JENOPTIK-VOTAN™ Solas Series for the Photovoltaic Market

JENOPTIK Automatisierungstechnik GmbH

JENOPTIK AG

- JENOPTIK AG hive off JENOPTIK Carl Zeiss Jena GmbH
- Founded: 1991
- Type of Enterprise: AG
- Sales 2008: approx.: 550 Million €
- Employees 2008: approx.: 3,500
- Research and development ratio: at more than 11 percent
JENOPTIK Group – Divisions and business units

Corporate Center

Optical Systems
- Optics
- Micro-optics
- Digital imaging
- Optoelectronical systems

Lasers & Material Processing
- Diode lasers
- Laser systems
- Laser processing systems

Industrial Metrology
- Surface roughness & contour
- Form & position measurement
- Dimensional measurement

Traffic Solutions
- Equipment
- Service providing

Defense & Civil systems
- Mechatronics
- Optronics
- Sensor systems

Target Markets

JENOPTIK-VOTAN™ Semi - for semiconductor industry
JENOPTIK-VOTAN™ Advanced - for flat panel display industry
JENOPTIK-VOTAN™ Solas - for thin film solar industry
JENOPTIK-VOTAN™ Compact - as stand-alone system for glass and ceramic industry
JENOPTIK-VOTAN™ Solas Series  
Scope of Delivery - TF Fab Overview

Development

Front end

Back end

JENOPTIK-VOTAN™ Solas 100/200  
Structuring Solution for the Photovoltaic Market

Thin film structuring  
Edge deletion  
Glass cutting
**JENOPTIK-VOTAN™ Solas 100/200**

Structuring Solution for CIS/CIGS Thin Film Modules

<table>
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Layer set up and structuring steps for CIS/CIGS technology

- **P1** separate contact 1
- **P2** serial interconnection
- **P3** separate contact 2

**TCO**
- semiconductor
- metal contact
- barrier
- substrate (glass)

**JENOPTIK-VOTAN™ Solas 100/200**

Top Side Processing of CIS/CIGS Thin Film Modules

**Task**
- Structuring for electrical separation of back side contact, absorber and TCO layer

**Machine Solution**
- **JENOPTIK-VOTAN™ Solas** back side contact ablation by laser (1064 nm)
  - different optical arrangements for various groove widths
  - structuring speed > 1.0 m/s
  - various sensor and process monitoring
- Mechanical structuring of the absorber and TCO layer
  - multiple scribing tool up to 22 parallel needles
  - each needle is force controlled
  - automatic alignment after tool change
  - various sensor and process monitoring solutions

**Advantages**
- no damage of glass, no delaminating, no lift off
- high positioning accuracy at highest throughput
- each needle is individual force controlled
- automatic re-alignment after tool exchange

**Machine Solution**
- **JENOPTIK-VOTAN™ Solas 114**
JENOPTIK-VOTAN™ Solas 100
P1 Structuring – Results 1/2

Optical configuration can be customised to the process and product requirements

- JENOPTIK Laser; wavelength 1064 nm
- Groove width between 20 ... 140 µm
- Substrate remains damage free
- High structuring speed (v > 1.0 m/s)
- Stable process conditions, high repeatability

JENOPTIK-VOTAN™ Solas 100
P1 Structuring – Results 2/2

- Transition area, free of micro cracks
- Straight groove borders
- Theoretical structuring speed up to 2200 mm/s

Top hat profile
JENOPTIK-VOTAN™ Solas 200
P2/3 Mechanical Structuring – Results

Optimised needle combs for different application requirements

- groove with between 30 ... 90 µm
- bottom layer stays undamaged
- high positioning accuracy according to pattern 1 lines
- high structuring speed (v ≤ 1.0 m/s)
- minimised chipping effects

JENOPTIK-VOTAN™ Solas 100/200
One Design Concept

one machine design
for various structuring tasks:
laser structuring (up to 12 laser processing heads)
or mechanical structuring (up to 22 needles)
JENOPTIK-VOTAN™ Solas 100/200
One Design Concept

- Optical structuring line analysing module
- Electrical resistance measurement module
- Granite based portal system separates x/y movements
- Cycle time and application depending tool set up possible (e.g.: ≤ 12 Laser, ≤ 22 needles)
- Proved and verified exhaust system
- PC based operation secures user-friendly operation

JENOPTIK-VOTAN™ Solas 200
P2/3 Structuring – Multiple Structuring Tool

needles combs of up to 22 needles available
  » high throughput

needle are individual online controllable
  » variable cells width adjustable
  » online compensation of temperature based dimension changes

each needle is active force controlled
  » high structuring quality, no tool jumping
  » layer 1 stays unharmed
  » full ablation with one path process

automatic realignment after tool exchange
  » minimised down times
  » stable and reproducible process
Layer set up and structuring steps for a-Si and CdTe technology

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JENOPTIK-VOTAN™ Solas 100/200
Bottom Side Processing of a-Si and CdTe Thin Film Modules

Task:
Laser structuring of the back side contact, absorber and front side contact for serial interconnecting

