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Slit Blade Surface Roughness

Summary

Surface roughness is an important criterion for aperture slit blades. A low surface roughness ensures that the knife edge of the blade is uniform and precise. This will eliminate backscattering and produce a quality beam profile. Over the past few years, ADC has developed a standard procedure for polishing slit blades. This procedure was developed in conjunction with feedback from Cornell High Energy Synchrotron Source (CHESS).

To ensure the quality of ADC's slit blades and polishing process, several samples were measured for surface roughness. Blades polished using ADC's standard polishing procedure were tested as well as blades polished using alternative procedures. A typical specification for these types of blades is 1-2 µm RMS. The resulting measurements showed that our standard polishing procedure produces blades that exceed this specification. Average RMS surface roughness of tungsten blades was 0.12 µm and 0.18 µm for tantalum blades with good repeatability for each material.

Samples were measured using a Veeco Dektak 6M Profilometer located in Cornell University's Nanobiotechnology Center. These measurements affirm the quality and consistency of ADC's slit blades. Details of the measurement procedure, measured data, results, and conclusions are presented in the sections that follow.

Surface Roughness Measurements

Measurement Procedure

This section describes the process used for measuring blade surface roughness. General operations of the Dektak 6M Profilometer are outlined as well as system capabilities. The final part of the section presents specific methods and parameters used in our tests.

Profilometer

Cornell University's Nanobiotechnology Center provided access to their Veeco Dektak 6M Profilometer, located in Duffield Hall. The Dektak 6M, shown in Figure 1, is an advanced thin and thick film step height measurement tool capable of measuring steps below 100Å . Samples are placed on a rotatable stage which also has a tilt function for leveling the sample. The stage itself can be adjusted in the x- and y- direction. A 12.5 μm radius diamond stylus runs across the surface of the substrate while recording its horizontal and vertical position. The Dektak 6M Profilometer is connected to a CPU and controlled through a graphical user interface. Stylus force, scan length, scan duration, measurement range, and profile shape are set by the user in the Scan Parameters window

(Figure 2). Scan length and duration affect the number of sample points recorded and the resolution of each scan. Vertical resolution is dependent upon user input of measurement range. Position of the

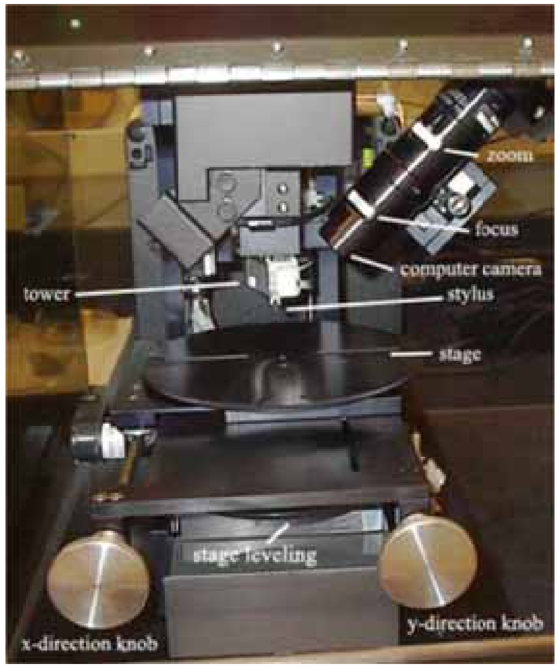

Figure 1. Veeco Dektak 6M Profilometer shown with key features and controls labeled.

stylus and material surface can be viewed from the computer screen while positioning the sample and during a scan. Following each scan, the surface profile is plotted within the Dektatk 6M user interface. Data plots can be leveled within the program, to account for any fine adjustments that can not be made manually.

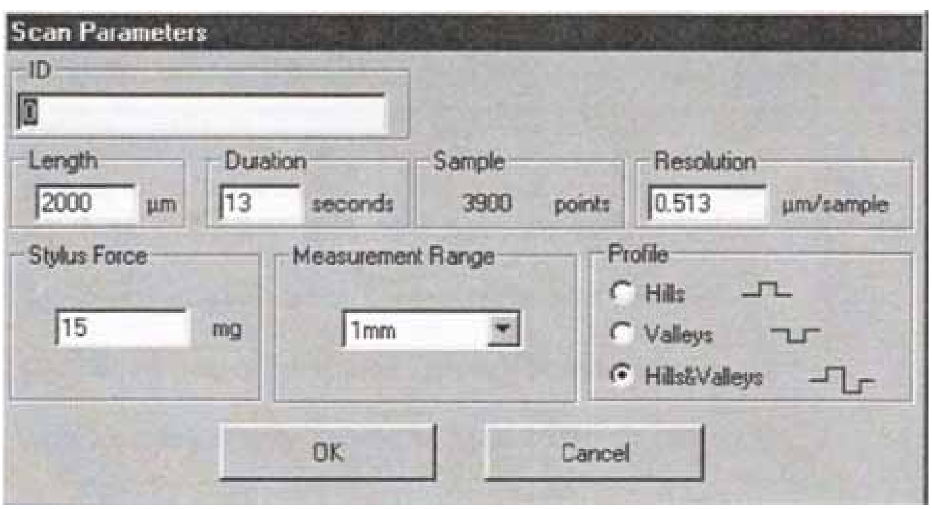

Figure 2. Scan routines are set by the user in the Scan Parameters window.

The 6M Profilometer scan parameters that were used for our samples are illustrated in Table 1. These parameters were chosen to optimize the horizontal resolution of each scan. The stylus force of 15 mg is typical for most materials and a range of 65.5 μm is typically used if only measuring surface roughness. A 2000 μm long scan was performed across several different sections of each blade. Measurements were taken along the polishing grain and perpendicular to the polishing direction. A total of 4 measurements were performed for each slit blade.

Table 1. Scan parameters used for all surface roughness measurements.

