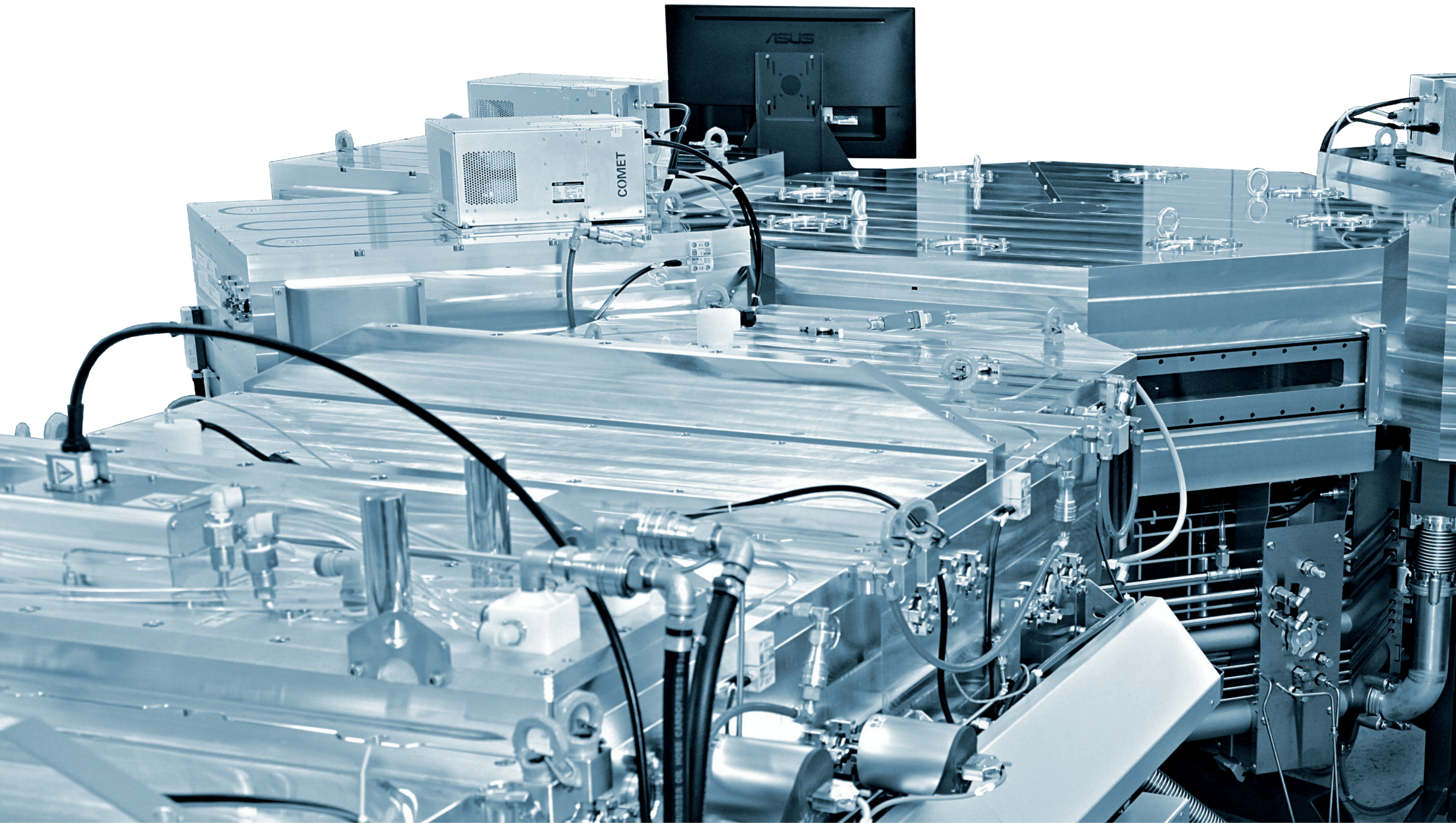


PECVD tool meets industry expectations for HJT

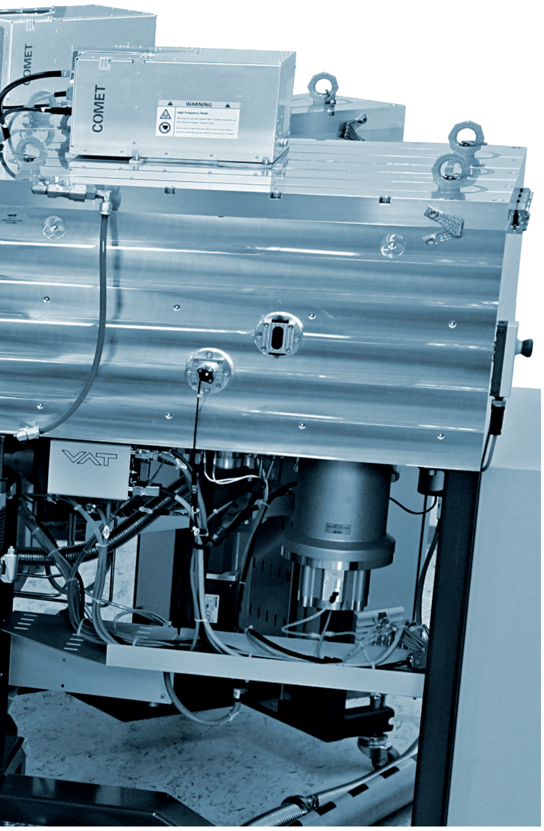
PES were eager to meet Frank Jürgens, Sales & Marketing Director, INDEOtec SA, to learn more about their innovative deposition platform for HJT and high-efficiency cells, OCTOPUS, using the Mirror reactor concept. It is both renowned and exclusive. He predicts higher and cleaner manufacturing standards including high-end, high-purity tool sets are on the near horizon and this dynamic company is ready to adopt them.

PES: Welcome back to PES Solar/PV magazine. Thanks for talking with us. For the benefit of our readers we would like you to begin by explaining about the background of INDEOtec and the importance of the Solar/PV industry to you.

Frank Jürgens: Founded in 2007, INDEOtec is a relatively new, Swiss based equipment manufacturing company, headquartered in Neuchâtel (NE), which specialises in high-end thin film deposition technology, mainly PECVD and PVD.

The senior team has an impressive track record of PECVD reactor technology and cluster tool development, for the display flat panel and PV thin film industry, which dates back to 1980. For example, key PECVD reactor milestones such as the Plasmabox and more than 6 system generations of the famous KAI PECVD cluster tool, for substrate panel sizes of Gen 5 and above have been developed by Prof. Jacques Schmitt together with INDEOtec CEO Omid Shojaei (Ph.D.) and successfully commercialised at Unaxis/Oerlikon, which resulted in revenues of > 2.0 Bn USD.

The next generations of PV cells will apply more and more sophisticated thin film manufacturing technologies in order to achieve efficiency levels up to 30% and even more.



INDEOtec's deposition platform named OCTOPUS, with its proprietary Mirror reactor technology, has been really tuned to the needs of novel cell concepts such as HJT and subsequent high-efficiency cell architectures. Also, our experience and knowledge in designing high-throughput systems made OCTOPUS III the champion.

PES: We have heard a lot about your reactor concept for PECVD deposition applications; could you please explain the various technologies and the advantages of the cluster tool, both in terms of performance and cost savings?

