

4SUR

faces

The Laser Technology Magazine by 4JET

Issue 1

EDGE DELETION
for Thin-Film Solar Cells

KEEPING TRACK
*4JET Systems
for Tire Marking*

LASER | SYSTEME | SERVICES

4JET

Editorial

As a provider of integrated solutions for laser surface processing, we get around a lot. Somehow - in retrospect one calls it strategy – we got stuck to tires and thin film solar cells.



What do tires have to do with solar cells? Almost nothing. The tire industry has been around for more than 100 years, production is extremely developed and the steps of development have become smaller. Thin film solar cells have been around for the past few years and the dynamics of development are high. Today, a thin film fab manufactured in 2006 is considered as outdated for the most part and a 2006 tire plant is all the rage.

However, if one compares some dimensions such as the time it takes the parts to move through the factory (some hours), the price per part (50-150 EUR), the weight (car tire and thin film panel about 15 kg each) and the daily fab output (several 1000 parts) the two worlds do not appear as remote as one might think: The products produced are small high-tech wonders which have to function for years under extreme conditions.

What can the two industries learn from each other? A tire maker with the technological dynamics of a thin film producer or a thin film producer with the yield of a tire maker will definitely stand out in their respective markets.

What the two did not solve yet? Conveying the complexity of their products and creating a brand. Few people know what tires are mounted on their car and those who are foreign to the sector hardly know the name of any solar cell manufacturer.

What both industries have in common? Laser technology plays an increasingly important role. Good for us. A range of application examples is introduced in this first issue of 4SURfaces.

Enjoy reading!

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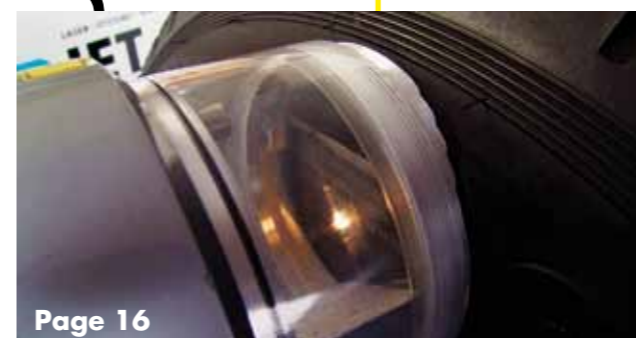
Page 04



Page 10



S. 14



Page 16



Page 27

Editorial

SOLARtechnology

Page 04 - 07

EDGE DELETION

for Thin-Film Solar Cells

Page 08 - 09

PRODUCTnews

Page 10 - 11

EYE TO EYE

Gerold and 4JET

Page 12 - 13

THIN-FILM, QUO VADIS?

An Outlook

TIREtechnology

Page 14 - 15

KEEPING TRACK

4JET Systems for Tire Marking

Page 16 - 17

NEW T-MARK COMPACT SYSTEM

for Tire Marking

Page 18

LASER MARKING OF TIRES

Application Report Continental Matador

Page 19

LETTING THE AIR OUT

No difficult Thing

Page 20 - 21

PERFECT SHAPE

Laser Cleaning in the Tire Industry

MIXEDzone

Page 22 - 23

SHORTmessages

Page 24 - 26

LASER CLEANING

An Overview

Page 27

RITA MAKES HEARTS BEAT FASTER

EDGE DELETION

for Thin-Film Solar Cells

Despite the one or two clouds in the sky: the expansion of the world-wide photovoltaic industry continues. Thin-film solar cells have a growing share as an interesting alternative to the conventional crystalline solar cells and solar-thermal systems. In manufacturing the glass substrates go through a sequence of processes, where thinnest layers of conductive oxide (TCO), semi-conductive material (e.g. amorphous silicon, Copper Indium-Selene or Cadmium Telluride) and a metal contact (usually Molybdenum) are deposited onto the glass. Between the individual deposition steps, the



Decisive criterion for edge deletion is insulation testing

deposited layers are electrically isolated using laser structuring systems. One of the last processing steps is the so-called edge deletion. The layer stack must be removed in an area of 10-15 mm from the outer glass edge

before the module will be enclosed in a lamination process. 4JET has pioneered in the use of lasers for edge deletion and has installed several systems in the last years. It is time for an inventory and a look ahead.

The Challenge

Today edge deletion processes must comply with the requirements of all established test standards such as IEC 61646 and 61730 as well as with volume production requirements. The significant characteristics are:

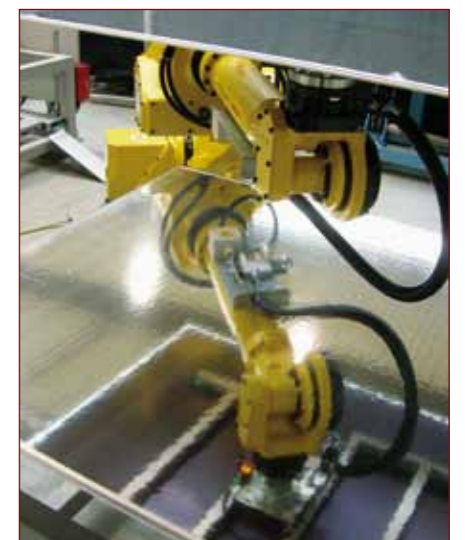
- Electrically insulated substrate surface (Quick test > 2 GOhm at 1kV between

two measurement probes in a distance of 5 mm)

- Visually clean, preferably unchanged glass surface without scratches and dust, which can be laminated without post-treatment
- A glass substrate free of micro cracks that might transport moisture and grow over time
- Reproducible processing zones and sharp transitions between edge and layer stack
- And of course, production-worthy solutions with minimal cost of ownership, high uptime and low maintenance requirements.

Why Laser?

The use of laser systems for edge deletion meets above requirements better than conventional blasting or grinding processes: The insulation resistance is typically higher than for blasting processes. The reason for that is especially the inhomogeneous processing of mechanical solutions. Depending on blasting pressure and particle size of the blasted material areas remain unprocessed, where TCO-residue (or molybdenum in the case of CIGS modules) remains. Laser processing only changes the roughness of the glass substrate in the range of



Robot-based edge deletion systems are particularly well suited for smaller substrates and two-sided processing

a few nanometers and thus by orders of magnitude less than sand blasting. In optimized processes the creation of Micro cracks can be eliminated or limited to certain locations, so that no long-term effects can occur in the glass. Opposite to that, mechanical processing causes significant damage to the glass substrate. Accuracy and repeatability of laser technology are significantly better than mechanical processes. Modern solid state lasers run thousands of operating hours without maintenance. The life time of the pump diodes is typically more than approx. 20.000 hours. Other maintenance is typically limited to the cooling circuit and exhaust systems. Conventional blasting and grinding processes on the other side require high maintenance and wear quickly due to high pressures and contamination build-up. Lasers convince with high flexibility and versatility. Different frame widths, adjustment to glass substrate tolerances, exposures in the center of the layer stack or so-called isocuts can be realized with systems offered by 4JET.

disposal fees for partially toxic blasting material increase the customer benefit. Furthermore, lasers provide a superior quality as well as higher yield and may make processing machines required for isocut or after-cleaning redundant. In some cases, the laser replaces two or even three other processing machines.