Scan Length (μm)	Scan Time (seconds)	Sample (points/scan)	Horizontal Resolution (μm/sample)	Stylus Force (mg)	Measurement Range (μm)
2000	30	9000	0.222	15	65.5

The Dektak 6M Profilometer camera allowed for us to capture a magnified view of the blade surface. An image taken from a tungsten blade is shown in Figure 3, where the grain of the material and the diamond stylus are easily seen. This view was also useful for alignment of each sample.

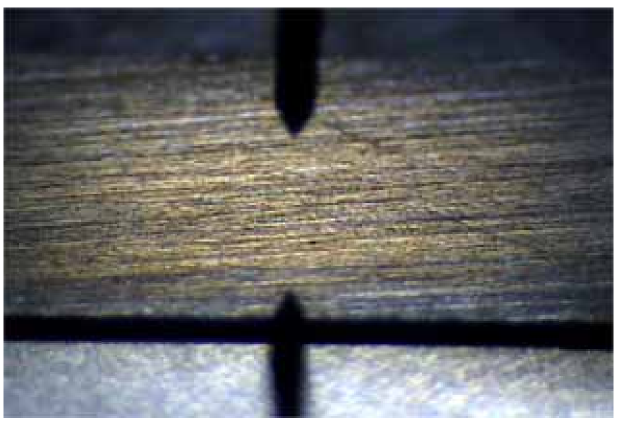

Figure 3. Image captured from Profilometer camera of a tungsten blade and the diamond stylus.

Processing Data

Results of each scan with the Profilometer can be examined within the user interface or saved for processing later. Raw data from each scan is exported to a .txt file where it can be processed in Microsoft Excel. In Excel, the linearity of each plot can easily be removed and the root-mean-squared (RMS) surface roughness calculated. Linearity was removed from the data sets by fitting a linear trend to the measured data. The trend is then subtracted from the entire data set. RMS surface roughness (R_q) is calculated using the equation,

$$R_q = \sqrt{\frac{1}{n}\sum_{i=1}^{n} y_i^2}\ , \qquad (1)$$

where y_i is the measured height of the ith data point from a series of n data points. Equation 1 describes the magnitude of the mean variation of the surface height, which is an important factor for surfaces used in optical applications.

Results

This section presents the results of our measurements. Unpolished blades were measured to understand the effectiveness of our polishing procedure. A total of 5 blades polished using ADC's standard polishing procedure were examined. There are many different methods that can be used for polishing blades. Different grades or successions of grit paper and grit paste greatly affect the quality of the finished surface. To examine these effects, we measured 5 blades that were polished using 4 different experimental polishing procedures.

Unpolished Surface

To provide a point of reference, unpolished surfaces of tantalum and tungsten were measured. The surface profile of an unpolished tantalum sample is plotted in Figure 4. The horizontal position of the stylus is plotted in the x-axis (μm) and the surface height in the y-axis (μm). The RMS surface roughness of the unpolished tantalum sample is 2.56 μm. Figure 4 indicates that the blade surface is non-uniform and unsuitable for use in an aperture.

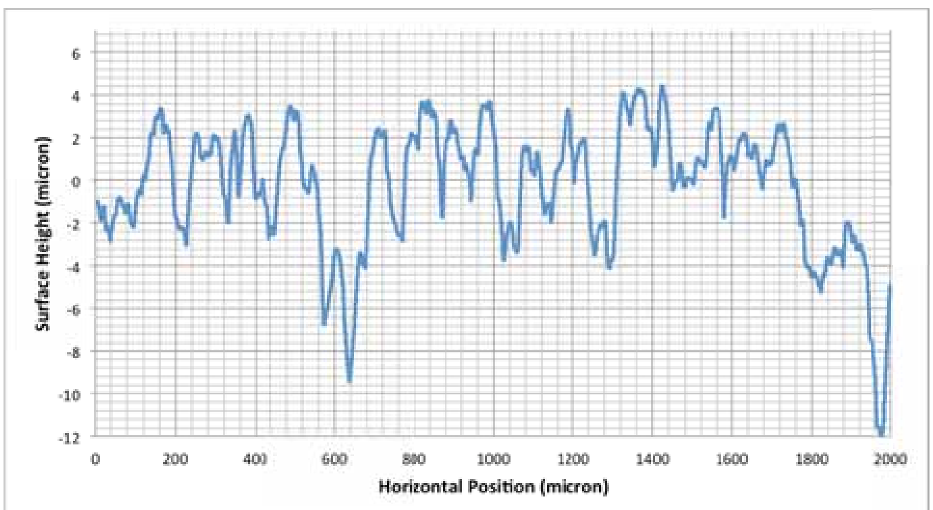

Figure 4. Surface profile plot of unpolished tantalum blade with linearity removed.

Polished Surface (ADC Standard Process)

A total of 5 blades, polished using ADC's standard polishing procedure were measured using the Dektak 6M Profilometer. Our standard polishing procedure has been developed over the past few years. This standard process is the result of feedback and testing done with the help of CHESS. Each blade was measured 4 times and the RMS surface roughness calculated using Equation 1. Measurements were taken from 3 tungsten blades and 2 tantalum blades.

The surface profile measured from the polished blades provides a stark contrast to Fig. 4. A plot of the surface profile from a sample of tantalum, shown in Figure 5, illustrates the effectiveness of ADC's standard polishing procedure. For the particular sample shown in Figure 5, the RMS surface roughness was found to be 0.16 μm, which is 16 times smoother than the surface of unpolished tantalum. Table 2 presents the measured RMS surface roughness of each

