3-D MEASUREMENT OF DIAMOND GRAIN UTILIZING LASER MICROSCOPE

Kitami Institute of Technology ○ Tammam MAHMOUD Akihiko KUBO Jun'ichi TAMAKI

Flat surfaces with arbitrary positions, sharp edges and tips between these surfaces and transparency are the characteristics of diamond grain (DG). Laser microscope (LM), as an optical stylus for surface topography measurement, abides by the physical behavior of the light (Laser) like reflection, refraction and diffraction. By taking a glimpse over these contradictory properties of DG and LM the measurement difficulties may be predicted. This study is a trial to understand and handle these difficulties.

1. STUDY MEANS

To carry out this study the means listed below have been employed.

1.1. Laser Microscope

The following table lists the specifications of LM in case of 100× lens use. This lens was used for the measurements.

Light Source	Laser-RED;He-Ne 632.8nm
Light Source Power	1.5 mW
Magnification	2500 in 14" monitor
Field of Vision	115 μm
Resolution	Horizontally: 0.1μm Vertically: 0.005μm
Lens Efficiency (in air)	0.95
Scanning Speed	X-Direction: 15.73 kHz Y-Direction: 60 Hz
Frame Memory	910 × 485 × 8 bit
Scan Rates	N (Normal),2,4,8,16

Two measurement ways can be used as described below.

I- Extracting one longitudinal line crosses the sample surface area under focus. This has been substituted by a program prepared to extract two lines, longitudinal and latitudinal ones.

II- Measuring all the area under focus. On the basis of this way the programs listed below have been prepared.

1.2. Computer Software

I- Program reads the LM frame memory where the screen data are saved and converts these data into 2-D matrix z(y,x). Where y represents the screen line number, x represents the screen column number and z takes the value (height) of a pixel at (y,x) location.

x ×	y ×	z
0~320	0~240	0~255

II- Program processes and smoothes the saved data. Two smoothing algorithms have been used:

- Polynomial Curve Fit used for disposal of noise overshooting.

$$Z(i,j) = \sum_{p=-m}^{m} \sum_{q=-m}^{m} \{G(p,q) X(i+p, j+q)\}$$

- Simple Moving Average used to minimize the meanders tarried after applying polynomial curve fit.

$$Z(i,j) = \frac{1}{2m+1} \sum_{p=-m}^{m} \frac{1}{2m+1} \sum_{q=-m}^{m} X(i+p, j+q)$$

III- Program makes templates for some measured samples that have a specific known shape and dimensions. This program is used to make comparison between theoretical and smoothed data to assess the smoothing effects.

1.3. Measurement samples

(A) Vickers hardness mark stamped on flat metal surface.
(B) Metal flat surface tilted against the horizon by 5°.
(C) Diamond flat surface tilted against the horizon by 5°.
(D) Knife edged diamond stylus with 90° prism angle and rounded top edge of 5μm radius.
(E) Conical diamond stylus with 90° conic angle and spherical tip of 5μm Radius.

2. MEASUREMENT RESULTS

At first the two metal samples have been measured in order to verify the measurability of metal surface.

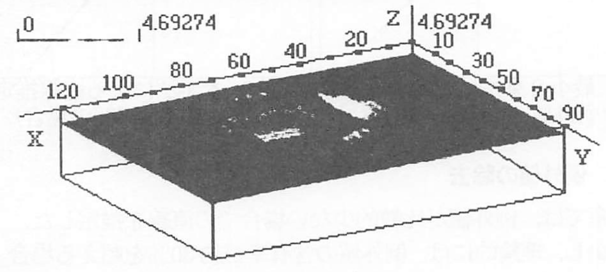

Figure 1 - Vickers Hardness (A). (Non-Smoothed, Scan Rate N)

As shown in Fig. 1, the very low noise level (less than 0.2μm) can be noticed in the both areas of flat surface part and pyramidal hole part. In this measurement scan rate is set on N mode. The measurement result of sample B is very similar to that of sample A where noise level was very low.

As shown in Fig. 2, measurement of sample C shows the measurability of diamond inclined flat surface. Where in case of small inclination angle the noise level is very low (0.2μm).