Process parameters

The key parameters influencing edge deletion have been understood. Without knowledge of the exact action mechanism a laser project can

average power with preferable short laser pulses and ideally high pulse energy. The design of the laser beam delivery system allows the economical use of "expensive" laser power. If possible, rectangular or square beam spots are used, in order to minimize overlap areas between individual pulses. A beam profile with homogeneous energy distribution to the edge zones is advantageous. However, if this is achieved at the expense of depth of focus, the

waviness is compensated by a dynamic beam control system. Processing zones and strategies can be changed via software, without tool change. Interface standards such as SECS/GEM, comprehensive data logging and VPN tele-service presence are requirement for the application in modern production. Typically the systems

include automatic power measurement and control at the source and at the processing location. Furthermore, 4JET delivers a process control module, which checks the complete area of the deletion areas for residue using a high-voltage test. The costs for the system were slightly reduced in the last years; the throughput of the 4JET systems was doubled during the same

time. Therefore, today's processing costs are only 40 % compared to the first machines installed.

Outlook

The dynamic development of the last years introduced a mature technology with reliable machines to the market. Beside further reduction of cycle times, future trends are the combination with other process steps, such as insulation cut or exposure of Molybdenum on CIGS solar cells, in order to further reduce overall investment costs. A transfer into processing of flexible substrates can be foreseen as well.

Summary

4Jet systems are already used today in the production of a-Si-, uc-Si-, CiS-, CIGS- and CdTe thin-film solar cells. The significant benefits of laser edge deletion, especially with regard to quality and operation costs, depreciate in short time the additional investment in comparison with conventional methods. A sufficiently large process window exists for all common layer stacks, when influencing parameters of glass, layer stack and laser processes are understood and adjustable in the production system. Condition for this is an integrated complete solution of process and engineering.



The INLINE system by 4JET enables full-area processing of substrates of any dimension

Costs?

Laser systems require higher investment costs than conventional methods. However, a simple price comparison misses the point. Only the increase in module efficiency due to a reduction of „dead area“ between insulation edge and absorber makes the investment for laser technology affordable in many cases (refer to info box). Low operational costs (spares and consumables costs < 2 EURO/h) and reduced manpower requirements ensure for an overall lower "total cost of operation" than methods used until now. Savings in

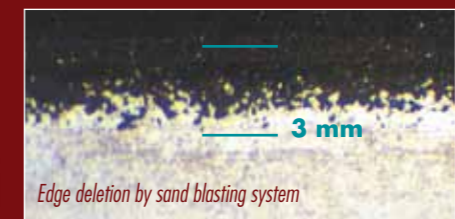
become a research project. Parameters with significant impact on the required processing strategy exist, for example doping of the front contacts (free charge carriers in the TCO volume), barrier layers on glass or the transmission of the substrate glass at the selected laser wavelength. Hence, the system manufacturer must have some process understanding. There are many different tuning knobs during design and ablation process optimization. State-of-the-art today is the use of diode-pumped solid-state lasers. Key selection criteria are the available

processing of warped substrates becomes more complex. The ablation strategy can be different from layer stack to layer stack: Some layers are best removed with single pulses and use of a high pulse energy, while for other systems multiple passes with lower pulse energy might be better suited.

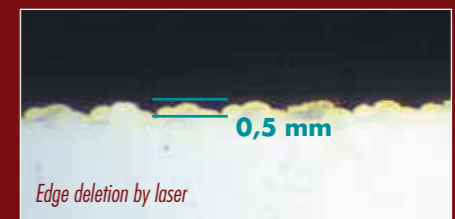
Design parameters

State-of-the-art edge deletion systems by 4JET today deliver an ablation rate of 30-60 cm²/s and insulation resistance of 2 GOhm/mm at 1 kV. Dimensional tolerance of the substrate can either be distributed to the layer stack or in the edge area. Glass

EFFICIENCY INCREASE BY LASER DELETION



Edge deletion by sand blasting system



Edge deletion by laser

Edge deletion with sand blasting system: Changes in the glass are clearly detectable. The blurry area between insulation edge and absorber costs precious efficiency. A transition zone of 3 mm does neither serve insulation nor absorption and is wasted. Laser

processing reduces the „dead zone“ to below 0,5 mm. What sounds like a detail, can be converted into convincing numbers: The 2,5 mm width gained corresponds to an absorber area of 125 cm² or 0,8 % of the total module area for a 1400 x 1100

mm substrates. For a 150 W module, the additional absorber area supplies approx 1,5 Wp additional energy output. The obtainable module price increases by more than one EURO and therefore by a multiple of the overall process costs of laser deletion.