Machine Solution:
- JENOPTIK-VOTAN™ Solas
  - different optical arrangements for various groove widths
  - structuring speed ≤ 1.5 m/s
  - various sensor and process monitoring solutions
  - Substrate temperature compensation ensures highest structuring accuracies

Advantages:
- Up to 12 laser processing heads
- Machine throughput adaptable to production tact time
- High speed and dynamic stages for processing speeds up to 2000 mm/s
- Machine base designed for panels of 1400 mm x 1100 mm (other sizes on request, design is up scalable)
- Easy line integration, fast loading/unloading
JENOPTIK-VOTAN™ Solas 200
P2/3 Structuring – Results

wavelength: 532nm
max. structuring speed up to 2000mm/s

JENOPTIK-VOTAN™ Solas 100/200
Machine Set up

Output conveyer
Exhaust module
Gripper
Air cushion bars
X-axis
Granite base frame
Optical module
Substrate
Input conveyer
JENOPTIK-VOTAN™ Solas 100/200
Process Control Options

Resistance measurement
» quality control for P1 structuring
» control of complete removal of P1

Transmission measurement
» quality control for P2/P3 structuring
» control of complete removal of P2/P3

Reflection measurement
» quality control for P2/P3 structuring
» control of complete removal of P2/P3

Vision system
» needle wear and breakage detection
» microscopic groove analysis

JENOPTIK-VOTAN™ Solas 100/200
General Design Concept

Granite bridge
» basis for different working instruments (needles or laser)
» high accuracy due to small thermal expansion
» Machine concept allows a wide range of up-scaling to bigger substrate

HMI based operation
» user friendly
» identical interface for all structuring processes
» complete adjustable machine parameters
» easy integration in any line concept
JENOPTIK-VOTAN™ Compact 500
R&D System

Special features of the R&D system:
- Suitable for all TF technologies
- Suitable for all TF structuring & ablation processes
- Substrate size up to: 470 x 370 mm²
- Customized tools included
- Same system features as production system
- Perfect small scale development tool

JENOPTIK-VOTAN™ Compact 500
P2/3 Laser Structuring – R&D Results

Laser structuring for pattern 2 and 3 of CIS/CIGS thin film solar modules lead to the following benefits:
- highest structuring quality
  - no flaking
  - clean and safe exposure of the back side metal layer
- module efficiency can be increased
  - small groove width between 5 … 20 µm possible
  - distance between the three patterns can be reduced
- reduced CoO
  - no mechanical wear
  - stable processing results, long maintenance intervals
JENOPTIK-VOTAN™ Solas
Structuring for Flexible Solar Cells

**Task**
Structuring of contact and isolation trenches for thin film solar cells on flexible substrates

Substrate: polymer foil, stainless steel foil  
Layer composition: BCO, semiconductor, (buffer layer), TCO  
Structuring inside a roll to roll process

**Image:**
- Mechanical structuring
- Laser structuring

**Source:** Silicon Solar

JENOPTIK-VOTAN™ Solas 400
Solutions for the Photovoltaic Market

**Images:**
- Thin film structuring
- Edge deletion
- Glass cutting
## JENOPTIK-VOTAN™ Solas 400
### Edge Deletion Solutions

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### Layer set up and deletion step (example)

- **Substrate (glass)**
- **Barrier**
- **Semiconductor**
- **BCO/TCO**
- **Laser ablation**

## JENOPTIK-VOTAN™ Solas 400
### Laser Edge Deletion and Glass Cutting - Requirements

- Surrounding ablation of all layers
- No microcracks in the glass
- Resistance > 1GOhm
- No melting zone on layer edge
- Straightness of ablation 0.5 mm
High power Nd:YAG laser (200W / 400W / 600W / 800W)
Ablation rate 25 ... 50 cm²/s (depends on material)
Laser process through the glass, exhaustion from layer side
Spot size 1 mm², rectangular shape

JENOPTIK-VOTAN™ Solas 400
Laser Edge Deletion - Process Results

• Ablation with laser (1064nm)
• Different pulse- and line overlaps for various materials
• Electrical insulation > 1 GOhm
• No damage of glass
• Ablation speed 50 cm²/s
• High transparency of ablated areas
JENOPTIK-VOTAN™ Solas 414
Laser Edge Deletion - System Layout

JENOPTIK-VOTAN™ Solas 426
Laser Edge Deletion – Large Substrates - Video
JENOPTIK-VOTAN™ Solas 500
Glass cutting Solution for the Photovoltaic Market

Technologies:
- Thin film structuring
- Edge deletion
- Glass cutting

Technology TLS – function principle

- Laser beam (red) heats up the surface, whereby compressive stress is induced into the material.
- Directly after the laser beam, a coolant (blue) is applied to the surface, causing tensile stress in the material.
- Starting from the initial crack, a crack propagates along the working line.
- Principle suitable for scribe and break or full cut.