FJ: The PV industry is extremely cost sensitive; i.e. everything which does not add value has to be minimised or avoided. Handling and automation is one of the non-value adding cost drivers. On the other hand, the future cell architectures require more sophisticated manufacturing technologies.

For the HJT cell technology, and specifically the case of PECVD deposition using the parallel plate plasma generation method, INDEOtec realised that state-of-the-art reactor technology always required a permanent wafer flipping between the top and the bottom deposition cycle. This creates unwanted handling, hence automation effort.

The INDEOtec team found a smart way to avoid exactly this unwanted wafer flipping and vacuum breakage. We invented the Mirror reactor concept, which is now both renowned and exclusive. It is a rather easy solution: for all depositions on the top wafer surface the Mirror^{TOP} reactor is used, vice versa the Mirror$_{BOTTOM}$ reactor is used for all bottom layers. A simple transfer of the tray from one reactor to the next is all that's needed to change the deposition side. The difference between this and the standard method is the tray needs holes – the wafers are supported on their edges only.

Another striking advantage is the implementation of a quick and extremely efficient reactor treatment method named 'ACCT', which suppresses the cross contamination of the layers by dopants. For HJT specifically, this allows us to deposit all silicon thin film layers per wafer side in one reactor. The effect: we can reduce the number of PECVD reactors by half.

Last but not least, the cluster tool concept is well suited for the so-called parallel processing. In OCTOPUS III three reactors per chamber do processing always simultaneously. Also, the shared usage of components, i.e. pumps, gas feeding, heating etc. avoids spending on components and thus saves CAPEX.

The combination of all these design features makes OCTOPUS III the tool with the highest throughput in its category, with > 3'400 wph the highest, the best footprint/performance and price/performance ratio.