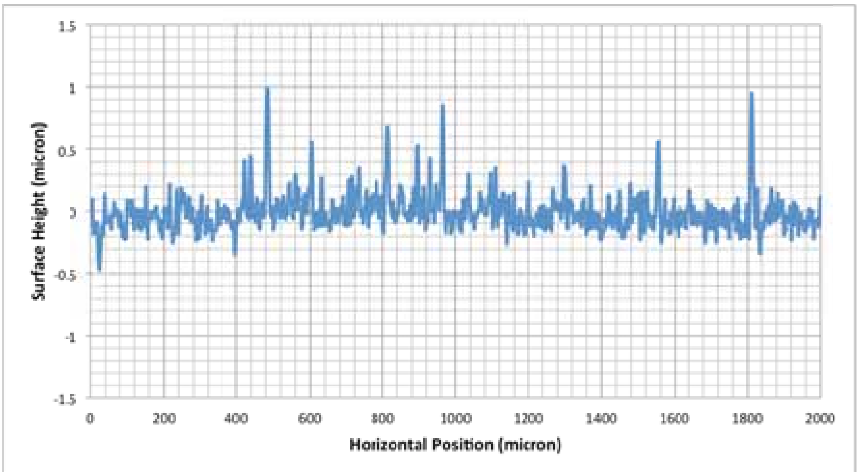

Figure 5. Surface profile plot of tantalum blade polished with ADC's standard procedure. The measured RMS surface roughness is $0.16\ \mu m$.

blade. Values are presented as an average of the 4 samples taken from each blade. Individual plots and tabulated data for each sample can be found in Appendix A of this report. The results of these measurements show that our standard polishing procedure produces blades with an RMS surface roughness that is a factor of 10 better than typical 1-2 μm specifications. This process also provides repeatable results, as the standard deviation for both the tantalum and tungsten blades was 0.05 μm.

Table 3. Average of RMS surface roughness based on blade material.

Blade Number	Material	RMS Surface Roughness (micron)
1	Tantalum	0.16
2	Tungsten	0.16
3	Tungsten	0.08
4	Tungsten	0.15
5	Tantalum	0.21

Polished Surface (Experimental Process)

A total of 5 blades, polished using experimental processes were measured using the Dektak 6M Profilometer. These experimental procedures deviated from ADC's standard procedure by using different successions of grit paper. We experimented with 4 different alternative procedures. Measurements were taken from 4 tungsten blades and 1 tantalum blade. A different procedure was used for each tungsten blade and one procedure was used on a tantalum blade as well.

Four profile scans were performed on each blade. An average RMS surface roughness was determined for each sample based on these four scans. Table 4 presents the resulting RMS surface roughness for each sample. Blade material and the experimental polishing procedure, labeled #1-4, are indicated in the table. The results indicate that the surface of the blades is

Table 4. Average of RMS surface roughness for each blade. Polishing procedure (1-4) and blade material are indicated.

Alternative Polishing Procedure	Material	RMS Surface Roughness (micron)
1	Tantalum	0.43
1	Tungsten	0.34
2	Tungsten	0.25
3	Tungsten	0.44
4	Tungsten	0.24

suitable to meet typical specifications, but does not reach the same quality as blades polished using ADC's standard procedure. This becomes more apparent from the surface profile plots for these samples. Figure 6 displays the profile plot from a scan of the tantalum blade polishing using alternative polishing procedure #1. The surface profile of this blade is less uniform than that of the surface profile plotted in Fig. 5. It also important to note, from Fig. 6, that several points exceed 1 μm with one point exceeding $2\mu m$. Additional surface profile plots for blades polished using alternative polishing procedures are located in Appendix B of this report.

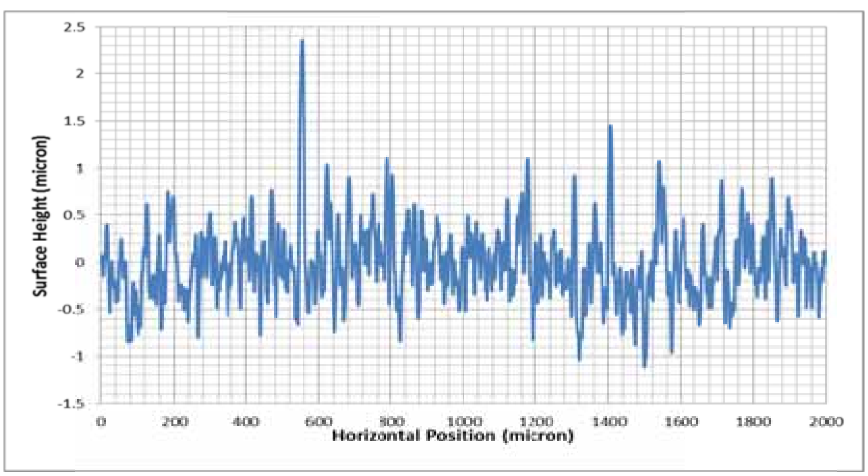

Figure 6. Surface profile plot of tantalum blade polished using an alternative procedure. The measured RMS surface roughness for this scan is $0.42\ \mu m$.

These results indicate that the alternative or experimental polishing procedures do not produce the same high quality blade surface achieved by ADCs standard polishing procedure.

Conclusion

Low surface roughness is important for a slit blade to function properly and to minimize backscattering. Surface roughness measurements were performed on 10 polished slit blades. ADC's standard procedure was used for polishing 5 of the 10 slit blades. The other 5 blades were polished using 4 different experimental procedures.

The resulting surface profile scans and calculated RMS surface roughness prove the quality and consistency of our slit blades. Both tantalum and tungsten blades were examined. Table 5 presents the average RMS surface roughness for each blade material. For both tungsten and tantalum blades the standard deviation for RMS surface roughness was 0.05 μm. These results indicate that ADC is able to consistently produce quality slit blades that far exceed typical surface roughness specifications of 1 to 2 μm. Measuring the surface roughness of blades polished using experimental processes indicates the effectiveness of the standard polishing procedure. ADC has developed this procedure over the past few years with help from Cornell High Energy Synchrotron Source (CHESS). When deviating from our standard procedure, we found that the surface profile of the blades was not as uniform and blades were not of the same quality. These measurements from experimental polishing procedures further illustrate the effectiveness of the standard polishing process ADC has developed.

Table 5. Average of RMS surface roughness of blades polished using ADC's standard process.