JENOPTIK-VOTAN™ Solas 500
TLS – Ablation-free Glass Cutting Technology
JENOPTIK-VOTAN™ Solas 500
TLS (Thermal Laser Separation) - Basics

1. Initial defect (scribe)
2. Heating (Laser)
3. Heat conduction
4. Cooling (Aerosol)
5. Resulting scribe

JENOPTIK-VOTAN™ Solas 500
Samples for Bending and Temperature Tests

Comparison between glass samples with various edge quality.
Analysis of glass properties in relation to the separation method:

Mechanical cut
Mechanical cut / chamfered
Laser cut

Material: soda lime glass
Thickness: 3 mm
**JENOPTIK-VOTAN™ Solas 500**  
Bending Test

Event of breaking appears at significant higher bending force. TLS samples reaches the strength of material. Any mechanical edge treatment reduces the overall strength.

**JENOPTIK-VOTAN™ Solas 500**  
Results of Bending Tests

- Edge post processing like chamfering/c-shaping does not improve the bending strength
- Bending strength rises only because of micro crack free edges
- Laser cutting leads to an up to 2.5 times higher bending strength
JENOPTIK-VOTAN™ Solas
Temperature Fatigue Strength Test

Complete heated glass samples are dropped into a room temperature water bath. The number of cracked samples indicates the fatigue strength.

Definition:
Temperature Fatigue strength is reached when 50% of the samples are cracked.

Result:
When the TLS samples succeed the breakage rate of 50% all mechanical scribed and post treated samples are already cracked.
JENOPTIK-VOTAN™ Solas 500
Advantages for Solar Module Production

**Higher bending strength:**

- Using the same glass thickness the snow load- and hail-stability increases
- For the same stability the glass thickness can be reduced

**Higher temperature fatigue strength:**

- The head-up and cool-down temperature ramps in the coating process can be shortened
- Energy consumption decreases
- Minimizing the scrap rate due to glass breakage in the coating processes

Glass Cutting Line for Thin Film Solar Modules
Integrated Laser Cutting Technology (TLS)

thermal laser separation (TLS)
JENOPTIK-VOTAN™ Solas
BIPV – Semi-transparent thin film solar modules

The laser machine JENOPTIK-VOTAN™ Solas 600 has been designed for the manufacturing of semi-transparent thin-film solar modules for solar-active building skins (BIPV = Building Integrated Photovoltaics) and can be integrated in the back-end production either directly in-line or as a bypass.

Semi-transparency can be created over the entire absorption area by way of selective laser ablation. The larger the ablated patterns, the greater the light transmitting capacity or transparency respectively. The machine concept features short processing time, pinpoint accuracy and reliability.

The pattern of transparent structures is freely programmable. This facilitates customized manufacturing. The cycle time is dependant on the form and distribution of the transparent structures. The flexibility of JENOPTIK-VOTAN™ Solas 600 assure the customization on developing trend of the market and new requirements of architect.

JENOPTIK-VOTAN™ Solas for BIPV
BIPV-Deletion Technologie with IR-laser

Laser process through the glass, exhaustion from layer side
Ablation inclusive TCO-layer

- High power Nd:YAG laser - wavelength 1064nm
- Typical parameters:
  - Laser power 400 W
  - Ablation rate 25 ... 50cm²/s (depending on material)
  - Spot size 0.5...1 mm², rectangular shape
JENOPTIK-VOTAN™ Solas for BIPV
BIPV-Deletion Technologie with green-laser

Laser process through the glass, exhaustion from layer side
Ablation without transparent and conductive TCO-layer

High power green laser - wavelength 532nm
Typical parameters:
- Laser power 30 W
- Ablation rate 10 cm²/s (depending on material and pattern)
- Spot diameter 0.32 mm, circular shape

JENOPTIK-VOTAN™ Solas 412+BIPV
Pattern

BIPV with horizontal stripes – Solas 412 + BIPV only

P3-Lines
BIPV-Lines
JENOPTIK-VOTAN™ Solas
Different transparencies in a-Si with line spacing

10% Transparenz
7% Transparenz
15% Transparenz
12% Transparenz

JENOPTIK-VOTAN™ Solas
Different transparencies with holes spacing

Spot sizes: 150 ... 1000 µm
Transparencies: 5% ... 90%

Laser: 532nm
Laser power: 10 ... 100 W
JENOPTIK-VOTAN™ Solas
Different overlap for complete ablation

15W laser, Spot size 160µm
Pulse overlap possible.
Single shots shows flaking.

100W laser (30W used), fiber coupled,
spot size 550µm
Single shots are possible.
Pulse overlap looks not very good.

In both cases the TCO is undamaged.

JENOPTIK-VOTAN™ Solas
Customizing ablation

For example: Logos
JENOPTIK Automatisierungstechnik services
Benefit from our Experience – Think JENOPTIK-VOTAN™ Solas

JENOPTIK-VOTAN™ Solas machine systems for Photovoltaic Market open new opportunities

JENOPTIK Automatisierungstechnik GmbH
Locations and Representations

Our service concept - global, at any time and comprehensive.
JENOPTIK Automatisierungstechnik GmbH

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