REPORT: Cutting of monocrystalline diamond by Laser-MicroJet®

For Anonymous

by Synova SA, Mr. Florent Bruckert, Mr Sylvain Hirth

1. TASK

This application aimed at cutting a maximum depth of monocrystalline CVD grown diamond using the Laser-MicroJet® technology.

2. TASK DESCRIPTION

SUPPLIED MATERIAL	Sample	CVD - Monocrystalline Diamond
	Diameter	91 mm
	Thickness	3 mm

With this application, we wished to explore the cutting limits in depth of the Laser-MicroJet® technology on a CVD-monocrystalline diamond. The provided disk was cut in several parts in order to test different geometries varying in depth and width. The disk was cut according to the drawing in Picture 1. The samples were then cut from the edge. The lines in colour in Picture 1 show the different cutting depths that were tested in this application. The red one is 20 mm long. The blue one is 24 mm long and the green one 48 mm long.

Release of application report			
	Project Leaders		Industry BU Responsible
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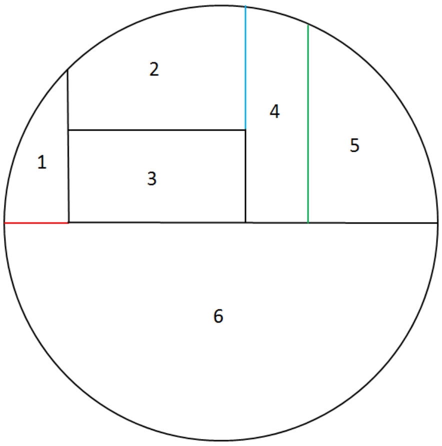
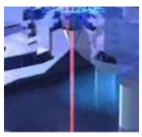
Date:	02.05.2014	Date:	05.05.2014
Visum:	FBR, SHI	Visum:	BC



PICTURE 1: Cut of the original sample and cutting depths tested

3. PROCESS: INSTRUMENT & TEST PARAMETERS

For this application, the LCS300, equipped with a frequency doubled, Q-switched, Nd:YAG laser, has been selected as the best machine configuration available in the lab. In the table below, the optimised processing parameters used in the experiments are summarised:

	**SYSTEM**	Machine type	LCS300	
		Fixture	Glued	
	**MICROJET® PARAMETER**	Nozzle diameter	60	*µm*
		Water pressure	350	*bar*
		Working distance	15	*mm*
		Assist gas	He	
	**LASER PARAMETERS**	Laser type	L101G	
		Wavelength	532	*nm*

Two sets of parameters have been used to reach a maximum cutting depth. They are summarized in the table below:

Set	Frequency [kHz]	Power (internal) [W]	Power (water jet) [W]	Pulse duration [ns]	Cutting speed [mm/s]
P1	6	40	29	170	10
P2	6	50	35	150	15

TABLE 1: Sets of cutting parameter used

4. RESULTS

The process time, number of passes and cutting depth for all the processed samples are shown in Table 2.

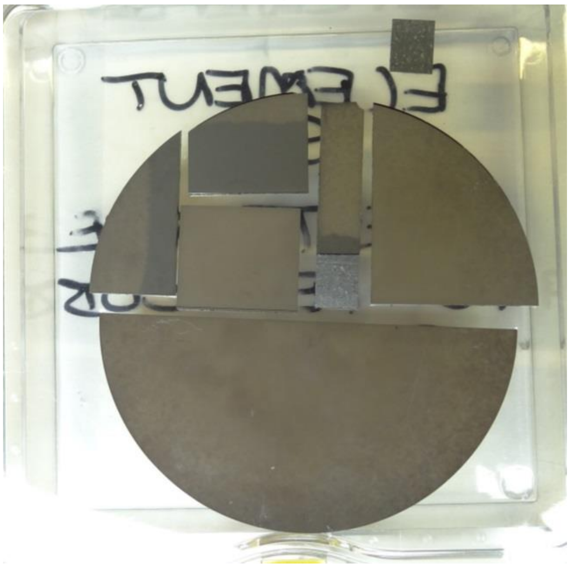
Sample	Parameter set	Process time	Number of passes	Cutting depth [mm]	Sample length [mm]
1	P1	7h26min	9 532	6	20
2	P2	5h45min	10 000	16	24
4	P2	1h56min	8 680	17	48

TABLE 2: Processing parameters

Only samples 1, 2 and 4 have been processed as they each have specific characteristics and so clearly represent the most general cutting options. Sample 1 has a long cutting path (40mm) and a rather short cutting depth (20 mm). On sample 2, the cutting path (28 mm) and depth (24mm) are roughly the same. Finally on sample 4 the cutting path is short (10 mm) compared to a very large cutting depth (48 mm).