Material	Average of RMS Surface Roughness (micron)
Tantalum	0.18
Tungsten	0.12

Appendix A

Standard Polishing Process

Located in this appendix are the surface profile plots for blades polished using ADC's standard polishing procedure. Scans are grouped based on sample number. The calculated RMS surface roughness for each scan is presented in Table 1.

Sample 1 – Tantalum

Average of RMS Surface Roughness: 0.15 μm

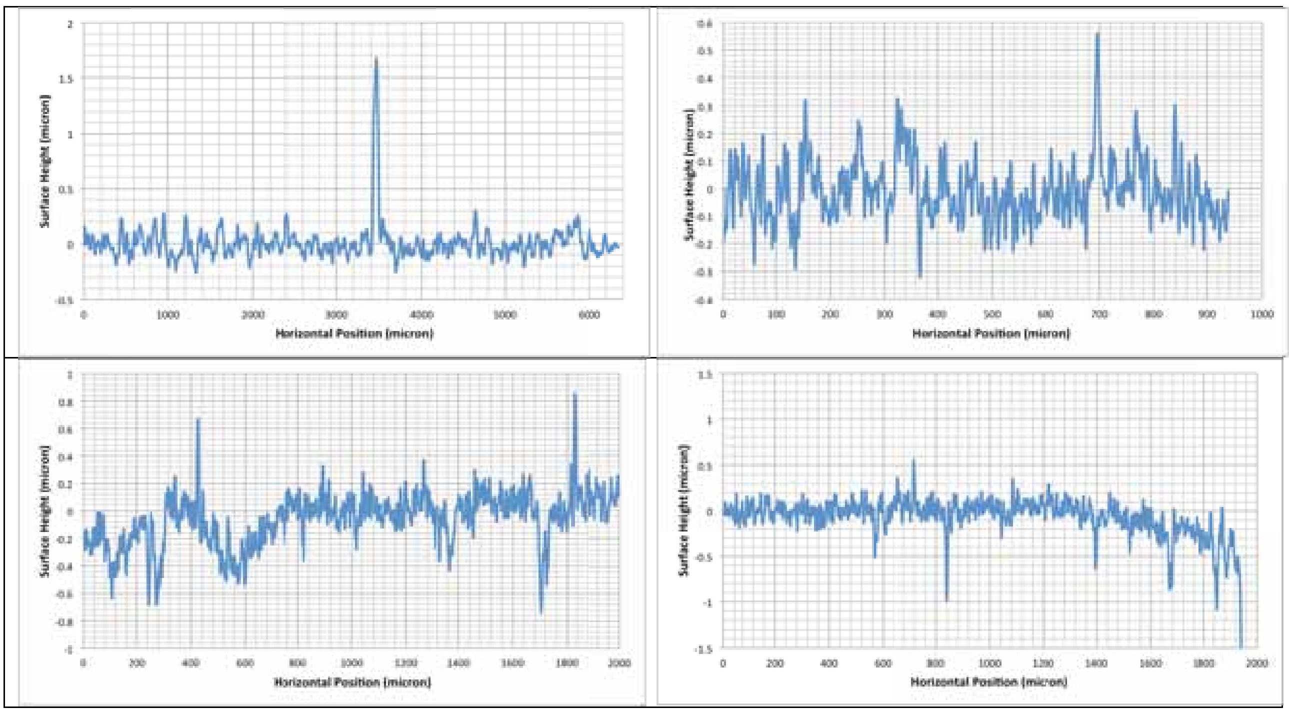

Figure 1. Scans from Sample 1 (CW from top left: 1-4).

Sample 2 – Tungsten

Average of RMS Surface Roughness: 0.14 μm

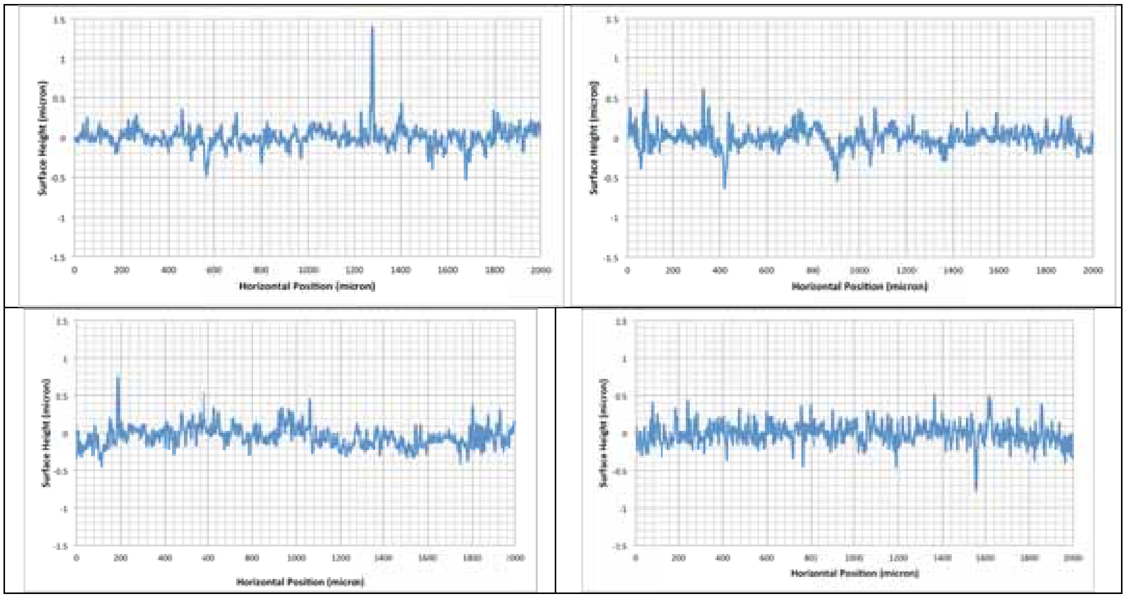

Figure 2. Scans from Sample 2 (CW from top left: 1-4).

