Swiss-US Energy Innovation Days 2018

SWISS MADE

INDEOtec

PLASMA PROCESS EQUIPMENT

PECVD-Mirror: A solution to reduce manufacturing cost of high efficiency solar cells «HJT» and Roadmap

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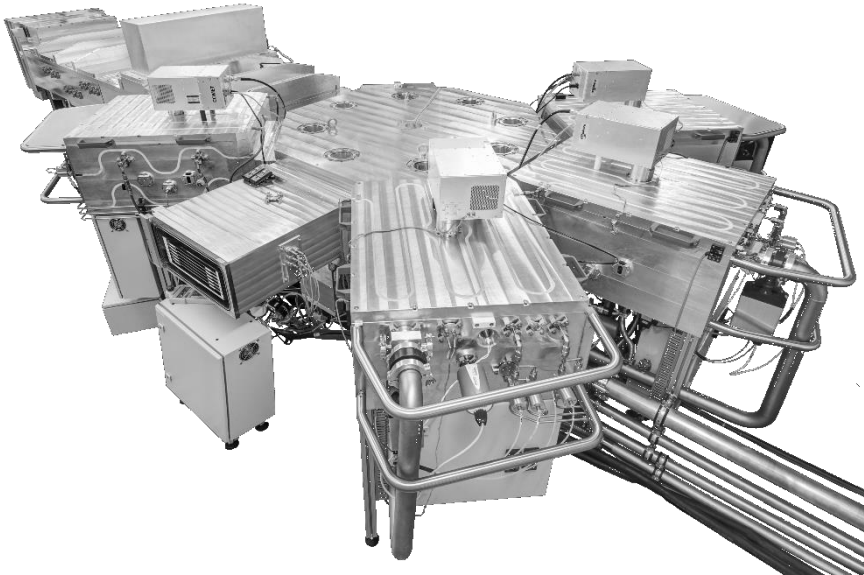
August 21st 2018

Neuchâtel, Switzerland.



Contents

1. **Indeotec: background & applications**
2. **Mirror-PECVD: Simplification & Cost Reduction**
3. **Take-aways**

The reactor size evolution

1981

«Old» times

Mr. Jacques Schmitt developed the «Plasma-Box» RF-PECVD reactor concept for Large Area Coating

1996 - 2005

Mr. Schmitt and Mr. Shojaei developed 6 generations of «KAI» PECVD systems for FPD mass production at Oerlikon (formerly Unaxis)

2003 - 2011

Thin film for PV

Oerlikon runs its Solar business with KAI 1200 (Gen 5) as the core system for the a-Si thin film turnkey lines, generating > 900 Mio CHF in revenues

Kai 1200 PECVD for FPD & TF-Si

2007

Company inauguration

The company was founded for converting new PECVD reactor ideas into reality.

2009 - 2010

OCTOPUS I

Indeotec develops the Octopus I system with a PECVD RF reactor for 5" wafers.

2012

OCTOPUS II starts with the PECVD Classic reactor for RF deposition, allowing low plasma ignition and excellent uniformity layers.

2014

The OCTOPUS II system is supplemented with a PVD module for top and bottom side deposition using planar or rotary cathodes.

OCTOPUS II

INDEOtec introduces OCTOPUS II for PECVD & PVD, for 450 x 350 mm substrates or 4 x 6" wafers.

