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Application Note No. 126

Cutting of Raw Diamonds with SYNOVA Laser-Microjet®

<u>Description of Product</u>

The diamond is the preferred precious stone for use in jewellery because of its hardness and its high dispersion of light. Finished diamonds are graded and certified as per the *four Cs*, which are *carat*, *cut*, *colour* and *clarity*.

The 'carat' is the standard unit of measure in the diamond industry and one carat (= 200 milligrams) has 100 points. As the size of a diamond goes up, the price goes up exponentially. Prices can range from $2,000 up to $60,000 per carat.

The two preferred cuts are round (Brilliant) and square (Princess). Other cuts are trapezoid (Baguette), octagon (Emerald), heart, pointed oval (Marquise), oval, pearl-shape and rectangular.

The colour of a diamond is graded from D to Z. Two examples are: D, E, F (colour-less, most valued) or S, T, U, V (light yellow).

The clarity of a diamond is graded from F (flawless, perfect), IF (internal flawless), VVSI (very, very small inclusions, 2 grades) VSI (very small inclusions, 2 grades) to SI (small inclusions, 3 grades) and I (imperfect, 3 grades).

The process of shaping a rough diamond into a polished gemstone is both an art and a science. The choice of cut is often decided by the original shape of the rough stone, location of the inclusions and flaws to be eliminated, the preservation of the weight, popularity of certain shapes amongst consumers and many other considerations.

Even with modern techniques, the cutting and polishing of a raw diamond crystal into a finished stone always results in a dramatic loss of weight; rarely less than 50%.

To optimize their yield from raw diamonds, manufacturers have invested heavily in equipment to plan how a diamond should be cut. Sophisticated diamond planning systems, equipped with laser and video camera systems, enable the raw stone to be viewed three-dimensionally so that flaws such as inclusions can be detected and marked. Thereafter, the software proposes various cutting options and recommends an option with the highest yield in terms of market value. After the selection of a cutting option, a laser marking machine marks a brown line along which the diamond must be cut.

After cutting, the diamond is shaped and polished with multiple facets in order to exhibit its brilliance. There are a number of factors to quantitatively judge the quality of cut: proportion, polish, symmetry and the relative angles of various facets. A diamond with facets cut only a few degrees out of alignment can result in a poorly performing stone in terms of brilliance.

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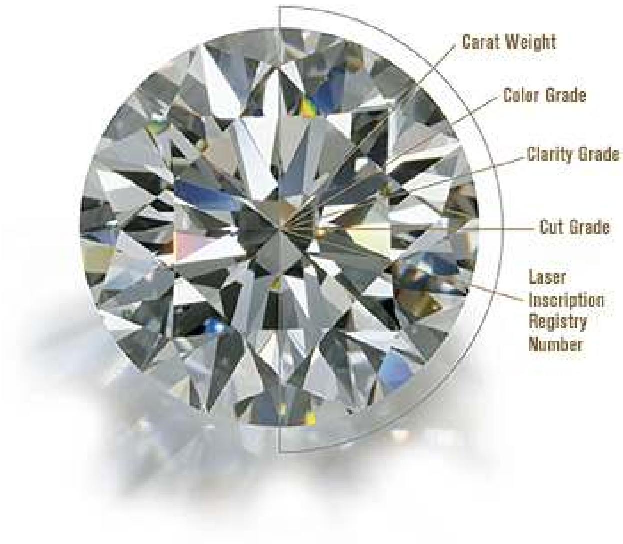

Description of Material

Raw diamonds mainly come from mines in Angola, Australia, Borneo, Botswana, Canada, Congo, Namibia, Russia, Sierra Leone, South Africa, Tanzania and Zimbabwe. The total world production is around 87 million carats and the 3 big producers are Botswana (25 million), Russia (22 million) and Canada (14 million).

Being a natural product, such stones are found in different sizes, shapes and colours. Each mining region has its particular characteristics but even here it is difficult to generalise and state that Canadian diamonds are harder and more difficult to cut than Australian diamonds.

Diamonds having hybrid crystalline structures, inclusions or internal material stress present special problems during the laser cutting process since they are liable to breakage. Many diamond processors still prefer to use traditional sawing machines, which are extremely slow but avoid the risk of diamond breakage.