The customer base of OCTOPUS II, our small scale system, is predominantly the PV research universe, namely labs and institutes. Apart from the Mirror reactor, the proof-of-concept was done with OCTOPUS II and the ACCT treatment, the system is highly attractive due to the various deposition chambers, which can be connected to the system, even as an upgrade at a later stage.

It is possible to use RF PECVD chambers for a wide range of silicon or Si-compound films, for example a-Si:H, SiO:H, SiC:H, but also crystalline structures like mc-Si, nc-Si or even epitaxial-Si or Si-compound layers. But also AR-coatings, such SiNx, SiONx or TCO layers (PVD chamber) can be deposited.

For example, a complete heterojunction film stack can be done with OCTOPUS II without breaking the vacuum. You enter the clean Si-wafer and can produce a complete device with all a-Si:H (intrinsic & doped) layer stacks, including TCO layers (ITO or similar) deposited on both sides by a PVD module. INDEOtec's process know-how has been demonstrated to many customers meanwhile.

PES: Has this led to a greater share of the market?

FJ: The market recognition and demand for OCTOPUS II is clearly visible since we introduced it in 2015. The sales success is truly worldwide and we expect more business, with PV cell architectures entering higher efficiency levels and thus more sophisticated deposition technology.

OCTOPUS III is in the prototyping stage and will be qualified both at INDEOtec and in the field by early next year. We face a clear and rising market demand for OCTOPUS III because of the benefits it offers to the PV cell manufacturing industry.

PES: You have an approach looking at cell and manufacturing steps & cost reduction, what does this mean to the end user?

FJ: The objective of the PV industry is pretty much straightforward: having manufacturing equipment and lines providing the highest available throughput, whilst consuming as low a footprint as possible. All this has to come at conversion costs as low as today's levels or even lower.