Sample 3 – Tungsten

Average of RMS Surface Roughness: 0.08 μm

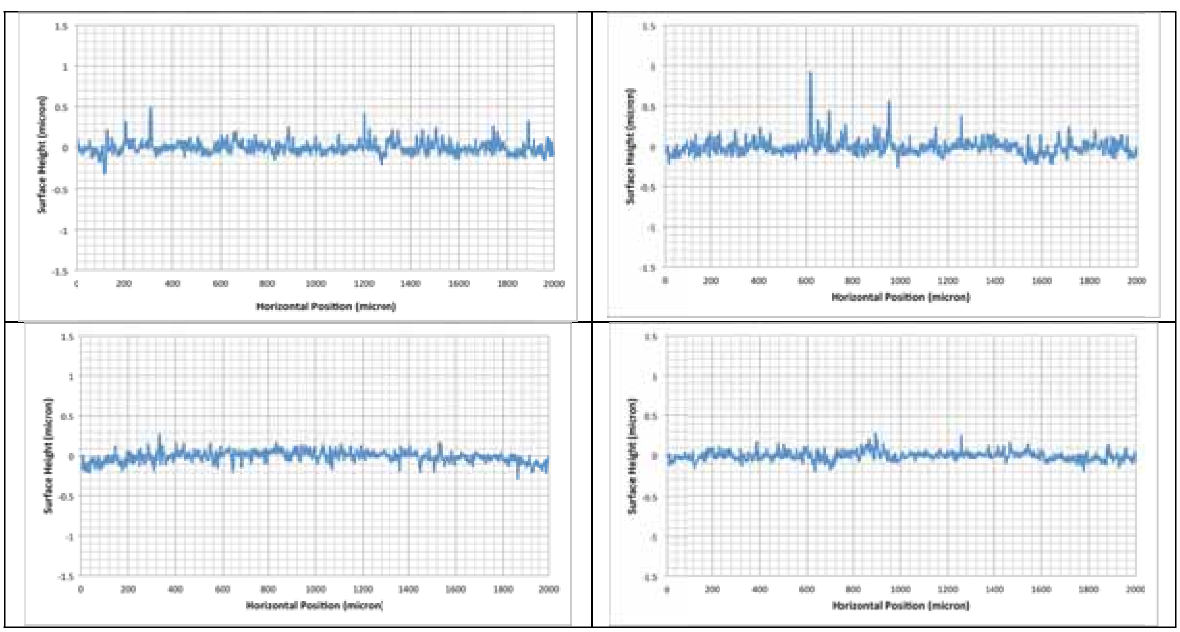

Figure 3. Scans from Sample 3 (CW from top left: 1-4).

Sample 4 – Tungsten

Average of RMS Surface Roughness: 0.15 µm

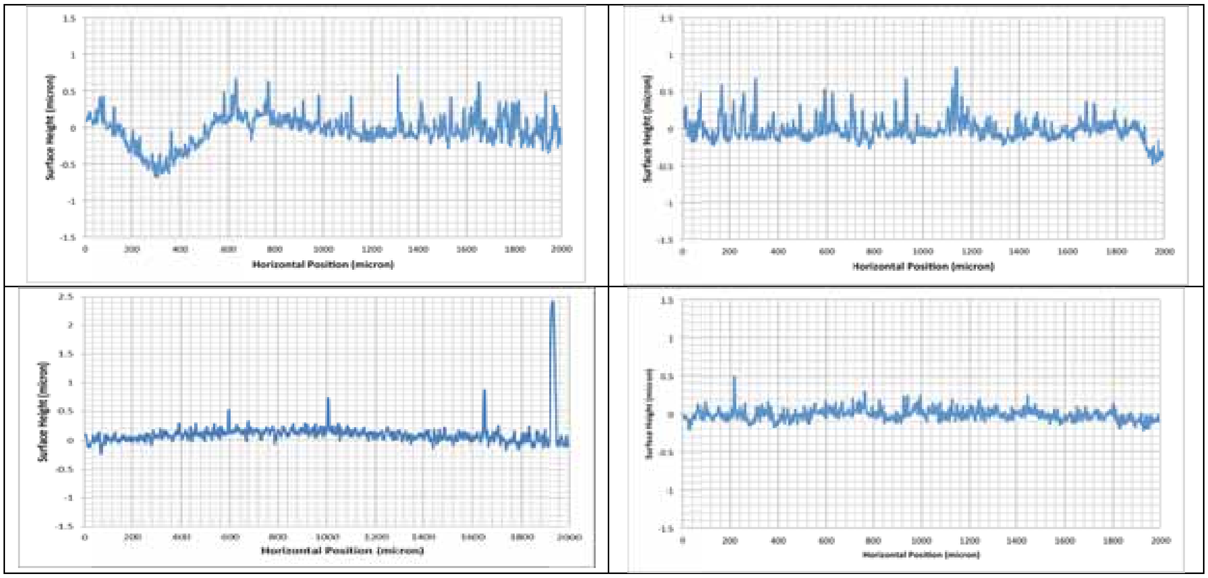

Figure 4. Scans from Sample 4 (CW from top left: 1-4).