2015

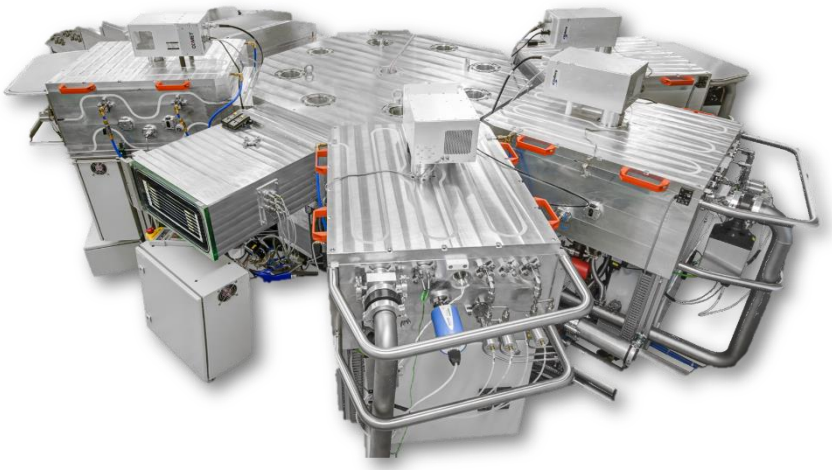
INDEOtec unveils the **revolutionary Mirror Reactor** for RF mode PECVD thin films, allowing top and bottom side deposition.

2016 - 2017

OCTOPUS III

The PECVD mass production system for PV heterojunction cell devices is going to be ready for sale.

Example layout



Pure PECVD configuration for small production

PECVD and PVD for complete SHJ deposition cycle

References & Collaboration partners

csem

ASU Knowledge Enterprise Development

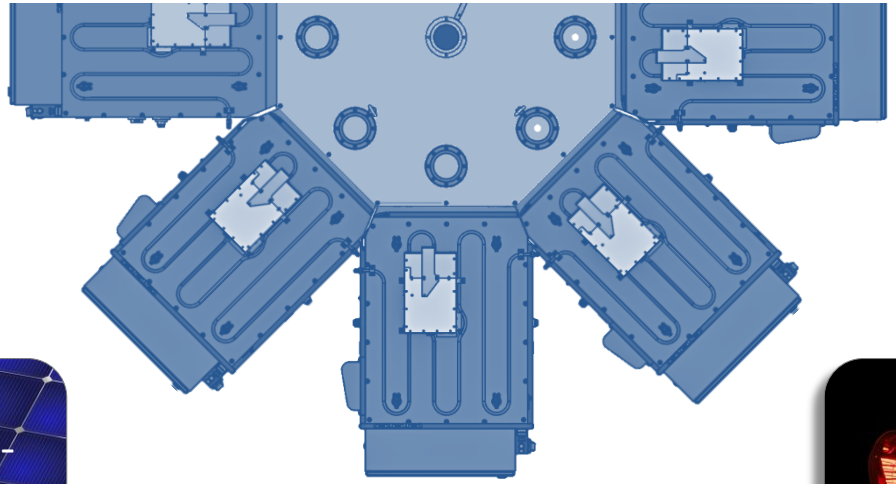
EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

IPVF
INSTITUT PHOTOVOLTAÏQUE D'ILE-DE-FRANCE

Fraunhofer ISE

Different markets for OCTOPUS



INDEOtec's **proprietary Mirror reactor technology** makes **OCTOPUS III** the tool with the highest cell production capacity and the best price-performance ratio in the PECVD tool market.

The **Mirror reactor technology** can increase the throughput 3-4 times for roughly the same price as current available tools.

The **Mirror reactor technology** and **new deposition techniques** improve the quality of encapsulation and TCO layers. Both is instrumental for OLED lighting applications.

The PV Market

- ✓ Of all **Renewable Energy** forms **Photovoltaics** is expected to further grow at a **phenomenal rate**. Today's PV panel production capacity of 130 GW p.a. will expand to a whopping size ranging from 600 .. 880 GW p.a. by 2035.