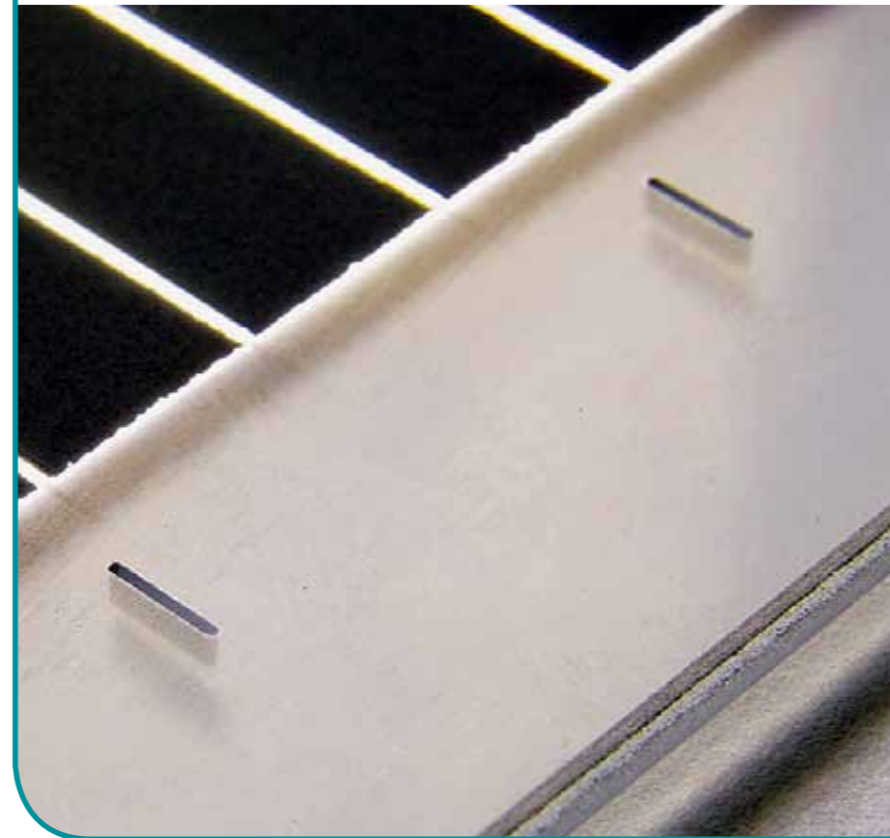
PRODUCT *news*

QVS-SYSTEMS *for thin-film solar cells*

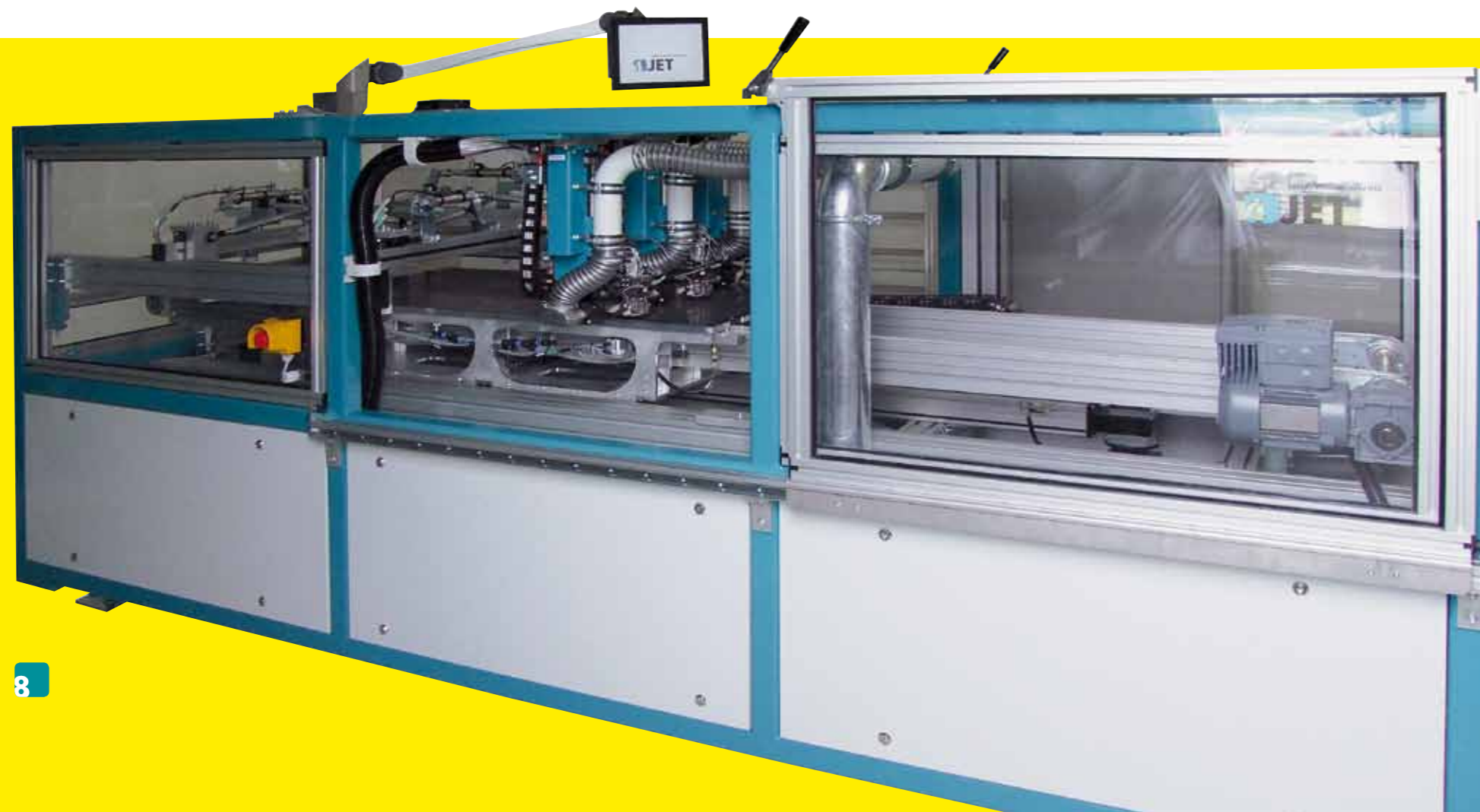


The requirements for edge deletion methods can be derived from IEC 61646 and 61730. According to that a defined resistance must be generated on the exposed border area. The QVS tool from 4JET enables full-area insulation measurement of the areas which were stripped using high voltage. The system detects conducting residue on the uncoated glass surface and the C-seam of the substrate. The compact station can be optionally equipped with additional test sensors and can be installed stand-alone or integrated into the backend.

SOLAR GLASS DRILLING



Depending on the module architecture of a thin-film solar cell drillings are required in the border areas to route the contacts through. Classical mechanical drill methods cause micro cracks which are problematic in the border areas. 4JET delivers laser modules for gentle glass drilling with a pulsed laser beam. The laser light is focused in the glass and routed through the entire thickness of the glass using a 3D scanner. The resulting boreholes do not change the mechanical strength of the glass and distinguish themselves by smooth edges. Random shapes such as cone holes or ellipses can be defined in the software. The aspect ratio (diameter to depth) of the boreholes is almost unlimited for solar glass applications.



MEX-SYSTEMS *for exposure of Molybdenum on CIGS solar cells*

One process step during manufacturing of CIGS solar cells exposes the Molybdenum layer deposited onto the glass by removing the semiconductor material and the TCO layer. For the following contacting with bonding or ultrasonic welding a preferably clean surface is required. The typically several