Sample 5 – Tantalum

Average of RMS Surface Roughness: 0.20 µm

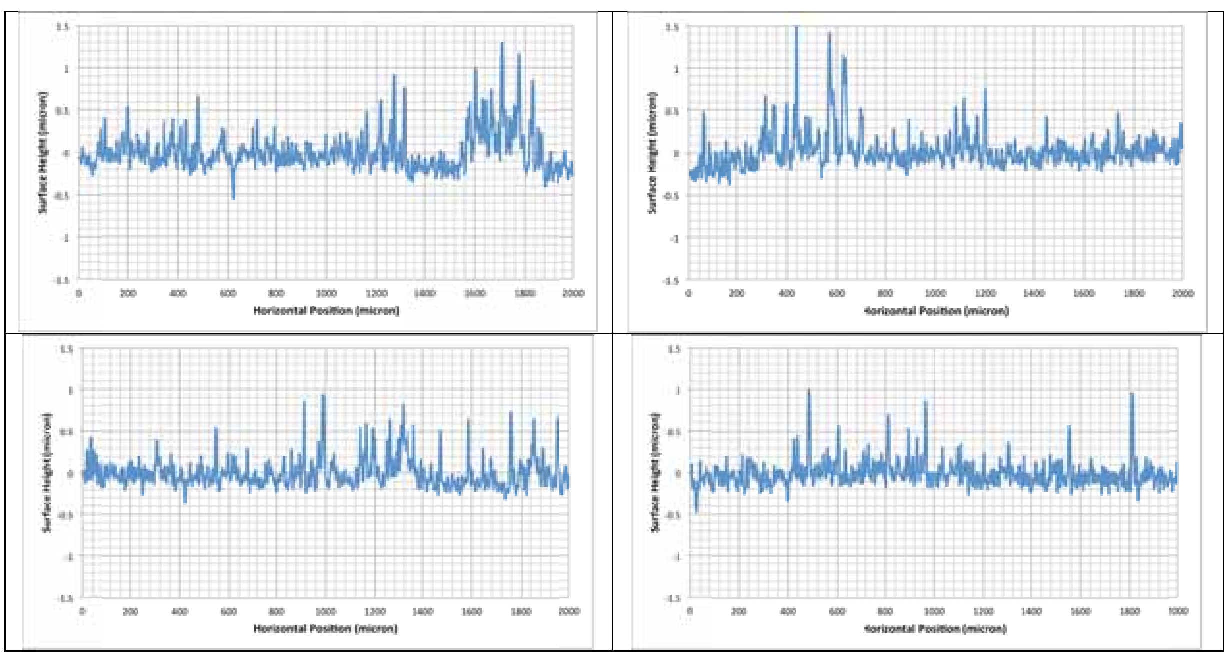

Figure 5. Scans from Sample 5 (CW from top left: 1-4).

Table 1. Calculated RMS Surface Roughness values for each scan of slit blades polished using standard ADC procedure.

Blade Number	Material	Sample Number	RMS Surface Roughness (micron)
1	Tantalum	1	0.127
		2	0.112
		3	0.204
		4	0.126
2	Tungsten	1	0.136
		2	0.132
		3	0.147
		4	0.141
3	Tungsten	1	0.078
		2	0.101
		3	0.056
		4	0.066
4	Tungsten	1	0.221
		2	0.149
		3	0.075
		4	0.169
5	Tantalum	1	0.229
		2	0.230
		3	0.161
		4	0.182

Appendix B

Experimental Polishing Processes

Located in this appendix are the surface profile plots for blades polished using experimental or “alternative” polishing procedures. Scans are grouped based on experimental polishing process. The calculated RMS surface roughness for each scan is presented in Table 1.

Process 1 – Tantalum

Average of RMS Surface Roughness: 0.42 μm

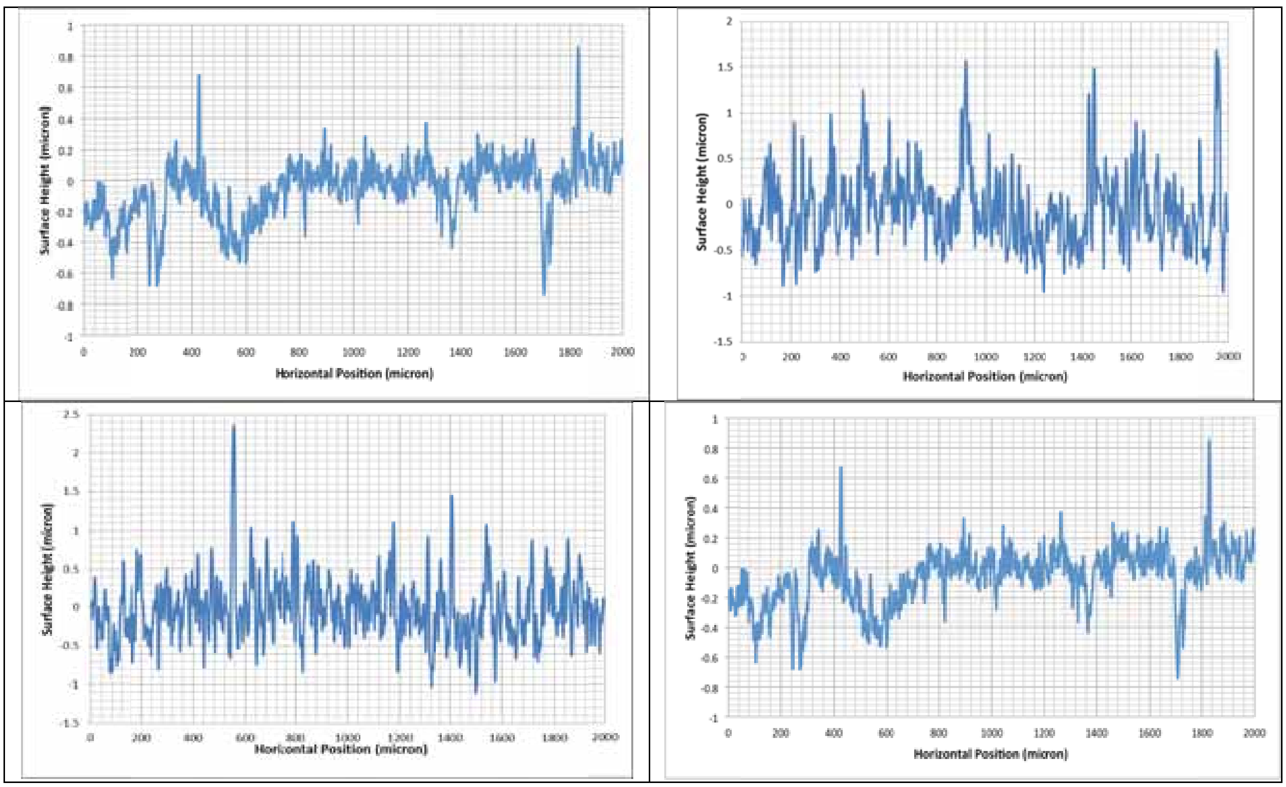

Figure 1. Scans from tantalum sample polished with experimental procedure #1 (CW from top left: 1-4).