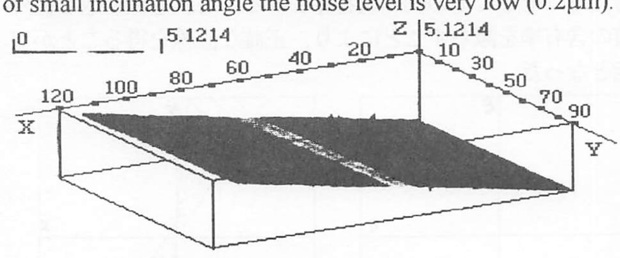

Figure 2 - Diamond Flat Surface (C). (Non-Smoothed, Scan Rate N)

As shown in Fig 3, measurement of sample D has a big contradiction with sample C. where high noise level is noticed.

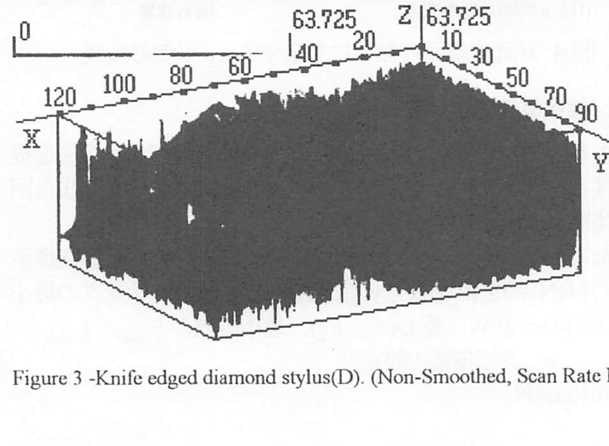

Figure 3 -Knife edged diamond stylus(D). (Non-Smoothed, Scan Rate N)

Fig. 4 shows the effect of scan rate changing from N to 8.

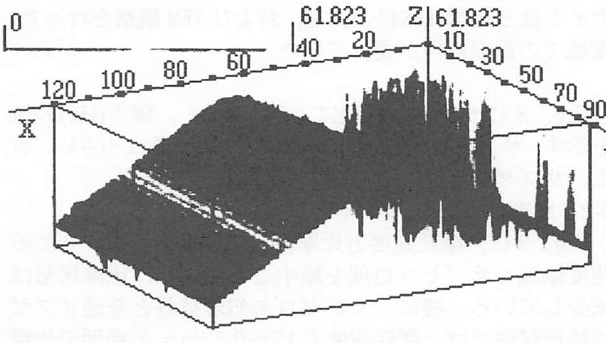

Figure 4 -Knife edged diamond stylus(D). (Non-Smoothed, Scan Rate 8)

The result after smoothing is shown in Fig. 5.

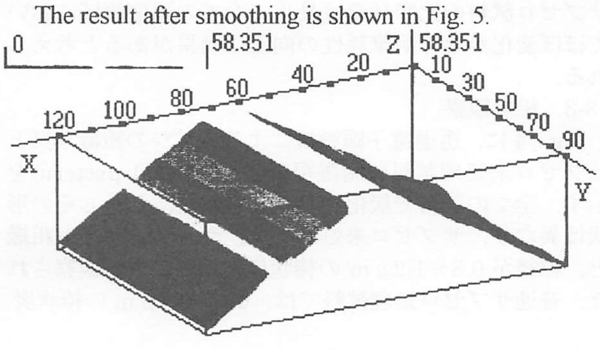

Figure 5 - Knife edged diamond stylus(D). (Smoothed, Scan Rate 8)

As shown in Fig. 6, with N scan rate, Measurement result of sample E was similar to sample D at same conditions.

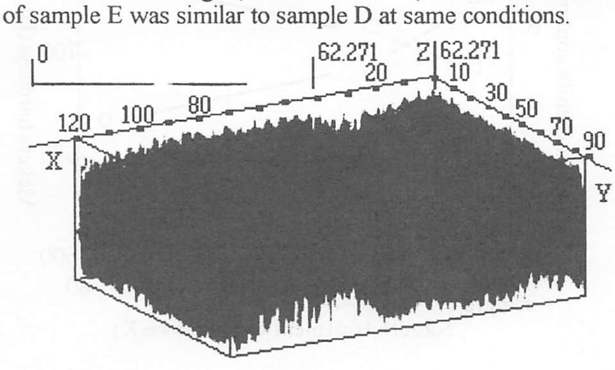

Figure 6 - Conical diamond stylus (E). (Non-Smoothed, Scan Rate N)

Fig. 7 shows the result after changing scan rate to 8 and smoothing.