The PV Market

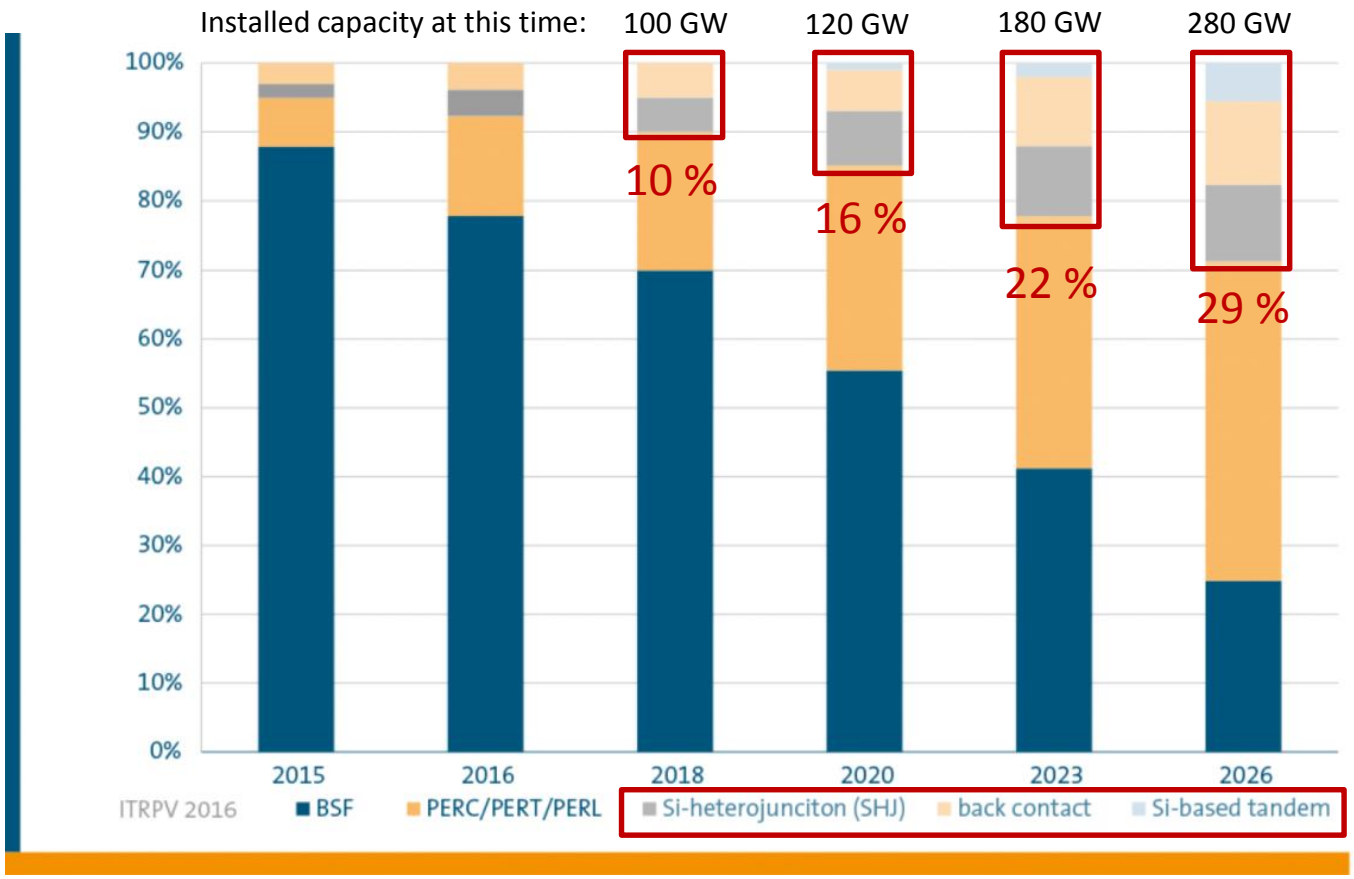
TOP DOWN

The graph shows the addressable market share for OCTOPUS III.

From 2018 .. 2023 the **additional capacity** to be installed is around **36 GW** in total.

INDEOTEC market research confirms 21 GW of capacity demand by 2021.