Process 1 – Tungsten

Average of RMS Surface Roughness: 0.34 µm

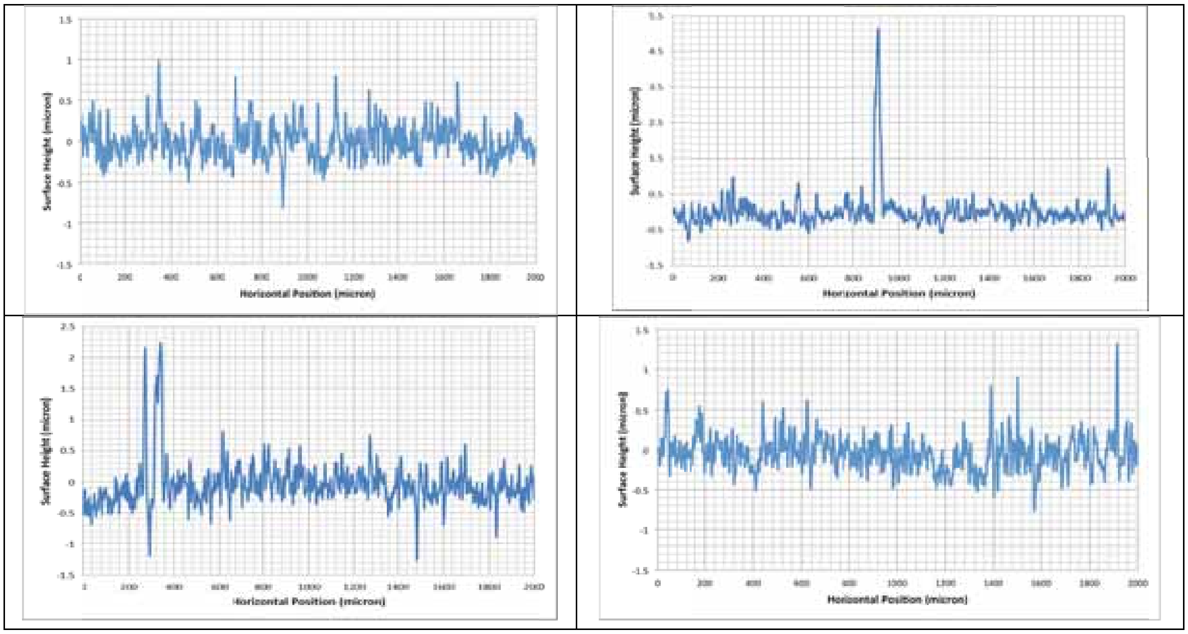

Figure 2. Scans from tungsten sample polished with experimental procedure #1 (CW from top left: 1-4).

Process 2 – Tungsten

Average of RMS Surface Roughness: 0.25 µm

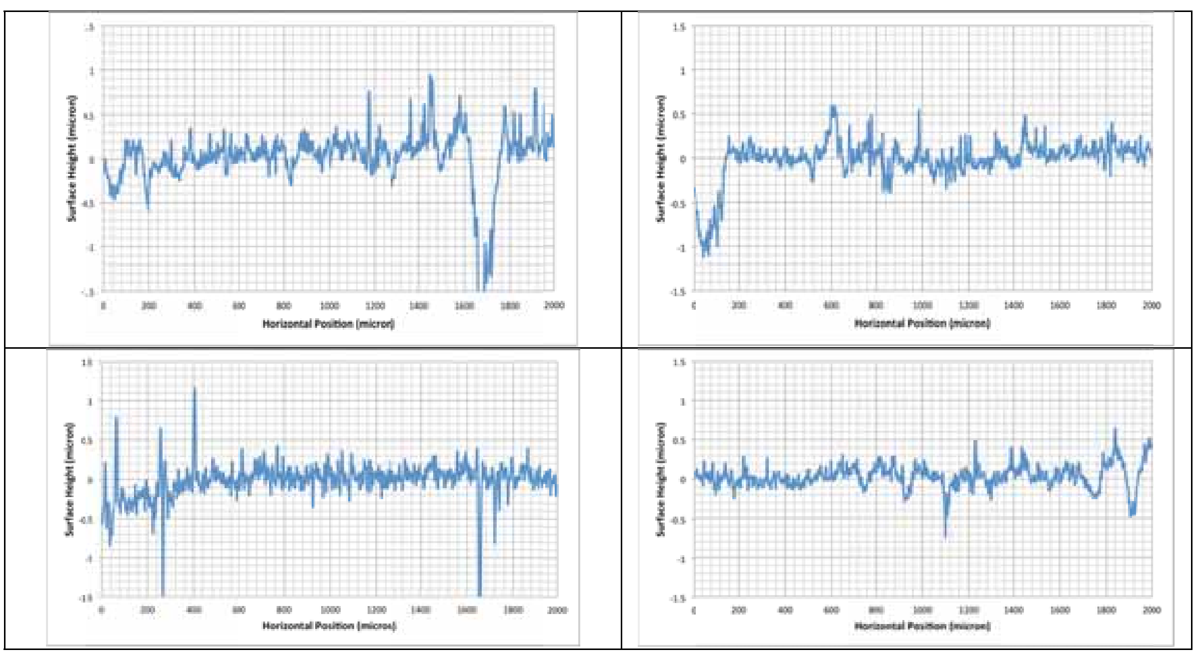

Figure 3. Scans from tungsten sample polished with experimental procedure #2 (CW from top left: 1-4).

