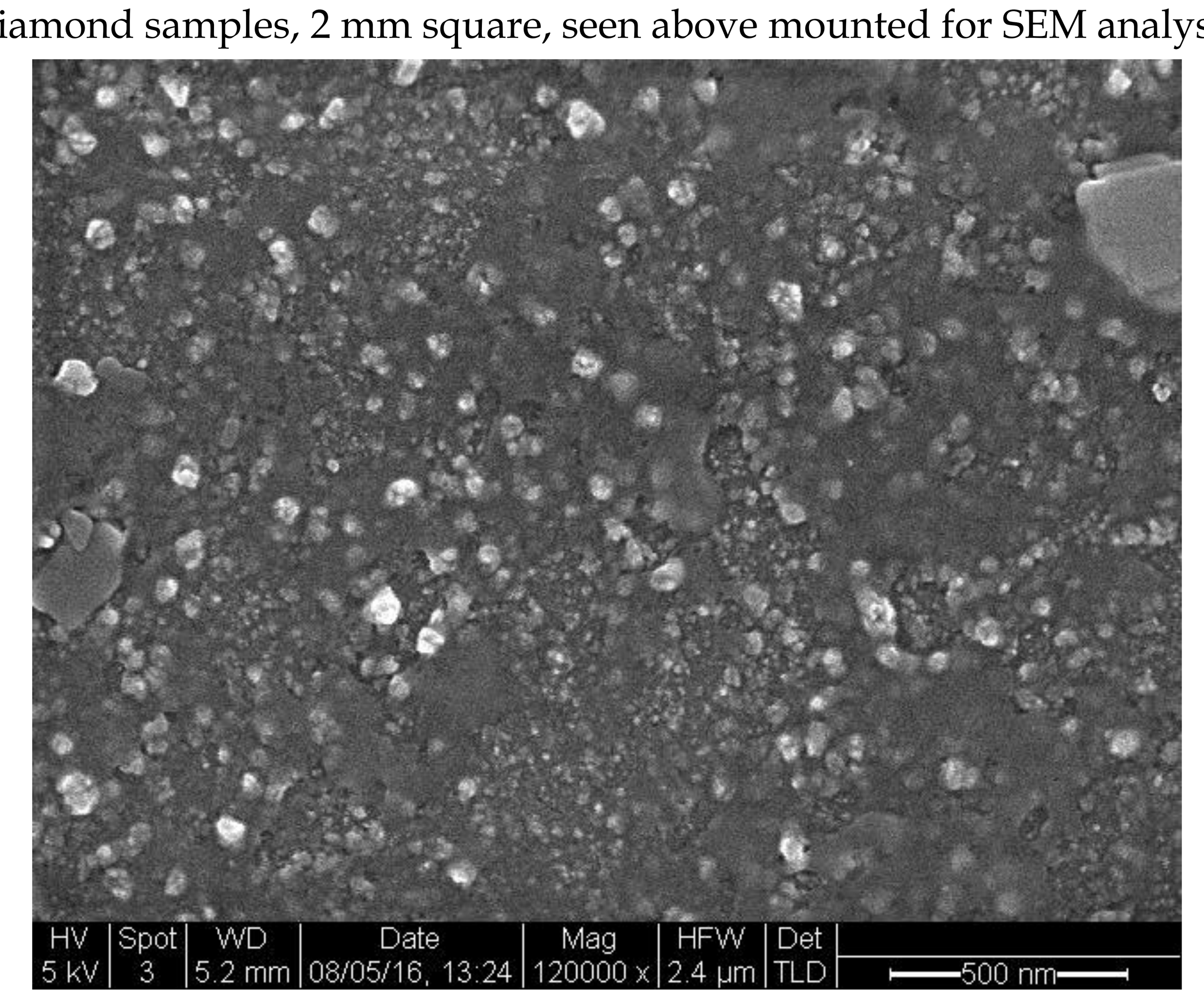


To understand how dynamic compression takes place in a polycrystalline material, we can predict the changes in the x-ray diffraction pattern that occur from the compressed material. This predictive model requires us to know the crystal grain size and orientation of our polycrystalline diamond material. Having a precise measurement of the crystal grain size in our samples will allow us to make more accurate predictions of the changes to the diffraction pattern in order to understand how the diamond sample responds to dynamic compression. Analyzing images of the samples from a scanning electron microscope (SEM) can give us information about the crystal grain size.