The Chinese company AAA expects 50% of the current cell capacity to be replaced by HJT in 6 .. 10 years.



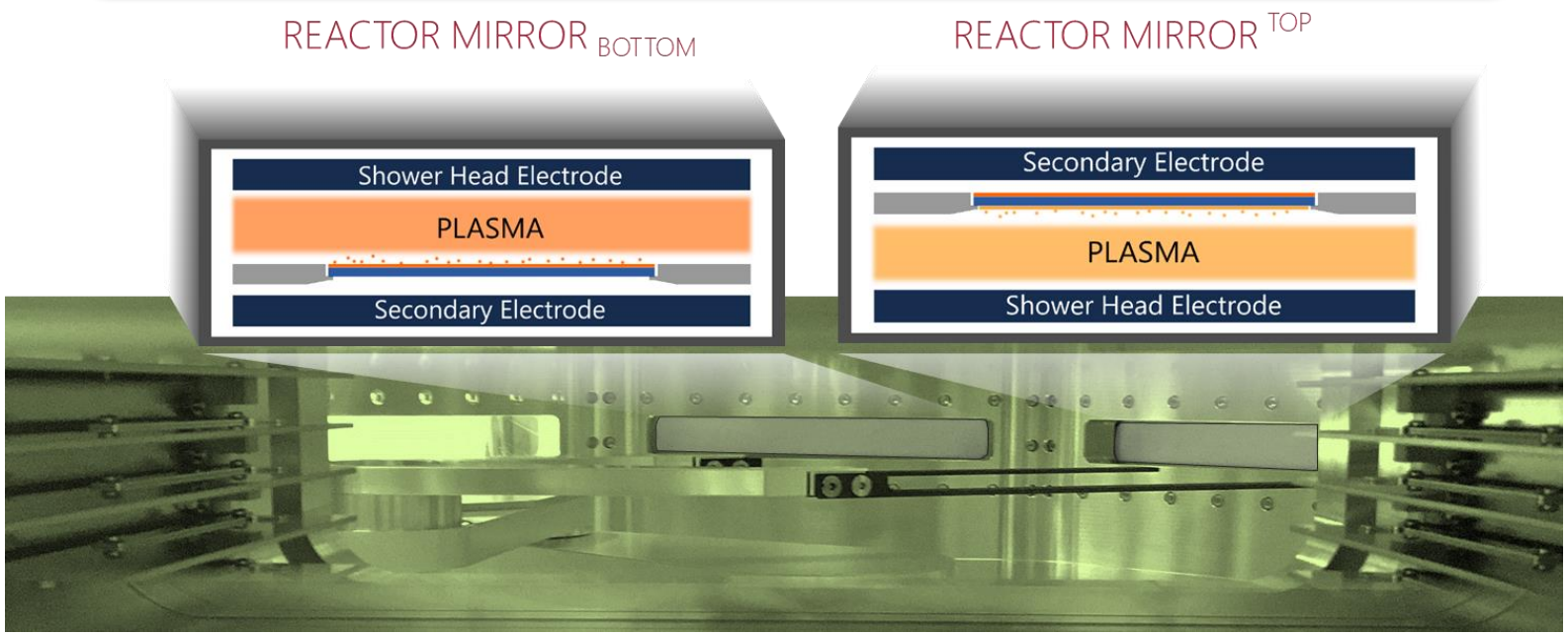
Worldwide market share for different cell technologies