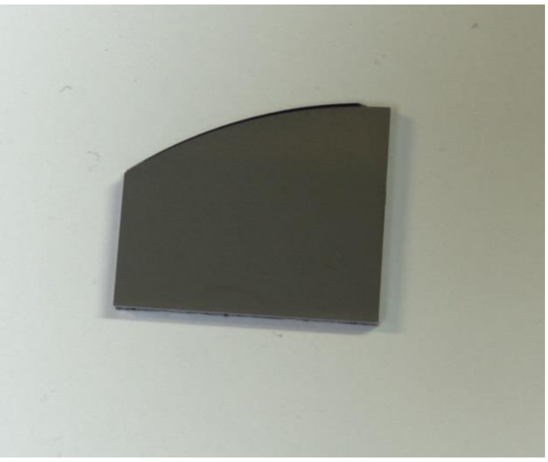
The equivalent cutting depth in sample 2 and 4 shows that the geometry of the diamond has a very small influence on the cutting depth. The increase of the cutting depth between sample 1 and 2, on the other hand, proves the significance of the changes in the laser parameters. A greater laser power seems to lead to a deeper cut. A further increase in laser power could not be tested as the energy density in the nozzle grows too high. The nozzle undergoes too much damage to sustain a reliable cutting process and eventually breaks. An increase in the nozzle diameter (change from 60 µm to 80 µm) while keeping the energy density constant has been tested but was unsuccessful to cut even the thickness of the original sample (3 mm). This is believed to come from changes in jet hydrodynamics, the water being fed back toward the jet inside the groove, disrupting the laser ablation process.

The following pictures show a macroscopic view of the samples:



PICTURE 1: Macroscopic view of the samples

PICTURE 2: Macroscopic view of sample 1



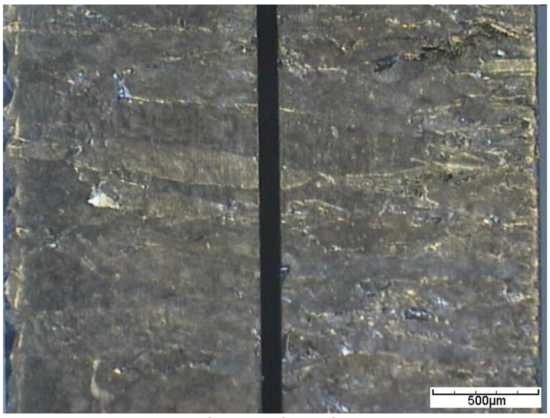
PICTURE 3: Macroscopic view of sample 2

PICTURE 4: Macroscopic view of sample 3

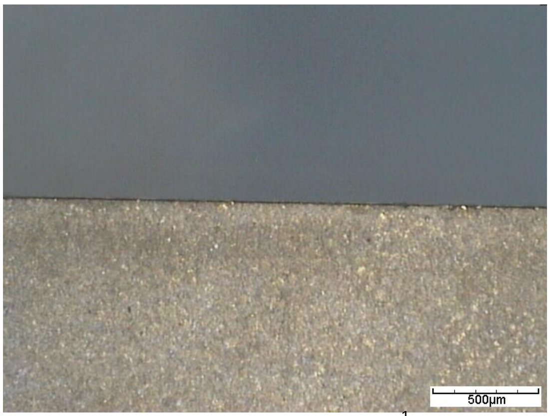
PICTURE 5: Macroscopic view of sample 4

PICTURE 6: Macroscopic view of sample 5

The following pictures show a macroscopic view of the samples:



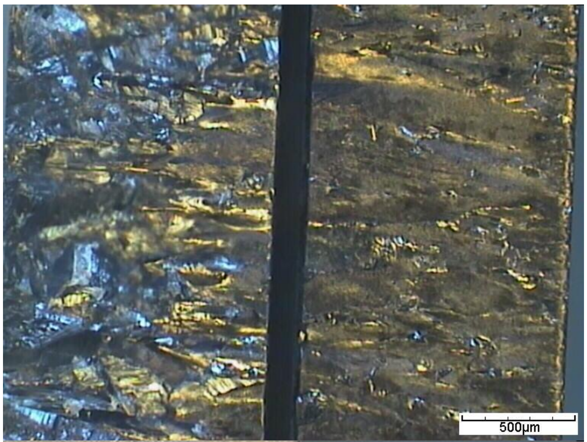
PICTURE 7: Sample 1, edge view

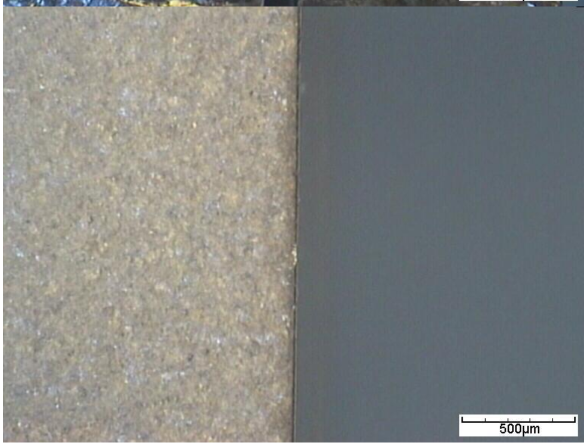


PICTURE 8: Sample 1, front side[1] view

[1] The front side indicates the side onto which the laser shines directly during the cutting process

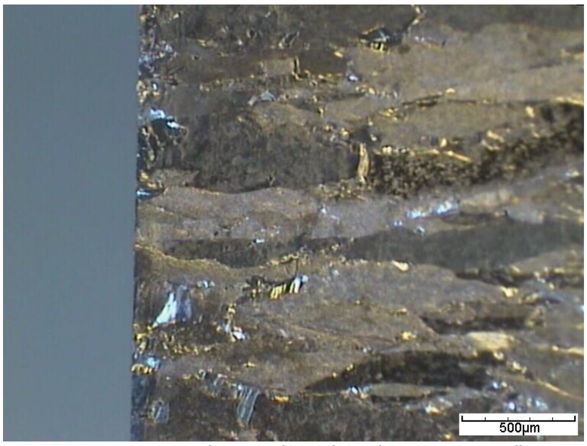
The front side (picture 8) refers to the first cut during which the original disk was cut into smaller samples. The actual processing was the cut of these smaller samples from the edge. This cut is clearly visible on the edge view (picture 7).



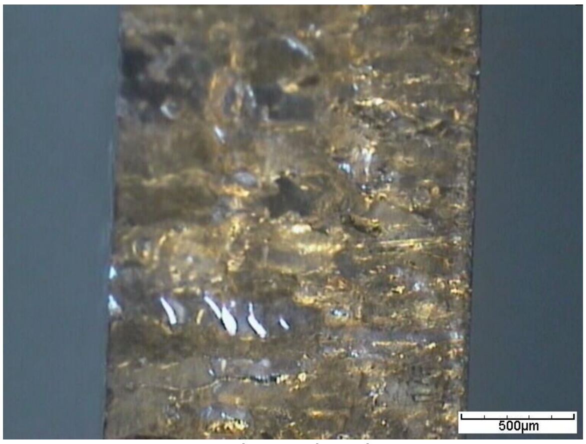


PICTURE 7: Sample 2, edge view

PICTURE 8: Sample 2, front side view

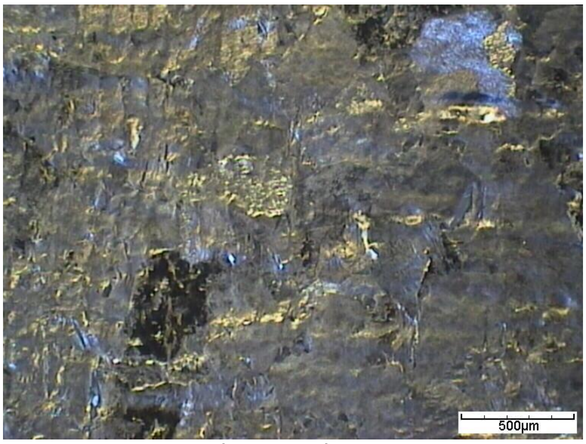


PICTURE 9: Sample 3, edge view (unprocessed)