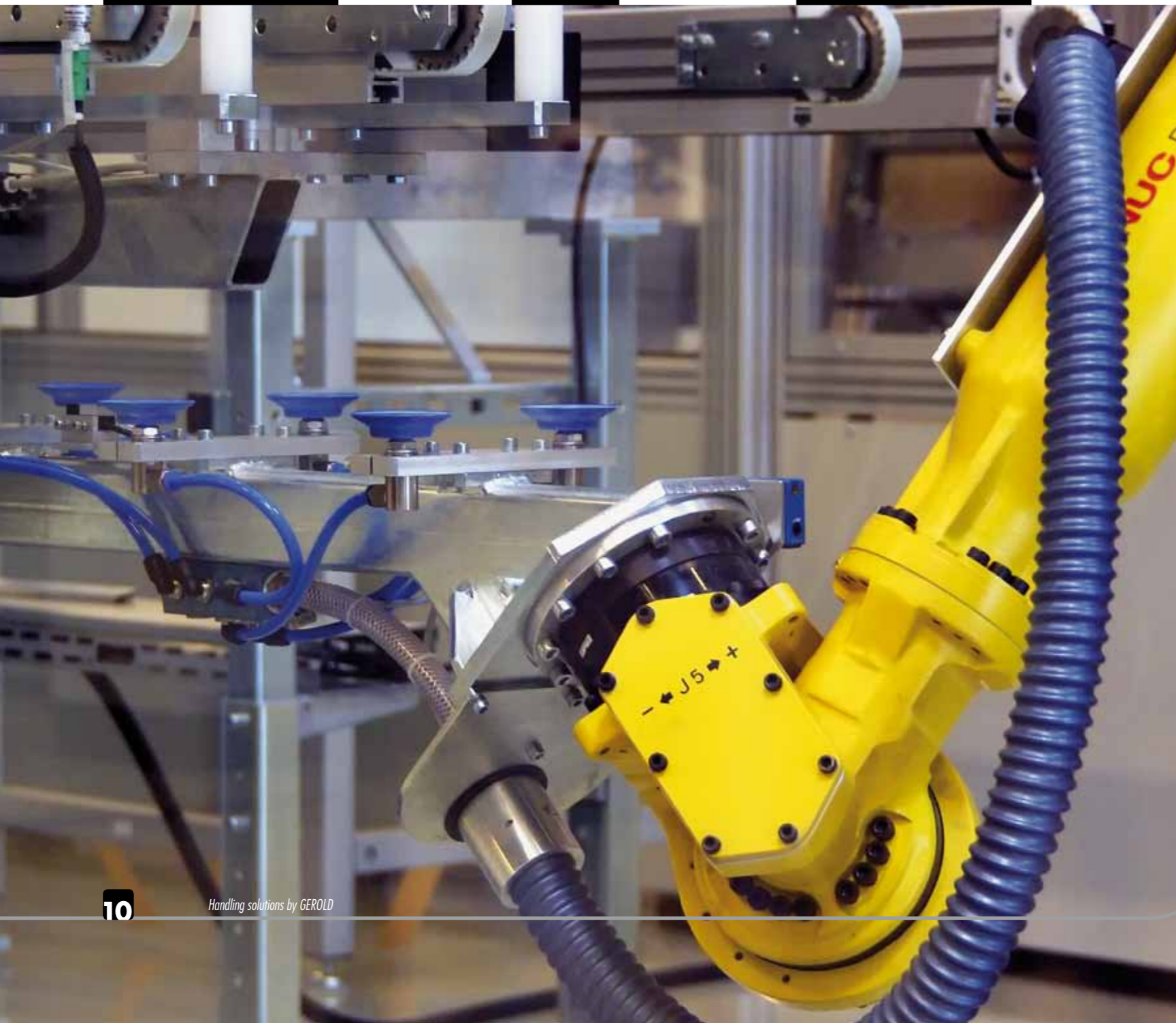
millimeter thick stripes are located along the short or long substrate sides. The MEX systems developed by 4JET allow for precise exposure. The use of one or more processing heads with a precise and low-wear tool maintains throughput of modern CIGS manufacturing lines without problems.



to

EYE

EYE



The dynamic growth of 4JET would not have been possible with this speed without powerful partners. An especially intensive cooperation is in place with Maschinenbau GEROLD GmbH & Co. KG in Nettetal. What started at the beginning of 2007 as an exchange of ideas for a customized machinery project has been developed in the meantime into projects with a dozen different manufacturers of thin-film solar cells. Jürgen Weiss, Business Manager of GEROLD, reports:

Maschinenbau GEROLD GmbH & Co. KG located in Nettetal/Germany is a globally acting automation specialist. The company founded in 1968, appears today especially as manufacturer of robot and automation solutions for Frontend and Backend production lines in the photovoltaics industry.

The collaboration between GEROLD and 4JET started beginning of 2007. When searching for a qualified supplier for laser applications in the photovoltaic industry, GEROLD addressed 4JET. In a first collaborative project, 4JET realized solutions for laser

edge deletion of thin-film solar cells with GEROLD. Quickly other projects evolved. Since then, the collaboration has continuously become more dynamic.

In the meantime, GEROLD and 4JET have realized numerous projects in the PV industry. Amongst others, 4JET systems are used for edge deletion of thin-film solar cells on glass substrates, exposure of the Molybdenum layer on CIS/CIGS substrates, cleaning of tool carriers as well as drilling of solar glass. GEROLD has supplied glass handling and automation solutions to many of these projects.

At the beginning of 2009 both partners introduced for the first time a complete solution for edge deletion and contacting of thin-film solar cells. 4JET is responsible for the edge deletion process by laser technology as well as the required mechanical exposure of Molybdenum whereas GEROLD is responsible for the fully automated contacting solution on modules of the „CIS family“. Bonding, welding or soldering can be selected as contacting solutions. The elimination

of a process-critical interface and especially the use of ultrasonic welding offers unique advantages. Interest in the PV industry is respectively high.

The collaborative dealings of both companies are supported by a similar structure and positioning. A highly motivated team and a high degree of customer orientation and flexibility characterize both companies. The geographic proximity of both company locations supports the execution of even complex joint projects.

[Author Jürgen Weiss joined Maschinenbau GEROLD GmbH & Co. KG in 1998. Since 2002, the MBA has been CFO of the company. Besides this, he is responsible for Marketing and Sales.]



@ www.gerold-mb.de

What's New from Gerold

AUTOMATIC FRAMING OF PV MODULES

Recently GEROLD launched an efficient production cell for automated framing of PV-modules. This is engineered in collaboration with Dutch company RIMAS. The production cell composes of a RIMAS-framer which is loaded by robot. Prepared frame parts are

taken from a magazine and placed into the framer. Depending on the individual frame design, a clinching and corner smoothing station finishes the work sequence. The cell concept is engineered for thin-film modules and c-Si-modules.

GEROLD station for frame assembly



THIN-FILM, QUO VADIS?

→ *An Outlook*



After dramatic changes in the entire Solar market – from the end of the Spanish solarboom to Chinas’s Golden Sun program – the photovoltaic industry is faced with new challenges. Short and medium term factors, such as silicon price, production limits or the overall economic situation dominate the analysis. Our author researches some market fundamentals and identifies three important parameters, which must be taken into account in the future.

[Meinolf Heptner is an independent analyst and investor in the area of renewable energies. After graduating as an industrial engineer and working at a consulting company and two medical engineering companies, he today consults companies in the PV industry.]

The business model of many thin-film start-ups to sell modules for more than 2 EUR/Wp into „unlimited“ markets and obtain unbelievable wealth is dead, as in the meantime prices of approx. 2 US\$ were achieved for crystalline modules. This will not change anymore, as the already existing production capacities (approx. 15-20 GWp/a) should exceed the maximum capacity of subsidized markets. Hence, the question arises, how much a thin-film module should cost in the unsubsidized market of the future.

Allowed system price

The value of a PV system is measured according to its generated power (kWh). A large investment at the beginning and only very low operating costs through lifetime are compared with slightly decreasing kWh results (with most likely increasing nominal value per kWh) over a very long period of time. If we simplify this and investigate this as a watt-peak

and ignore „secondary questions“ such as taxes, leverage, degradation and operating costs, the model can be reduced to three input parameters:

- value of the generated power in the first period (generated kWh x price per kWh)
 - change rate of this value (forecasted inflation)
 - discount rate to present value
- For an interest rate of 8 %, the following example can be obtained:

NPV-Matrix* (Assumption: 25 years life time)

8 %	1,0 %	2,0 %	3,0 %	4,0 %	5,0 %
0,10	1,16	1,27	1,39	1,53	1,69
0,12	1,39	1,52	1,67	1,83	2,02
0,14	1,63	1,77	1,94	2,14	2,36
0,16	1,86	2,03	2,22	2,44	2,70

*Net Present Value

You can recognize, how severely factors impact, which do not have anything to do with a PV system per se. For clarification here a concrete example:

The „Market Price Referent“ (MPR) in California, which must be used by CA suppliers as benchmark for their purchasing decisions, amounts in 2009 to approx. 11,5 \$c/kWh. For a yearly outcome of approx. 1400 kWh/kWp you could assume the „value“ parameter with approx. 16c. As MPR calculates with yearly price increases of 3%, the PV system should cost approx. \$ 2,22 / Wp, if the investor expects an interest of 8 % for the invested capital.