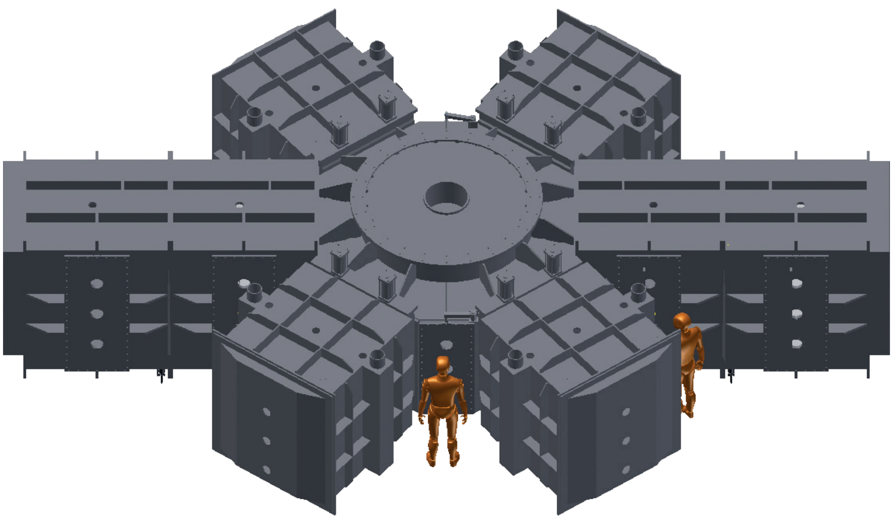


Image 1: illustration of OCTOPUS III PECVD system for HJT device processing

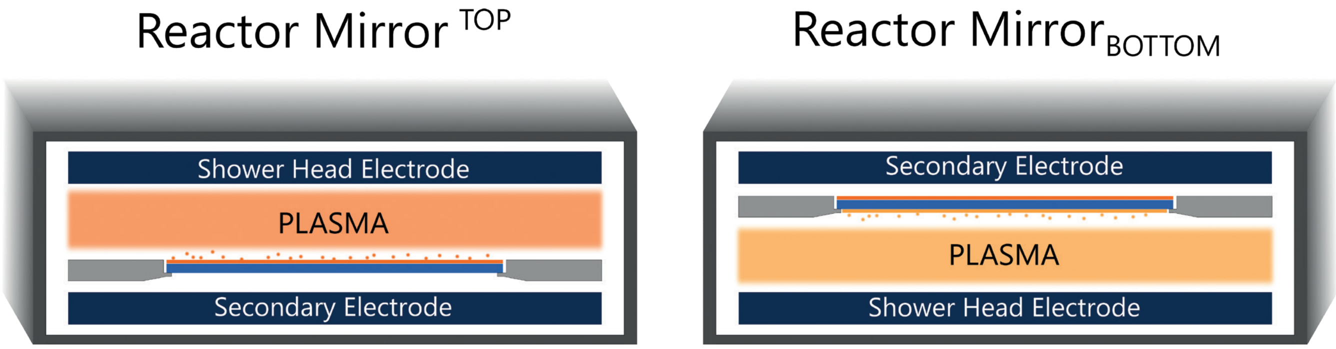


Image 2: Principal illustration of the Mirror reactor concept

Speaking numbers for HJT, the industry still looks for PECVD equipment with a capacity of > 3'000 wph and a design potential to increase the throughput even further. The conversion cost benchmark of a PERC manufacturing line needs to be within reach or should come close for an HJT line. The cost of ownership of the PECVD process is critical, because it represents approx. 40 - 50% of a heterojunction line CAPEX.

OCTOPUS III matches all these requirements. The system is designed to provide a throughput of > 3'400 wph and can principally double the capacity, whilst generally keeping its footprint of 9.6 x 11 m. The conversion cost level is already close to the industry expectations.

PES: We would be interested in hearing about the USP's (Unit Selling Points). What is it and how does it work in practice?

FJ: Let me summarise this as follows:

- Highest Throughput by the Mirror concept, (No wafer flipping), combined layer deposition in ONE reactor (ACCT), parallel processing, (reactor stacking)
- Very low footprint by parallel processing, (reactor stacking), reduction of reactors (ACCT)
- Low CAPEX by Mirror concept, (less automation), reduction of reactors (ACCT), parallel processing, (shared usage of components)

PES: Can you provide us your principal roadmap for the OCTOPUS mass production equipment?

FJ: We are planning of having our OCTOPUS III Alpha tool fully qualified in the first quarter of 2019. At this point in time the official product launch will be initiated. But we have also started with the next-generation development of OCTOPUS IV, which addresses the higher throughput demands, as well as potential advances in the HJT-based cell architecture.

PES: From where do you operate and which are the key markets for INDEOtec? Are there any areas, geographically speaking, that you like to break into?

FJ: INDEOtec will apply a manufacturing model, which matches the cost down requirements of the industry. Critical components, SW and system control will always be manufactured in house, whereas the standard components we will source from third parties. We will have local assembly shops in key regional markets.

In terms of market penetration, we expect to have the major part of the PV equipment business in Asia, but we also see promising developments in North America and the Middle East.

In general, the global PV market expects a staggering growth in the next decade and most likely we will see more regions entering the PV value chain, simply due to the rising demand of PV cells and modules.

PES: What is the single biggest challenge facing the PV high-efficiency cell market today?

FJ: Over one year the PV industry has added roughly 40 GW of production capacity, now reaching a total amount of > 130 GWp, according to the ITRPV report for 2017. 90% of this capacity is state-of-the-art, such as BSF and PERC and the PV industry is really conservative in changing the technology so easily and quickly. The invested capital in this giant production capacity is simply too big and has to pay off.

The entry opportunity for high efficiency cells, such as HJT, is given with a reasonable efficiency advantage of 1% to PERC along with a competitive cost structure. This entry point is now there and the efficiency advantage has to be maintained.

However, an HJT cell manufacturing line differs significantly from the current line technology; therefore cell manufacturers are starting to make greenfield investments in order to maintain the business edge over BSF/PERC.

PES: Looking ahead into 2018 and beyond, which trends and/or changes are you anticipating in the market and why?

FJ: The current investment cycle for the PERC technology is still ongoing, but we see clear signs of a change towards the next generation cell technologies like HJT, HBC, TopCon and similar, simply because of the higher efficiency potential of > 28% which these new cell architectures provide. Forecasts expect a technology shift towards HE (high efficiency) cell devices to go >35% of market share in the next eight years.

And, similar to the semicon industry, a higher device performance will require improved and innovative deposition technologies. All this is accompanied by higher and cleaner manufacturing standards including high-end, high-purity tool sets. INDEOtec is already prepared for this and can quickly adopt these standards, based on our experiences in clean and high-purity industries like flat panel display.

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Prof. Jacques Schmitt, a member of INDEOtec's advisory board, developed the Plasmabox reactor concept, at Unaxis in the early 80's. The PECVD box-in-a-box concept describes a separate vacuum box, with its own gate valve and sealed entirely from the surrounding, outer PECVD chamber wall. Today this concept is widely acknowledged as a base design for PECVD reactors among European equipment manufacturers.

Omid Shojaei, CEO of INDEOtec, developed more than 6 generations of KAI PECVD reactors and cluster production systems for the display industry. Apart from very rigid cleanliness conditions and excellent film properties, the form factor (display size) was the key driver for high-throughput and big size reactors.