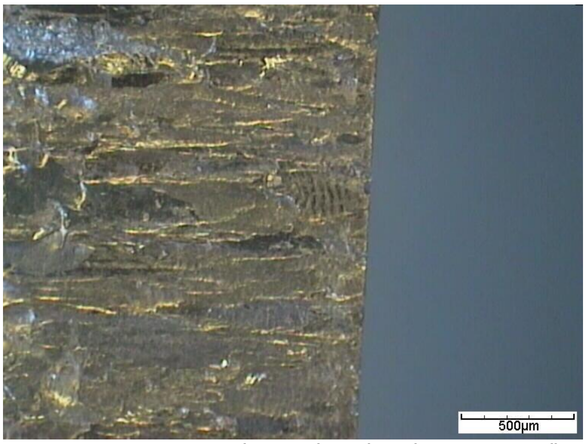


PICTURE 10: Sample 4, edge view

Sample 4 was processed. In order to evaluate the cutting quality, the cut part was then cut free from the sample allowing for roughness measurement (see below). Therefore the cut does not appear in Picture 10. The cut side view of sample 4 is presented in Picture 11.

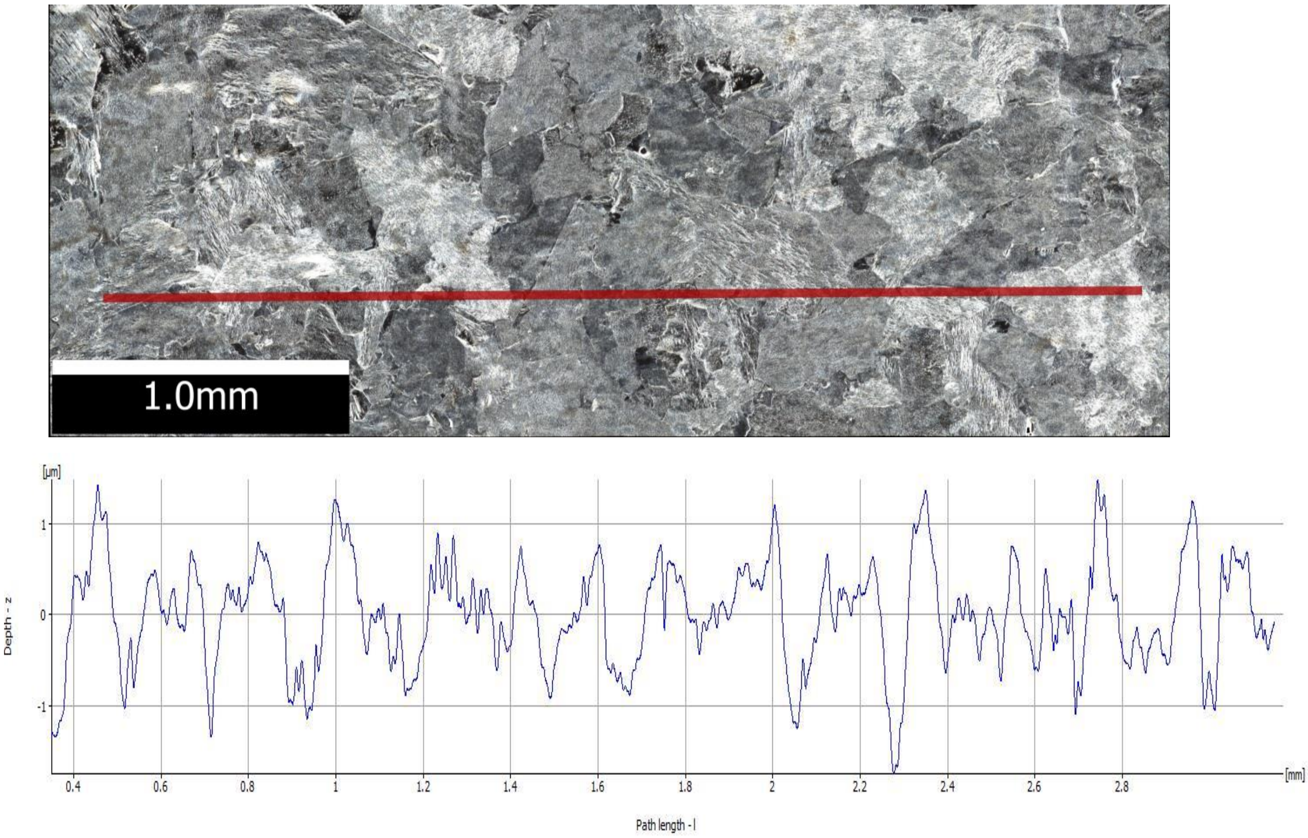


PICTURE 11: Sample 4, cut view



PICTURE 12: Sample 5, edge view (unprocessed)