System Price Structure

In principal, three different categories „module price“, „module depending balance-of-system (BoS) costs“ and „not module-depending BoS costs“ (project development, technical planning, margins...) can be differentiated. Based on size and efficiency of a module the required number of modules (with the required mounting structure, wiring and assembly) as well as the total area required to realize a project can be

determined. Qualitatively it can be observed, that lower efficiency and dimensions of a module ceteris paribus increase the required number for a given total output and hence require a cheaper module, if the same kWp price should be achieved. Basically this is a scaling effect. High-performance modules distribute the costs of a given plant infrastructure to more Wp and are therefore less expensive. Compared to a typical crystalline module with an efficiency of approx. 14 % and BoS total costs of approx 1,3 \$ /wp, this BoS premium can be estimated as approx 12 c/Wp at 11 % efficiency up to 47 c/Wp at 6,5 % efficiency (at same module size). When modules are smaller, common for many thin-film suppliers, then the reduction might be even larger. These values do not depend on the module price and there might be constellations in which even a free-of-charge module might not be competitive!

Conclusions and Course of Action

Without substantial reduction of the BoS costs PV systems will only be competitive in especially favorable situations. Firstly, this favors larger systems and secondly, reduces the absolute price spread between c-Si and thin-film modules. Manufacturers of thin-film modules must especially increase their efficiency, not only to reduce the Wp costs of the module, but even more to reduce the BoS disadvantage versus more efficient modules. Further possible actions would be larger modules, especially efficient – preferable proprietary – assembly concepts or completely different module forms, leading to lower BoS costs, for examples by gluing them as foils or using them as replacement for windows or roof tiles. Another idea is to improve the kWh yield per kWp or form of the earnings profile. Some sources postulate, that a kWh earnings advantage versus crystalline technology was already given due

to lower temperature coefficients for efficiency loss due to heating, but this could not be proven so far.

However, in the long-term something else could have significant impact: Thin-film technologies seem to have advantages over crystalline modules in energy return time at system level (approx. 0,8 years vs 1,5 years for installations in South Europe) and interestingly also in economic scaling (capital requirement / Wp scales stronger, less working capital due to shorter cycle times). When you realize, that at a current world energy demand in the order of magnitude of 16 TW and an estimated total output of 10 GW cumulatively installed until today, PV systems today cover less than 0,01 % of this demand, then one thing becomes obvious: In order for PV to achieve a significant share of the overall supply, the realistic growth speed will be the determining factor.

4JET Systems for Tire Marking



KEEPING TRACK



Accuracy repeatability of the fully automated T-Mark



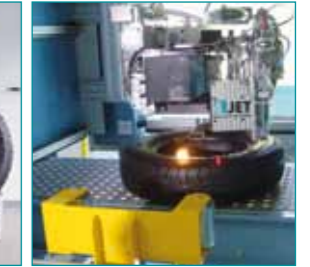
Cross section of a laser engraving with 0,2 mm engraving depth



Tire marking with T-Mark compact



T-Mark compact system



Fully-automated T-Mark system

Traceability of goods and parts is required in all industries: No matter if you look at cables in a plane, brake pads in a car, pain killers or organic eggs: Individual batch or serial numbers can be found on more and more goods. The more consistently you can trace the production and supply chain, the easier you can find and eliminate weak spots. At the same time, it is possible to uniquely identify goods in the worst case of a product recall and to systematically take them out of circulation.

If you inspect the sidewall of a commercially available tire, you can see a multitude of logos, numbers and codes. The majority of information, such as the manufacturing logo or dimensions, is unchanged and therefore engraved in the vulcanization molds used to cure the tires.

Besides that, there is variable information, which cannot be engraved onto tires of the same size. This includes information regarding manufacturing dates, origin, country permits, OEM customers, noise index and other information, which may

change during the product life cycle. During retreading of truck tires even the entire tire history is added to the new side walls.

Information like this is added to the tire using embossed stamps, which are mounted into the molds. When the information changes the corresponding stamp in the mold must be replaced. For that, new stamps must be manufactured and distributed, sometimes to several 100 molds used at the same time. In modern tire companies with daily production of up to 70000 tires, this is a logistic nightmare causing numerous mistakes and high costs.

Laser engraving enables fast, visually appealing, tamper-proof and long-lasting tire marking after manufacturing. ASCII codes and logos can be directly changed and applied per software. The laser beam vaporizes the tire rubber and leaves a fine trench in the side wall. The marking is recessed into the tire and therefore protected from wear.

The applications realized already today show the versatile potential of laser marking in the tire industry:

- Individual serial numbers on truck tires
- Customer-specific logos on truck and passenger car tires

	Stamp in mold	Paper bar code	RFID	Laser
Individual info	No	Yes	Yes	Yes
Durable	Yes	No	Yes	Yes
Machine-readable	Conditional	Yes	Yes	Conditional
Human-readable	Yes	Conditional	No	Yes

Tire marking technologies overview

- DOT week codes on passenger car tires
- E-numbers and noise index on truck tires
- ECE 109 information on retreaded truck tires

4JET has developed two system concepts for this process. The fully automated T-Mark systems enable the automatic positioning, location detection and marking of tire side walls for „batch size 1“. Tires are centered, optically measured and the marking is engraved on the exact pre-set target location. T-Mark systems have proven themselves in three-shift operation. More than 10 million tires with a T-Mark marking can be found on the streets today.

Recently, 4JET has added the T-Mark Compact to its portfolio: a hand-held marking device, especially for applications in retreading or marking of test tires in tire depots. The device can be easily positioned at the side wall and the tire can be marked with the entered information „at the push of a button“.

Flexible handheld laser marking for retreaders and warehouses

NEW T-MARK COMPACT SYSTEM

Besides the fully automated T-Mark system 4JET does now offer a cost-effective hand-held solution.

The new T-Mark compact is a manual laser system, for marking of tire sidewalls with serial numbers, product specifications or logos. The system allows the marking of standing and lying tires of any size, for passenger car, truck, bus and OTR sizes.

The user can enter the information to be engraved via barcode reader from a database or manually via touchpad.

Possible applications of the T-Mark compact are for example the permanent marking of test tires at the manufacturer or at the warehouse, as well as country and customer specific tire engravings after production. Another application is engraving of information according to ECE 109 into retreaded tires. Laser engravings replace the procurement and preparation of Aluminum stamps and offer better appearance.

The mobile base unit contains controller and exhaust

The hand-held system is easily positioned using a balancer



Step 1 – Job selection or data entry



Step 2 – Positioning



Step 3 – Engraving!

