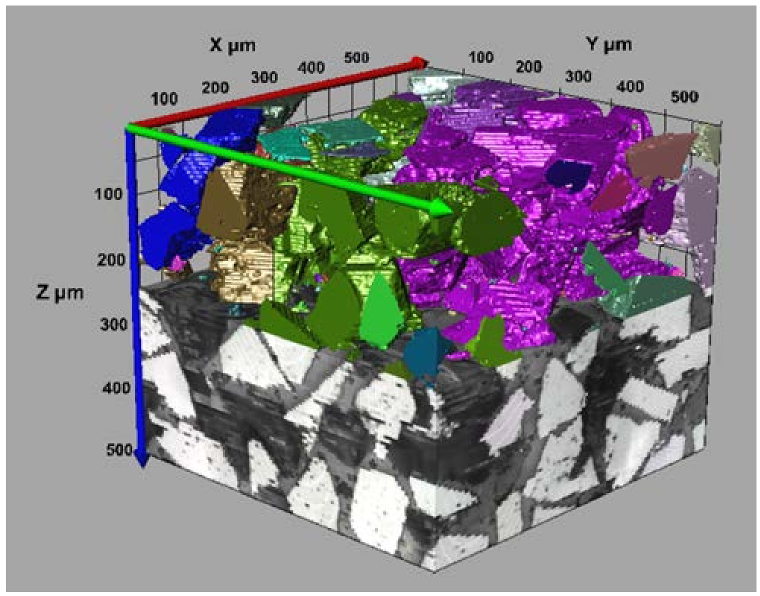
3D INSIGHTS



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3D Characterization of Abrasive Particles in Resin Bonded Cubic Boron Nitride (cBN)

We analyzed the distribution of abrasive particles, or grains, in a resin bonded cubic Boron Nitride (cBN) sample using Robo-Met.3D®. The Robo-Met.3D system revealed the desired morphology features in the sample. 3D analysis revealed a consistent volume percentage of grain distribution, compared to the section-to-section variability observed in conventional 2D analysis.

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MATERIAL BACKGROUND

Cubic Born Nitride (cBN) features a hardness and thermal conductivity approximating diamond. However its chemical and thermal stability is higher than diamond, which makes it a suitable cutting tool material for specific engineering applications[i]. Accurate characterization of abrasive particle (aka grain) distribution (size and shape) plays a critical role to analyze mechanical properties of cBN. In this application note we describe the serial sectioning analysis of a resin bonded cBN sample.

AUTOMATED SERIAL SECTIONING ANALYSIS USING ROBO-MET.3D®

Robo-Met.3D is a fully automated serial sectioning system for three dimensional microstructural reconstructions. Common applications of Robo-Met.3D include studying porosity in additively manufactured components[ii] and thermal barrier coatings[iii], and fiber orientation effects in woven materials[iv].

A proprietary resin-bonded cBN sample was provided UES, for analysis of grains. Optical images were automatically acquired with the microscope built into the Robo-Met.3D system, at a magnification of 200X. The resultant spatial resolution was 0.5 microns along X and Y axes. About half a millimeter of z-dimension was analyzed (500 microns) in 100 slices at an average slice thickness of 5.0 microns. Each slice contained a montage of 2 X 2 images, for an image size of approximately 600 microns along x and y axes each.

Fig. 1: Raw 2D Image

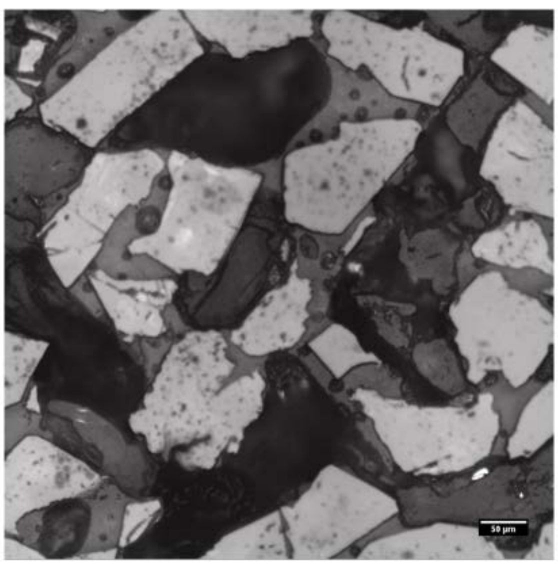


Fig. 2: 3D Image (stack of 350 slices)

