Precision cutting and grooving with the Laser MicroJet

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Outline

- Company – Products – Markets
- Laser MicroJet principle
- Selected applications
  - metal cutting
    - fuel injection nozzles
    - micro-springs
  - wafer dicing
  - laser doping of solar cells
- Conclusion
Company

Founded: 1997
Headcount: 60 employees
Products

Cutting of masks
- Laser Stencil System (LSS)

General purpose
- Laser Cutting System (LCS)

Cutting / grooving of wafers
- Laser Dicing System (LDS)
- Laser Grinding System (LGS)

Selective doping of solar cells
- Manual LCP Doping
- Inline Doping w/ Rena GmbH
- Hybrid Laser Saw (HLS) w/ Disco Corp.
Laser MicroJet Principle

- Water jet generated using small nozzles (20 – 160µm) and low water pressure (100 – 300bar). The water jet is not cutting.
- High-power pulsed laser beam focused into nozzle in water chamber
- Laser beam guided by total internal reflection to work piece
- Long working distance (>100 mm)
Laser MicroJet Principle

**Avantages:**

- Water jet guides laser ⇒ long working distance
- Water jet expels molten material ⇒ cleaner surfaces
- Water jet cools material ⇒ less HAZ
**Goal:**
- direct and optimize fuel flow into combustion chamber
- high pressure to atomize fuel into spray
- dimensions: 180 – 260 µm, ± 2 µm
- thickness 120 – 220 µm
- materials: stainless steel, AISI 440C (hard, resistant to wear and corrosion)
Fuel injection nozzles
Fuel injection nozzles

Cutting speed: 4 times higher with LMJ

Drilled with EDM

Drilled with LMJ
Fuel injection nozzles

- **Process:** cut four 310 µm holes with 18° angle

- **Automation:** 200 nozzles / hour
Fuel injection nozzles
Cutting of micro-springs

Annealed stainless steel - 150μm thickness

No post cleaning treatment
# Cutting of micro-springs

1. Cutting of micro-springs made of annealed stainless steel (150µm thickness)
2. Process parameters:

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>Machine type</th>
<th>LCS300</th>
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<td>MicroJet® diameter</td>
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<td>Water pressure</td>
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<tr>
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<td>Fixture</td>
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</table>
Cutting of micro-springs

Initial cut strategies resulted in a twisted spring. Optimization in cutting strategy allowed to eliminate built-in stress!
Based on Disco dual parallel spindle DFD6361
Fully Automatic Dicing Saw

- Performs loading, alignment, cutting, cleaning, drying and unloading fully automatically
- Wafer diameter up to Ø300 mm
- Cutting speed 0.1 - 600 mm/s
Hybrid Laser Saw (HLS)
Hybrid Laser Saw (HLS)

Cutting 600µm thick silicon wafer using saw followed by LMJ, cut in sequential passes
Dicing of thin wafers

Cutting of thin Si wafers

- 50 microns thick Silicon wafer
- 200 mm/s

Cutting of thin GaAs wafers

- 100 microns thick GaAs wafer
- 40 mm/s

Cutting of thin GaAs wafers

- 23 microns

50 microns
High doping emitter layer necessary to obtain good ohmic contact to metallization

Standard solar cells: Uniform emitter doping introduced using diffusion furnaces

Consequence: N+ emitter over entire surface
Solar cells

Consequence of having N+ emitter over entire surface:

High surface recombination in blue response (photons with high absorption coefficient)

Solution: use of selective emitters

Deposit high doping layer only below metallic fingers, not between fingers

Different techniques to introduce selective emitters exist, some based on lasers
Laser Chemical Processing

Idea from ISE*, based on Synova IP:

Start from water jet-guided laser technology; replace water by chemical jet

Lasers Chemical Processing (LCP)

LCP-doping physical model

Step 1
- Guide laser beam into chemical jet ($\text{H}_3\text{PO}_4$ for selective emitter)
- Laser pulse heats up surface (532nm, 1W, 10ns, 30kHz)

Step 2
- Evaporated / melted material ejected
- Separation of jet from surface
LCP-doping physical model

Step 3
- Vapor flume collapses
- Jet carries away debris
- Contact jet to surface reestablished

Step 4
- Carrier liquid decomposes thermally
- Liquid phase diffusion of dopant
LCP-doping physical model

Step 5
- Si resolidifies

Conclusion
- Self-aligned process
- Perfect epitaxy if pulse not too short
- Damage-free local diffusion
- No need for post-process anneal
Solar cell experiments

- Strong improvement of blue response using selective emitter by LCP-doping
- IQE close to 100% from 300nm to 900nm
- Dip around 1000nm due to non-optimized LFC process

Efficiency gain of 0.5 – 0.7% absolute
(e.g. efficiency increases from 17% to 17.5%)

Manual LCP machine

For R&D purposes
Manual loading / unloading
About 15’ per wafer
Automated LCP machine
Areas of application:

• local diffusion without thermal defects
• structuring combined with standard metallisation techniques
• structuring combined with self aligning electrolytic NiAg plating, NiCuAg plating in preparation
• single process for selective emitter or local BSF forming

Machine specification:

Process: local SiN ablation and n++ type diffusion
Dimensions: 9500 x 3500 – 4000 x 2000 mm (length x width x height)
Throughput: 1200 – 4800 wafers / h
Wafer thickness: > 160µm
H₃PO₄ consumption: 0.4 – 0.8 l/h
Power consumption: 30 – 50kW
Conclusion

Laser MicroJet technology is a versatile and cost-effective tool for precise cutting of

- Thin metals
- Semiconductors
- Hard materials
- Ceramics
- Diamonds

Extensions of the technology, like Laser Chemical Processing (LCP), opens up a whole range of new applications.
Example: laser doping for introduction of selective emitters in solar cells
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Where others see impossibilities, we see solutions