FLEXIBLE, SHARP, COST-EFFECTIVE:

4JET's leasing offer is especially attractive for tire retreading companies: For only 1.710,- EUR per month including spares and service plan a T-Mark compact can be put into operation.¹

For a retreading company with a production volume of 150 tires per day, the calculation looks as follows:

Conventional Marking

Wages/Tire ²	1,17 €
Material Cost/Tire ³	0,22 €
Total costs/Tire	1,39 €
Total costs/Month	4.992,00 €

Laser marking with T-Mark compact

Wages/Tire ²	0,29 €
Leasing cost allocation	0,47 €
Total costs/Tire	0,76 €
Total costs/Month	2.751,00 €

Besides more flexibility in comparison to aluminum tags or vulcanization labels and the advantages of an improved appearance laser technology saves over 2.000,- EUR per month!

¹ Calculation example for companies in Germany, subject to credit approval, 0,- EUR down, 36 month term, final payment 6.000,- EUR

² Hourly rate 35,- EUR

³ For Aluminum tags or vulcanization labels

TIRE MARKING WITH LASER

at Continental Matador

Continental Matador Puchov (Slovakia) is a leading producer of truck tires. Its products are sold to leading trailer manufacturers and the replacement market all over Europe. Andrej Jancik, responsible for Quality Control and Tire Uniformity in the Puchov plant explains about Continental Matador's approach to product traceability:

„As most products, truck tires must be uniquely marked with a serial number. For this reason aluminium plates which were manually inserted in the curing mould before loading of green tires were used for identification. In the Puchov plant we have mostly fully automated our curing area already several years ago and replaced almost all manual processing. For that reason we purchased two T-Mark laser engraving systems for marking our tires with a barcode number in 2005. The machines are located in the Final Finishing area and tires are processed

in the machines before entering our warehouse. Every tire carries a barcode label. The barcode number allows to trace very important information about all building steps of the tire, for example operators, semi-products, building, curing, the kind of quality controls performed and the results. These bits of information are very important to handle and verify potential claims by customers and for this reason we have decided to also permanently engrave the serial code to the tire sidewall. The laser marking is more durable than a barcode label and can be checked even a long time after shipping the tire. For identifying the mark position on the black sidewall, a laser scanner and camera is being used in the 4JET machine. After the initial installation the systems were tuned step by step and continuously improved. At the present time the readability is about 99,5 percent, which we consider a perfect result.



Andrej Jancik from Continental Matador Puchov

Since each tire has to be marked, the laser systems are considered key production equipment. Any malfunction during full production would cause big problems with the work organization in the curing area and Final Finishing. I can confirm that the 4JET units work failure-free and the cooperation and technical support by the supplier is on a very professional level. “

Two T-Mark systems at Continental Matador Puchov



AIR LETTING THE OUT

No hairy matter

While the classic masculinity of a three-day-beard may be just what some products need to make them look appropriately marketable, shagginess in modern tyre design is really the last thing you want. However, it is a fact of life that this annoying rubber residue forms at all the points in the mould where air escapes, as a matter of principle.



Nothing beats a close shave

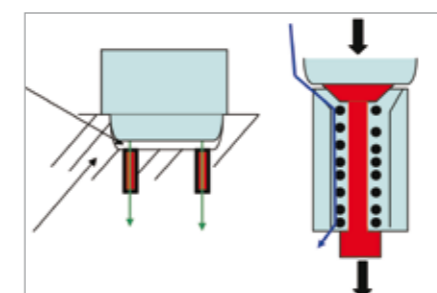
The most obvious solution for removing this unsightly stubble is simply to cut it off immediately after the curing of the tyre. This is, however, an expensive matter, because the flexible rubber prongs are highly resistant to cutters, and there is also the problem of what to do with the waste – each tyre produces on average around 40 g of waste rubber, which, assuming a standard annual rate of production, amounts to 400 tonnes of these little black spikes.



The secret of smooth skin

So the question is: how can these rubber spikes be prevented from forming in

the first place? One possibility is to employ a so-called puzzle mould, which removes the majority of the air by way of numerous gaps positioned between the mould segments (the puzzle pieces). But the need for additional air ducts means that some stubble remains behind even with this method. Not to mention that puzzle-type moulds are highly complex, and therefore rather expensive to produce. Another method, which is far more successful and more extensively tested, is to use a complex valve system. This constitutes a highly effective and technically sophisticated way of ensuring that the surface of the tyre remains smooth and flawless. It can be employed in any kind of tyre mould, regardless of whether it is new or old. The spring valves obviously cost money, adding around 5-10 % to the price of the mould,



but this still places it well under half of the price of a puzzle mould. The installation of these valves requires a certain level of experience, but after a while, the process can be performed without any problems. A bigger disadvantage is the increase in the maintenance requirements of a mould employing valve technology. It is no longer possible to sandblast the mould, and valves need to be replaced every now and then, or additional

valves installed. Another alternative worth considering is the so-called micro vent. This method employs micro-fine slits which allow the air to escape while retaining the rubber in position. Unlike the valve system, this technique involves no moving parts in the mould, which makes the installation and replacement of the components considerably simpler. Since they are also far less complicated to produce, micro vents represent the greatest cost-saving potential. However, as a recent technology, it is as yet not in widespread use, and there is a lack of user experience data for some application fields.

@ www.dahmen-gmbh.de



Author Bernd Dahmen is founder and General Manager of Dahmen GmbH. The company manufactures directly milled molds for passenger car, truck and earthmover tires. The company employs 130 staff at its locations in Alsdorf and Wunstorf, Germany.

PERFECT SHAPE

Laser cleaning in the tire industry

ENOTECH AG in Dieburg, Germany is a medium-sized industrial service provider with approx. 80 employees. Besides production and sales of dry ice and the manufacturing of dry-ice presses, laser cleaning is one of Enotech's central business areas. The company is providing a mold cleaning service for tire manufacturers in Germany and other European countries, including leading companies such as Goodyear, Dunlop and Pirelli.

Tire molds typically require cleaning every 1000 to 3000 curing cycles. Conventional cleaning methods such as sand blasting require disassembly of the heavy molding tools from the presses, whereas cleaning with dry ice causes high operating costs and significant noise emissions.

Although Enotech is a producer of dry ice, the company offers their customers a laser cleaning service which also includes mold maintenance and logistics. The customers thereby eliminate the need to invest in cleaning systems, but pay per cleaned mold instead. So far, Enotech is using 4 mobile TMCS laser systems supplied by 4JET.

@ www.enotech.de



Cleaning of a tire mold with laser

We interviewed Winfried Peschke, founder and General Manager of ENOTECH:



How does a dry-ice-solution provider arrive at using lasers?

At the time, when we made the decision to offer our clients laser technology for cleaning of their tire molds, the use of dry-ice technology was only possible by manual systems. Our own and our clients' safety requirements were an important criterion. Manual cleaning with dry ice has significant hazard potential. Another important reason for the decision to use laser technology was the flexibility of the laser systems. Opposite to dry ice, the laser does not care whether the tire mold is warm or cold during cleaning. Even the by now automated dry-ice cleaning is only effective on warm molds. Also the quality of laser cleaning is significantly better due to the degrees of freedom of the 5-axis optics of the systems. Our clients appreciate this and remain true to lasers often for a long time.