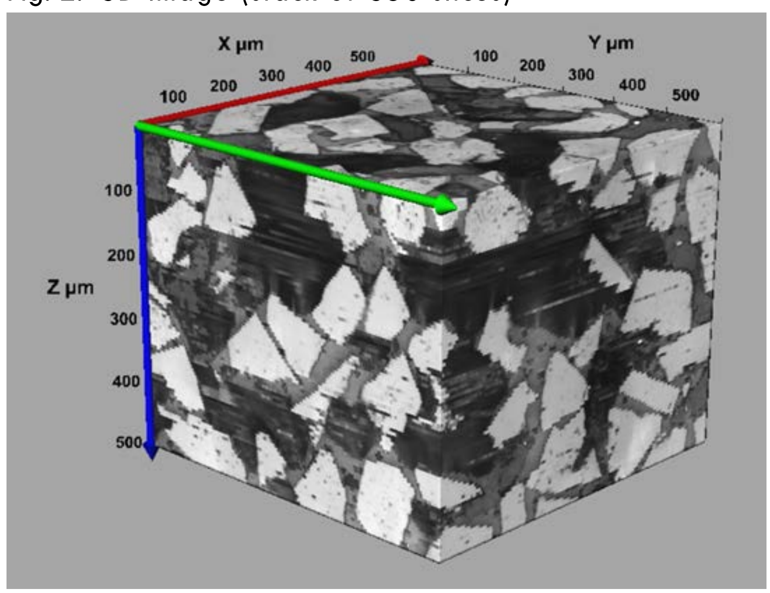


IMAGE PROCESSING

The 2D image tiles from each layer were stitched into montages (or mosaics) and then registered with the images from the next layer using Fiji and Image J software. 3D analysis was performed using Image-Pro Premier 3D v.9.3 (Media Cybernetics, Inc., Washington, USA). For 3D analysis, the loaded z-stack of 100 slices was processed with subsampling along X, Y and Z directions.

A 3D isosurface was created without any filtering to extract the volume distribution of the grains (Figs. 3, 4). An image histogram was used to threshold the grains. The segmented images were analyzed using routines built into Image-Pro, to analyze the distribution of the grains. The volumetric conclusions (with ~ 1% error) are presented in the table below.

Fig. 3: Partially Segmented Grains

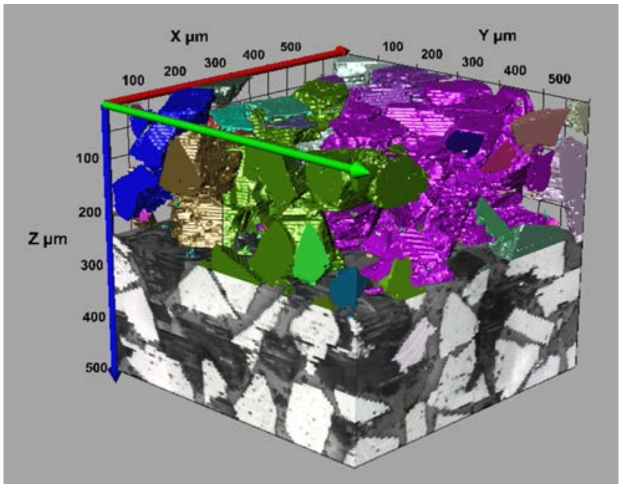
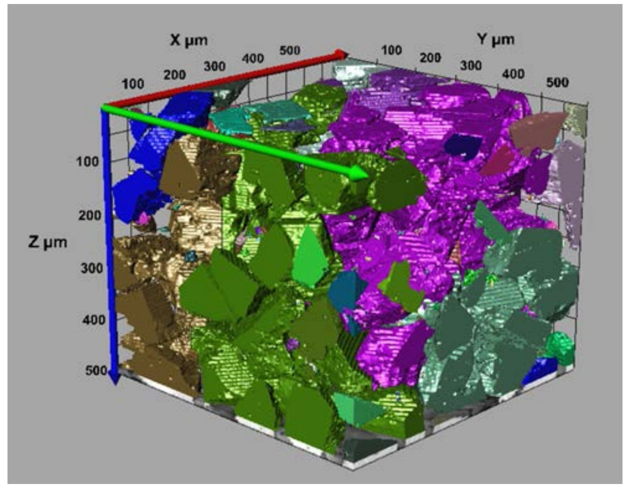