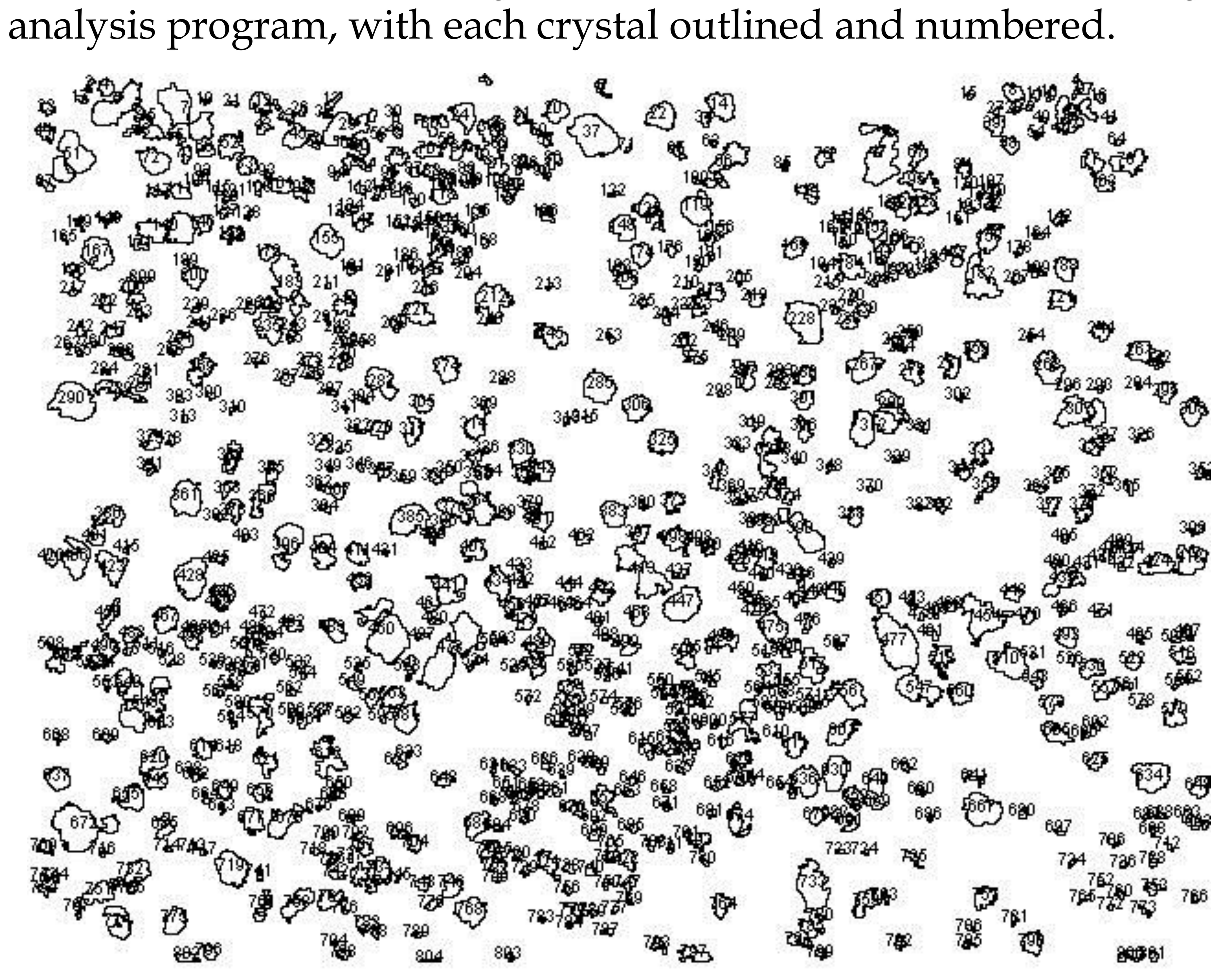
Research



Diamond samples, 2 mm square, seen above mounted for SEM analysis.



The image above shows an SEM image of the surface of the diamond sample. The image below shows the output of the image analysis program, with each crystal outlined and numbered.



Results

I worked with samples of polycrystalline diamond to measure the size and orientation of the crystals within each sample. The samples were 2mm square, and the crystals were expected to be only a few nanometers across, so this was a difficult task. I used a scanning electron microscope to view the crystals and developed a image analysis program to study the images and measure the average crystal size and orientation. I determined that the diamond crystals in our samples are 18.91 nm in diameter on average and that our material has uniformly random orientation of crystals across all areas of each sample. Crystals of different sizes or different orientations respond differently to shocks waves and compress unevenly. Studying the stress response of diamond samples under these extreme conditions is especially useful, as polycrystalline diamond shells can be used in inertial confinement fusion reactions, and we would like to be able to predict the behavior of the material during such experiments.

Further Study

We determined that the orientation of the crystals is random based on visual inspection of the SEM images, but analysis with electron backscattering diffraction imaging will allow us to see the texture and orientation of the crystals more precisely. Based on the nanometer-scale size of the crystal grains, a Transmission Electron Microscope may provide a clearer picture at this scale.

Acknowledgments

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