How many molds do you clean on an average day?

Of course, as a service provider we are always available, when you need us. Thus, cleaning volumes are quite different. However, when observing a longer period of time, we clean on an average day approx. 25 to 30 molds. Cleaning with a laser takes approx. one hour per mold, whereas disassembly and cleaning using a

blasting system would take several hours.

Where do you see the advantages of laser cleaning in comparison with competitive technologies?

If we talk about competitive technologies capable to clean the press and the disassembled mold, the only competition is dry-ice technology. As already mentioned before, a significant advantage of laser technology is its independence from the temperature of the tire molds. Here significant energy costs can be saved. We also see a clear trend, that manufacturers produce smaller batch sizes and thus change the molds more often. Therefore, cleaning inside the presses will be reduced. Of course, this trend also brings „other“ classical methods, such as chemical, sand or ultrasonic cleaning back into the focus of some tire manufacturers. Which direction will be taken in the future is strongly depending on the specific situation of each tire plant. In summary I still see the most advantages for laser technology.

Are some tire compounds or molds not suitable for laser cleaning?

I have not had a completely unsuitable mold under a laser yet. Border cases exist, where the economic side is not flattering, especially when cleaning takes too long. The same is true for a few of the compounds used. Unfortunately, I cannot provide you with any further information without revealing internal details of our clients.

Is a better eco-balance or lower energy consumption a sales argument or more a „nice to have“?

In today's time, with continuously raising energy costs, I can definitely answer this question with Yes! In comparison to dry-ice cleaning the energy balance will always be positive for laser technology. Only the energy required for compressed air supply in dry-ice cleaning is approx. 30 times higher than the total energy costs for a complete laser cleaning. Cost for heating the mold for an offline cleaning, the energy required to manufacture liquid CO₂ and the energy loss during the production of dry-ice pellets are not even taken into account. In a total energy balance, 6 kW for the laser compare with approx. 150 kW for dry-ice cleaning. These numbers should inspire everybody to start thinking.

Where do you see the trend in tire production, especially in mold cleaning?

A clear trend is surely the production of smaller batch sizes of one tire type and thus shorter duration of a mold in the press. If due to that the molds are disassembled anyway, then a cleaning can be done at the same time as well. A significant advantage of laser and dry-ice cleaning, namely the possibility to clean inside the press, loses in importance. Instead of that, quality, flexibility and total cost of the cleaning process will be more important in the future. At the same time, the tire molds become geometrically more complex. This means a new challenge for cleaning technologies. I think the technology of the future must not be the fastest, but should be capable to adapt the best to changing requirements.



New **SERVICE LOCATION** in Dresden



In order to support the growing number of installations in the East of Germany, 4JET opened a new maintenance and service location in Dresden. Under management of **Michael Krauß** especially production lines in the photovoltaic industry are supported. In the greater areas Leipzig and Berlin 4JET offers their customers a technical 24-h-hotline as well as guaranteed service response times for „on-site“ work of less than 12 hours.



New **LOCATION** in Alsdorf

Three years after its foundation in Hückelhoven 4JET has moved their head office to Alsdorf (Aachen). The company moved into a 2.200 m² large location with modern office, laboratory and assembly areas in the IGA Park. The location offers good infrastructure for development as well as for manufacturing of machines. This includes – besides a modern assembly area and ceiling cranes, also two large application laboratories, offices and sufficient warehouse space.

SPECIAL HONOR



for 4JET

4JET is Germany's most innovative company 2009. During a ceremony in the Federal Ministry of Economics 4JET was honored for its laser systems with the „Gründerchampions“ award 2009 in the category „Technical Innovation“. Prior to that, 4JET was honored as one of the 16 state champions out of a group of over 200 companies and was now awarded the national championship. The KfW company award was awarded in 2009 for the third time and was remunerated with 18.000,- EUR. Besides 4JET also TASSA GmbH from Niedersachsen was honored for the „sustainability“ of their

Joerg Jetter from 4JET together with the winners of the other regions

products, as well as Hein & Oetting Feinwerktechnik GmbH in the „Growth category“. The awards were bestowed by the parliamentary State Secretary in the Federal Ministry of Economics, Hartmut Schauerte and the Director of the KfW Bank Group, Stefan Breuer. The laudation was held by Skateboard-Guru Titus Dittmann, founder of the corresponding Skateboard manufacturer.



Cleaning with

LASERTECHNOLOGY

An Overview

4JET is known today mainly for their products in the area of the tire- and photovoltaic industry. However the company also develops laser-based systems for surface cleaning for other industries. Until now, 4JET profits from the work of Dr. Heinz Jetter, who in the last 20 years initiated numerous innovations in laser processing. For 4SURfaces, Dr. Jetter has prepared an overview about today's state of art in laser cleaning.

Since the beginning of the 90-ies industrial applications have been around for „cleaning“ or “stripping“ of surfaces with laser radiation. Behind these buzzwords a number of different processes are hidden, which remove a thin layer from a surface using laser radiation. Principles and application areas vary according to the used laser type. Pulsed lasers of different wavelengths, such as Q-switched solid state lasers or fiber lasers, CO₂-TEA lasers or Excimer lasers are especially suited for cleaning. Besides that, continuous CO₂ lasers can be used to

solve some cleaning challenges. The different cleaning procedures differ in their working principle.

Cleaning with pulsed Solid State Lasers

Diode-pumped pulsed solid-state lasers, such as Nd:YAG or Nd:YFO laser emit wavelengths in the area from 1064 nm down to 266 nm, even though mainly 1064 nm lasers in the infrared area are used for large-area cleaning today. The pulse length in today's typical cleaning applications is in the range from a few up to 100 nanoseconds. The

use of Picosecond lasers in industrial applications is increasing. Solid state lasers operate with high repetition rates in the kHz range (this means several 10000 pulses per second) and deliver average power from a few Watt up to approx. 1 kW.

Organic top layers as well as metals can be removed. Due to the comparably low absorption of short-wave light in organic top layers, the removal often does not happen by layer-wise ablation „from top to bottom“, but by absorption of the laser radiation into

the substrate and therefore underneath the layer to be removed. The layer is then removed “from the bottom”.

The low-maintenance and compact systems are the most attractive sources today for many cleaning applications. The short wavelengths allow the beam delivery via flexible fiber optics and therefore simplify the integration into automated or manual systems.

Cleaning with CO₂-TEA-Lasers

A classic under the cleaning laser is the pulsed CO₂-TEA laser. This laser emits short pulses (us) with high pulse energy

(several Joules). The pulsed light hits the contaminated surface with peak powers of up to 100 MW. The abrupt induced energy cannot extend and blasts off the coating in a small area. The impact zone corresponds to the size of the laser beam spot on the surface, the penetration depth ranges around 10 µm per pulse. By repeating this process several times the surface is exposed pulse by pulse.