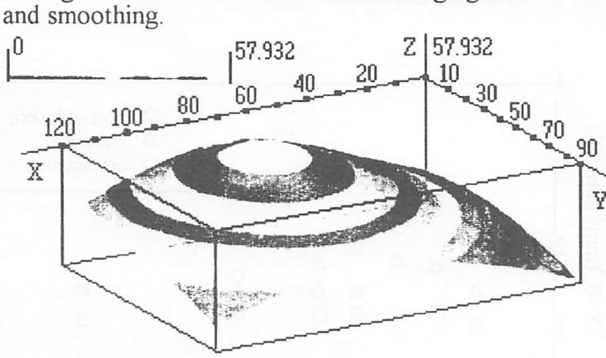

Figure 7 - Conical diamond stylus (E). (Smoothed, Scan Rate 8)

In both of Fig. 5 and Fig. 7 the meanders can be noticed as a long fluctuation. These meanders has been minimized where the total removal could not be achieved yet.

4. ANALYSIS

4.1. Noise formation contributors

I- Laser rays phase disparity. When two rays gather at focus point with $\lambda/2$ phase difference then a dark point known as Fraunhofer Diffraction Pattern will occurs. This may cause an overshooting.

II- The angle of incidence. The measured surface angle against the incident ray also plays an important role where the right angle is the optimum one.

III- Surface roughness of specimen. This will cause ray dispersion especially if the incidence angle is far from 90°.

IV- Specimen material. It has a significant effect on Reflectivity.

For opaque materials:

Reflectivity = 1- Absorptivity

For transparent materials

Reflectivity = 1- (Transmissivity + Absorptivity)

4.2. Noise reduction factors

To understand the reduction factors, LM measurement system should be known. Regarding that the measurement method is explained as follows.

During specimen holding table (X-Y table) travels vertically between the preset up and low positions, LM performs the horizontal scanning on the specimen part passes the scanning focus point. So that the important settings are up and low position, time interval between these two positions and scanning rate.

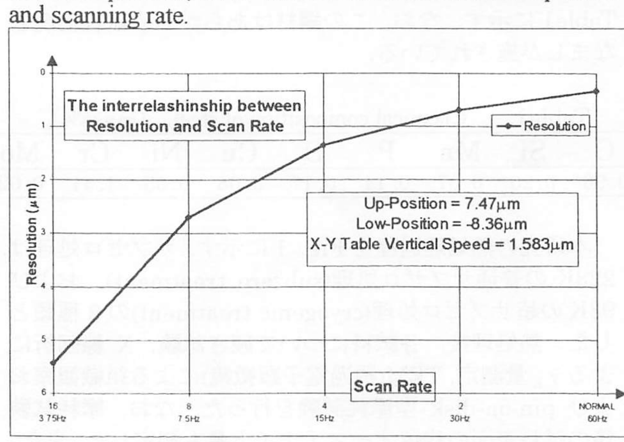

Figure 8-The relationship between scan rate and LM Resolution

From Fig. 8, the relation between LM scan resolution and scan rate can be understood.

When scan rate increase (X and Y scanning speed become faster) the resolution will improve (resolution value become small), but the LM sensitivity will drop and noise will increase.

If the vertical speed of X-Ytable become faster resolution and sensitivity will drop.

If the difference between up and low positions is big, the vertical resolution will drop and noise will increase.

5. CONCLUSION

The high accurate measurement of diamond grain always collides with this grain characteristics which form a fecund environment for noise formation. However, transparency, which is the major problem of diamond and the major source of noise has been partially treated, but the remaining effects which impairs the accuracy still needs more efforts to be totally removed.

This achievement can be obtained by finding the suitable smoothing algorithm has a low accuracy damage.