Process 3 – Tungsten

Average of RMS Surface Roughness: 0.45 µm

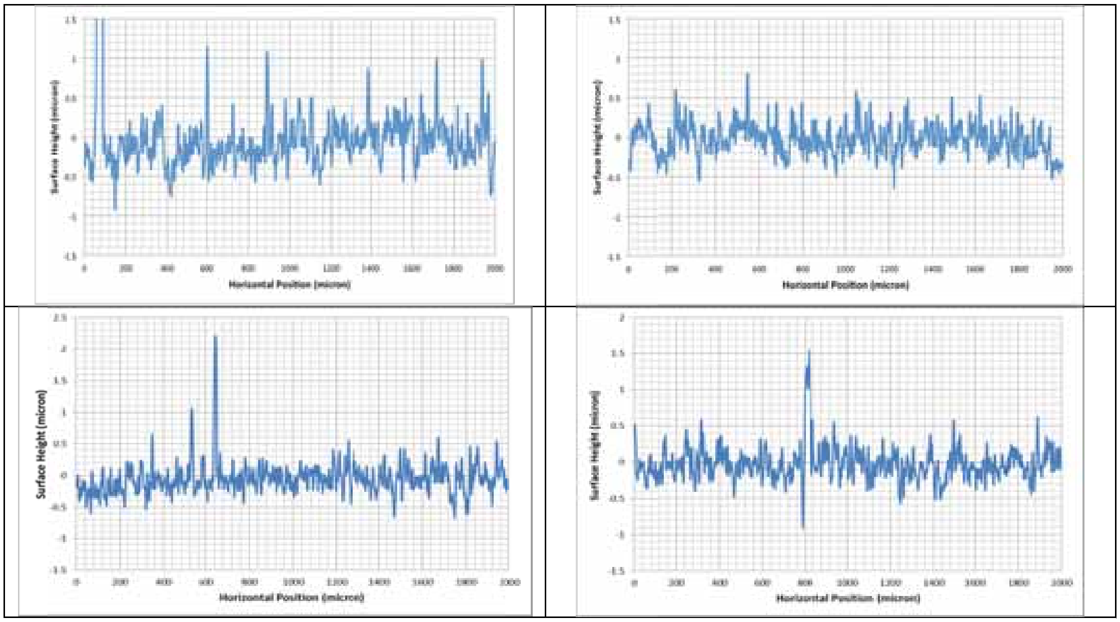

Figure 4. Scans from tungsten sample polished with experimental procedure #3 (CW from top left: 1-4).

Process 4 – Tungsten

Average of RMS Surface Roughness: 0.24 µm

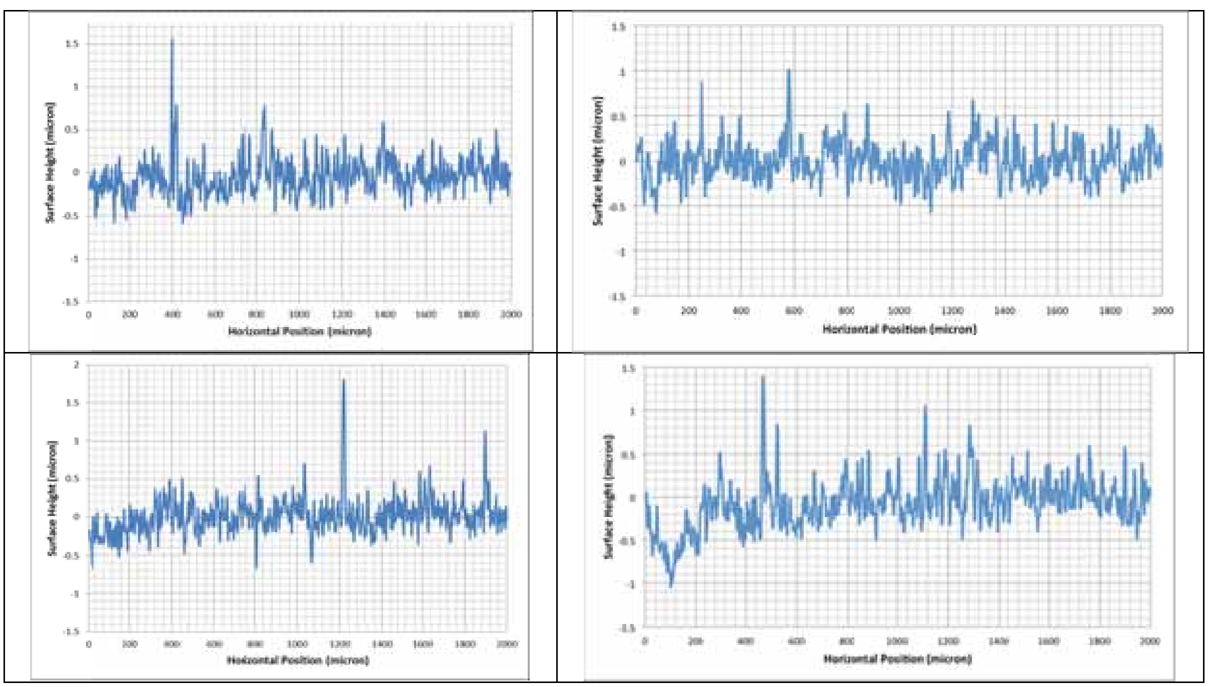

Figure 5. Scans from tungsten sample polished with experimental procedure #4 (CW from top left: 1-4).

Table 1. RMS Surface Roughness values for each scan of blades polished using experimental polishing procedures. Experimental procedures are number 1 through 4 and are noted along with blade material.

Experimental Procedure #	Material	Sample Number	RMS Surface Roughness (micron)
1	Tantalum	1	0.459
		2	0.400
		3	0.400
		4	0.417
1	Tungsten	1	0.219
		2	0.539
		3	0.227
		4	0.373
2	Tungsten	1	0.378
		2	0.247
		3	0.141
		4	0.246
3	Tungsten	1	1.086
		2	0.192
		3	0.243
		4	0.258
4	Tungsten	1	0.217
		2	0.213
		3	0.305
		4	0.240