The ablated material – usually fine dust or gas – is locally exhausted and routed to a filter. In the short pulse

duration the CO₂ laser light is hardly absorbed by the substrate such as an aluminum vulcanization mold. This does not lead to any mechanical, chemical or thermal impact of the substrate. Especially organic materials can be well removed from surfaces by pulsed CO₂ lasers.

Besides that, also mineral layers such as oxides and ceramics can be processed. Almost any material can be used as substrate. Metals are especially suitable, as they reflect the laser radiation and therefore are

Pulse-by-Pulse removal with TEA laser – after 12 pulses a 100 µm thick nylon layer is exposed. The process stops on the metal surface

not impacted themselves. It is also possible to remove paint layers from paper without damaging or even browning the paper. Due to the wavelength of 9 – 10 µm rigid mirror systems are need for beam delivery.



400-Watt-TEA-CO₂-Laser from 4JET

Cleaning with Excimer lasers

Although Excimer lasers reach significantly lower average output power than CO₂ lasers, both lasers are comparable in their cleaning principle. Excimer lasers operate at significantly shorter wavelengths (157 nm to 355 nm) and their radiation is still absorbed by very thin layers. The comparably low cleaning power restricts the use for large-scale cleaning, however Excimer laser systems are suitable for fine cleaning, for example in semiconductor packaging. The high maintenance requirements and the high operating costs in comparison with solid state or CO₂ lasers are a significant disadvantage.

Cleaning with „Continuous Wave“ lasers

A third cleaning process can be achieved using continuous CO₂ lasers. The so-called „CW“ laser radiation is focused into a small laser beam spot (a few 100 µm diameter). The radiated material evaporates due to heat impact. Cleaning with „continuous wave“ is only suitable for a few applications. However, the CW laser is the tool of choice for marking of organic materials due to its high cost-efficiency.

Materials and process times

A multitude of materials can be processed and removed using CO₂, solid state and excimer laser processes. Speed is defined by the applied laser power and the absorption of the top layer. During volume removal using CO₂ and Excimer lasers, typically between 15 – 30 mm³/s material can be removed per 100 W laser power induced into the top layer.

Higher removal rates can be achieved for solid state lasers due to the different working principle („from the bottom“).

The materials that can be removed with laser processes include:

- Process residues (e.g. in molds) such as byproducts of curing rubber (soot,

- mold release agent, rubber)
- Resin residue
- Products for injection moldings for plastics
- Isolation layers (e.g. on CU conductors) such as PU, PVC, PTFE, PP, Capton, PUR, PET, PI
- Wear and corrosion protection (e.g. on tubes) such as PA, PVF
- Coatings (e.g. cylinders or molds) such as rubber or Teflon
- Paints (on metal and composite materials)
- Powder paints, water paints
- Oxides
- Metals



Author **Dr. Heinz Jetter** has more than 30 years experience with laser technology. After graduating in Physics he has been working at the BATELLE Institut, the Max Planck Gesellschaft, SIEMENS AG and Rofin Sinar. He founded JET Lasersysteme GmbH in 1993. The company is today a consultant to 4JET.

RITA LETS HEARTS BEAT FASTER

FTE Automotive Möve GmbH in Mühlhausen in Thüringen has a decade-long tradition in the manufacturing of components for clutch- and brake systems for the automotive industry. Approx. 300 employees produce for clients such as Audi, BMW, Daimler, Ford and VW. Especially qualified employees, high quality awareness, and flexible manufacturing equipment distinguish the company.

line and merged with the controller in shortest time. A Siemens S7 with Profibus is used for the functional sequence.

If and when Rita gets another sister remains to be seen – the throughput of more than 2000 parts per hour make this system most likely the fastest available machine for this application.

@ www.fte-automotive.de



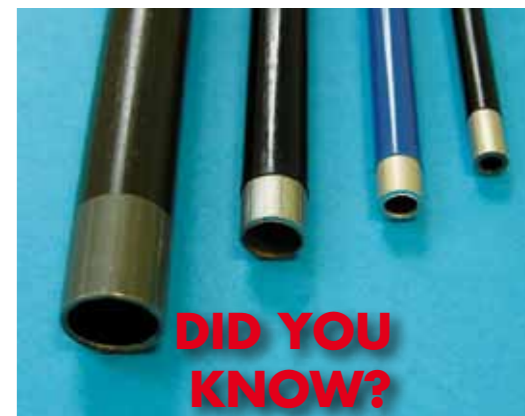
FTE Projektleiter **Heiko Heim** explains the decision to use laser:

„During removal of thin PA or PVF layers from galvanic coated base tubes, mechanical methods cause damage to galvanic coating or plastic residue remains on the tube causing contaminations in the hydraulic system. Lasers operate contact-free and remove the plastic layer completely down to the galvanic coated tube without causing any damage.“ The first 4JET module was installed already in 2006 and convinced: „We have been using one 4JET module in continuous operation for several years. It has distinguished itself by high reliability“, says Heiko Heim.

The newest addition to the modern machinery portfolio is called Rita. She is already the fifth sister of a group of fully automated transfer systems for the machining of tube endings. Using Rita (a German acronym created by FTE’s engineers) tubes are cut to length, the plastic coating is removed from the endings via laser and the tubes are flanged and optically inspected.

Two 4JET laser systems work in parallel on the system and reach a cycle time of less than a second per part. Pulsed TEA laser with an average power of 300 Watt strip the parts on both sides. 4JET uses TEA lasers for this application due to their relatively short pulse length at high pulse energies of above 2 Joules. Using beam shaping the square beam spot can be projected into a line shaped spot on the pipe ending, which can be adjusted to the required removal length on the part. The residues generated during processing are exhausted immediately and collected in a filter system. Wear and contamination of the beam delivery optics is largely eliminated due to a sophisticated purge air system.

The modules supplied by 4JET were installed „plug and play“ in the transfer



DID YOU KNOW?

The lasers originally used at FTE were manufactured by GSI Lumonics Group in England. 4JET acquired this product line in 2008 and has manufactured the lasers for incorporation into their own laser systems since then. TEA-CO₂ Lasers are especially suitable for cleaning organic material from sensitive metallic surfaces, such as chrome-plated or nickel-plated molds, as well as tin-plated conductors of cables. The heat dissipation into the substrate is reduced and the layers are blasted away explosion-like. Top layers can be removed selectively in steps. The high pulse energy comes with a high focal depth of several centimeters, a value impossible for many other lasers. Due to that, the TEA laser is also suitable for processing of wavy surfaces, such as for example cleaning of complex molds.



Residue free laser deletion of a PA tube

Cleaning Methods Overview

	Pulsed solid state and fiber lasers	Pulsed CO ₂ TEA lasers	Excimer lasers	CW-CO ₂
Cleaning principle	„lift off – from bottom“	Volume removal „from top“	Volume removal „from top“	Evaporation
Typical average laser power	Up to 1 kW	Up to 400 W	Up to 100 W	kW
Wavelength	266-1064 nm	9-10 µm	Up to 355 nm	9-10 µm
Beam delivery	Glass fibre/Mirror	Mirror	Mirror	Mirror