Fig. 4: Fully Segmented Grains



Each grain was identified with a specific index value based on size. As shown in Fig. 5, a majority of the grains are in the size range of 5 – 200 microns. The aspect ratios of the grains lie between 1 and 25 with a few outliers in the first few slices, possibly due to fall-out issues. Variability in grain distribution was also observed between 2D and 3D (Fig. 6). Regularly spaced single 2D slices have been analyzed for grain size distribution. The area percentage calculated from these conventional image analyses varied from 22 to 43 area % of grains. These results are compared to direct experimental measurements using Robo-Met.3D (37 vol %) as shown in Fig.6.

Fig. 5: Comparison of grain size and shape distribution

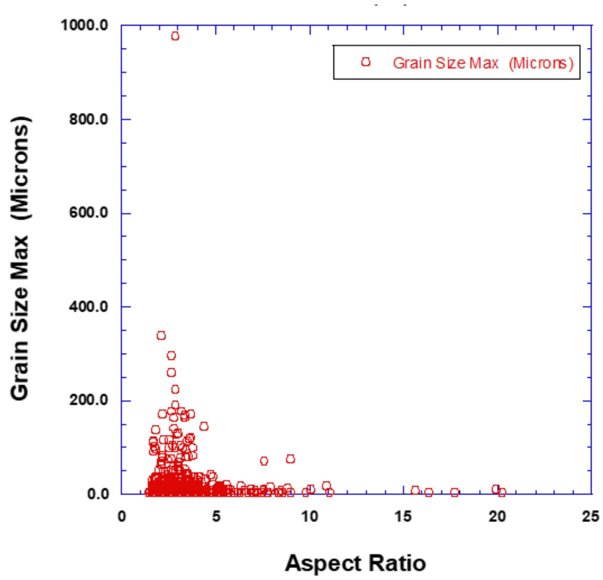
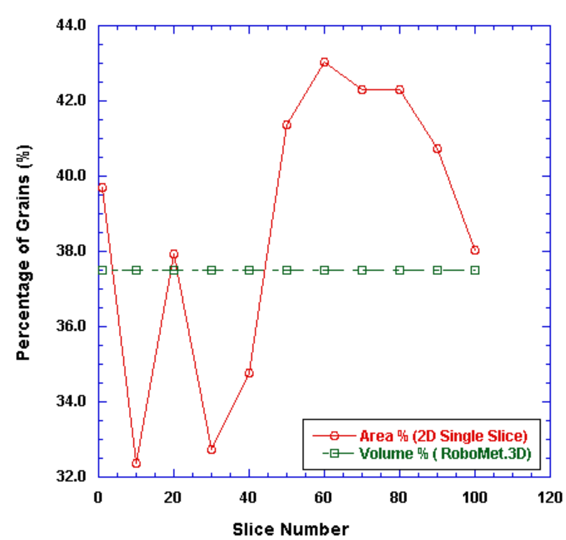


Fig. 6: Slice to slice variability in grain distribution



Visualization of the 3D topological features using serial sectioning methods such as Robo-Met.3D creates a better understanding of the actual microstructural features compared to using the estimations such as surface area and volume fraction from classical stereological methods. Such direct measurements provide accurate representations, which are imperative to correctly detect grains of critical size and shape for mechanical properties evaluation.

CONCLUSIONS

Identification, segmentation and quantification of the grains in a resin-bonded CBN material was accomplished using Robo-Met.3D, aiding in the structural analysis of the material.

CONTRIBUTORS

Bryan Turner (UES), and Satya Ganti (UES) performed the image collection and post-processing, and Kristin Keller contributed to the analysis. Animated views of the data are available at http://www.ues.com/forums/forum/applications/.

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