4.1 ROUGHNESS MEASUREMENTS RESULTS

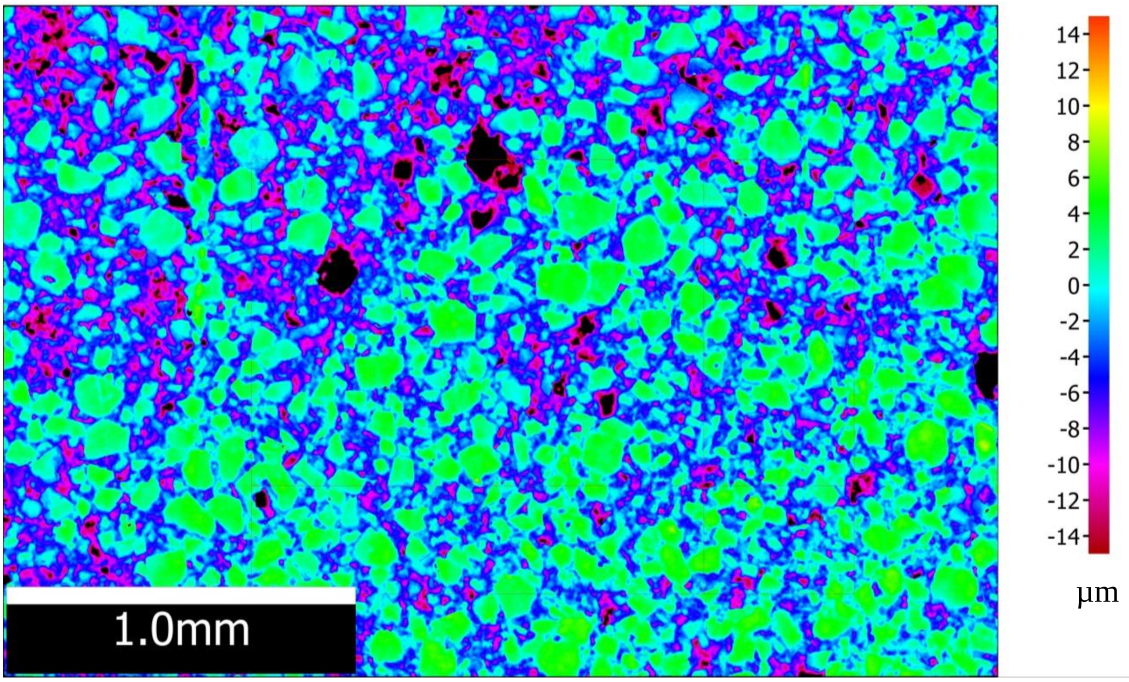


PICTURE 13: Roughness measurement

The roughness results are shown in Table 3:

Reference of measurement	Sa , L_c = 250 µm, size = 2 x 2 mm^2	Ra, L_c = 250 µm, roughness profile length = 3 mm average over 50 profiles = 30 µm
Sample 4	0.7 µm	0.45 µm

TABLE 3: Roughness results



PICTURE 14: Measurement for surface roughness Sa #1

5. CONCLUSION

The cutting of monocrystalline diamond has been performed with a SYNOVA LCS 300. This machine is based on the MicroJet® technology and combines the advantages of the high energy pulsed laser with a hair-thin water jet. While the laser is used for material ablation, the water jet is used for guiding the laser light, cooling the edges and preventing the sample from particle contamination, advantages that are essential for cuts with high quality.

These tests show that:

- The increase in energy density allows deeper cuts
- A change in the nozzle diameter does not affect the maximum cutting depth
- The roughness is low (Ra = 0.45 µm)
- The material grains due to the CVD process are clearly visible on the cut edges

We are open to further discuss your needs regarding:

- The final dimensions
- The use of a rotary axis to cut from two opposite edges and thus increase the cutting depth
- The material structure. We believe that the cutting saturation observed on this CVD grown sample is essentially due to the material structure. The material grains created by the CVD process lead to an inhomogeneous ablation rate and absorption (the max depth reach on a natural stone was 24 mm using the Laser-MicroJet® technology. We are open to discuss the cut of different kinds of monocrisalline diamonds (structure, internal tensions, CVD growth orientation…)

We thank you for your interest in our technology and we hope our results meet your requirements.
Our sales agent will contact you soon to obtain a feedback about the analysis of these results and to discuss with you the further steps.