Description of Manufacturing Task

The raw diamond is glued to a holding device and then aligned using a video camera and a large flat screen monitor. This alignment ensures that the stone is correctly positioned on the Synova DCS laser cutting machine so that the laser cuts the stone along the marked laser line. The diamond will move in the X axis while the vertical green laser beam in the Y axis can cut the diamond into two parts to a virtually unlimited depth. To reduce weight loss during the cutting process, nozzles with diameters ranging from 30 to 50 microns are used. The maximum permissible laser power will be within 40 Watts allowing fast material removal and short cutting duration.

The basic requirement, however, for the process to perform effectively is to use ultra-pure water (TOC value 30, resistivity 18 MOhms) for the water jet-guided laser. This will ensure a beam of good length and a long nozzle life.

The advantages of this cutting process are clean, smooth and parallel sliced surfaces, reduced weight loss, lower risk of breakage in so-called 'stress' diamonds and an increased cutting depth as compared to conventional lasers.

Description of Conventional Manufacturing Process (Status of the Art) and Problem

Currently, diamonds are cut on conventional infrared and green lasers, identified as 'dry lasers'. The conical laser beams in these dry lasers have several limitations: they require a precise focal length, leave non-parallel walls and have a small cutting aspect ratio. Furthermore, the increased heat leaves particles and reduces the lustre in cut surfaces. The greatest danger, however, is the risk of breakage in 'stress' diamonds. In the case of low quality diamonds, such breakage losses could average 1.7% over a period of a year.

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Water Jet Guided Laser Technique

In 1993, scientists at the Institute for Applied Optics at the Swiss Federal Institute of Technology Lausanne succeeded in creating a water jet-guided laser, called by its inventors Laser-Microjet®.

The laser beam is focused in a nozzle while passing through a pressurised water chamber. The geometry of the chamber and nozzle are decisive to coupling the energy-rich laser beam in the water jet. The low-pressure water jet emitted from the nozzle guides the laser beam by means of total reflection at the transition zone between water and air, in a manner similar to conventional glass fibres. The water jet can thus be referred to as a fluid optical wave-guide of variable length.

Because a pulsed laser is used; the continuous water jet is able to immediately re-cool the cut, resulting in only a very slight depth of thermal penetration. The result is a very narrow, parallel, burr-free, clean cut, without any thermal damage.

Cutting with water jet guided laser

Solution with Laser-Microjet® Process

The raw diamond stone sufficiently absorbs the 532 mm green wavelength of the Microjet® laser. The diamond can be cut without any breakage and uneven surfaces. Non-parallel cutting surfaces are completely avoided. In addition, the cutting aspect is such that large diamonds can be cut in a single operation instead of cutting from two sides as is the case in conventional lasers..

These following pictures show the excellent cutting quality.

Laser- Microjet® cut Diamond, cut surface, magnified (10x)

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Benefit for the Customer

The customer now obtains the following advantages:

- Smooth and parallel cut surfaces
- Less risk of breakage in the case of 'stress diamonds'
- No material deposition
- Lower weight loss due to kerf width 35 – 55 microns
- Large diamonds up to 10 mm cut in a single setting
- CNC control enables cutting of any shape
- Higher power
- Faster cutting speed

Consequence of the Benefits

Because of the huge improvement in the quality and productivity compared to conventional laser cutting; the Laser-Microjet® process will be the future choice for cutting of diamonds.

Machine for Laser-Microjet® Cutting of Diamonds

Synova offers a state-of-the-art, clean-room compatible machine, especially adapted for cutting of diamonds. Optimum cutting parameters are preloaded. The machine designation is DCS 300. The machine has a precision of +/- 3 microns, a processing area of 240 X 240 mm and a maximum axis velocity of 1000 mm/s.

The system is equipped with CCD camera and fast image treatment software, allowing automatic alignment and inspection. The operation interface is a 15-inch flat colour screen with touch panel, the machine software is based on Windows XP. The machine can be connected to LAN network for data transmission. The integrated modem allows telediagnostic service. Adapted CAM software can convert all DXF data, fast and easy without special knowledge. A complete list of options is available, such as chiller, alternative laser sources, water treatment system, 2D-reference scales, and transformers.

The CE and S2 certified Synova machines are field proven and used for 24h production.

DCS 300 (Diamond Cutting System)