Applicable market for OCTOPUS III

BOTTOM UP

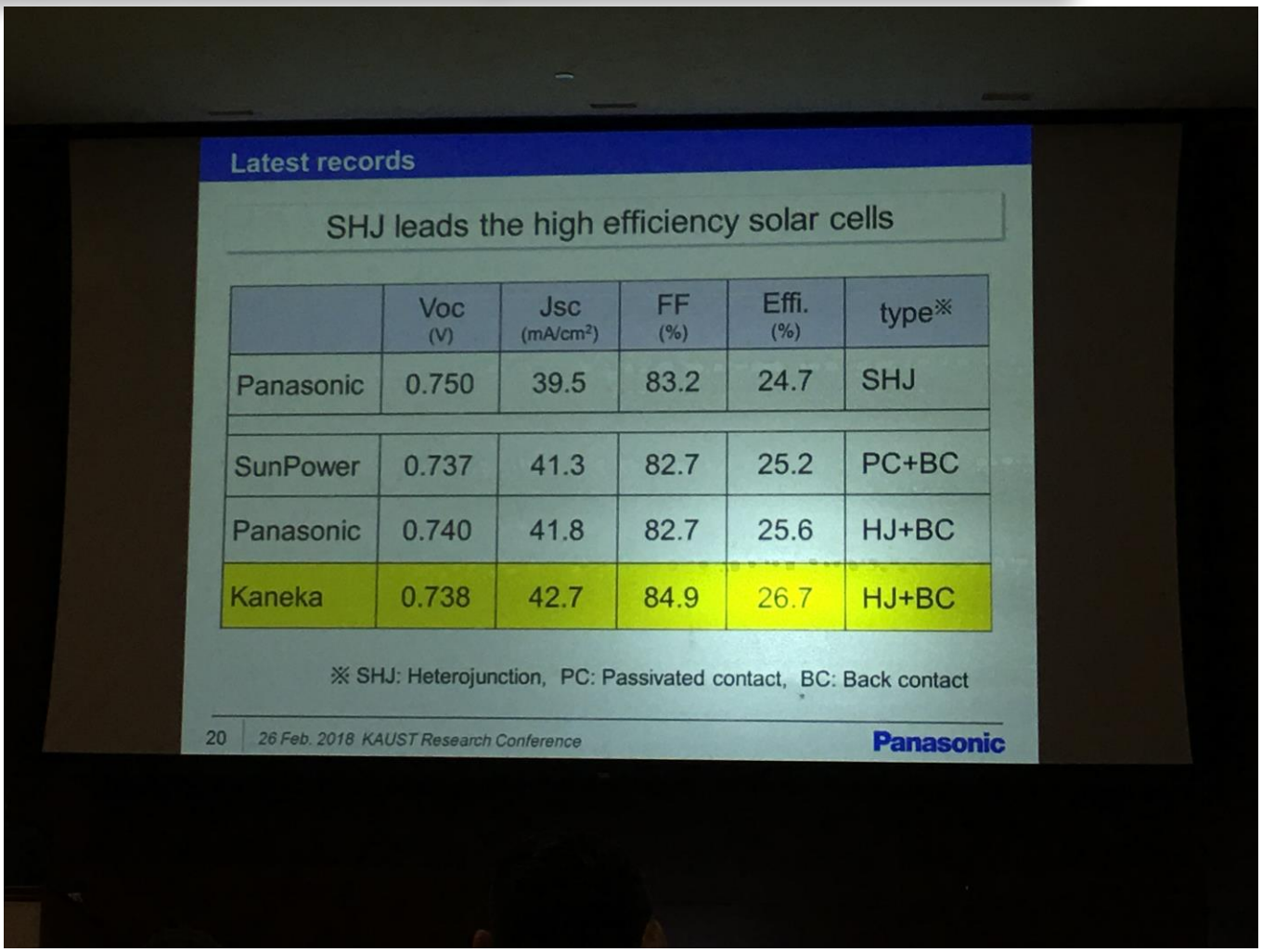
The total addressable market for OCTOPUS III until 2023 is **1'600 Mio US $.**

✓ For the PV cell device manufacturing step INDEOTEC offers its OCTOPUS III PECVD thin film deposition tool to market, equipped with its **unique and proprietary Mirror Reactor technology**, which makes the tool the best performer in terms throughput, footprint and price/performance ratio. INDEOtec forecasts a **compound revenue of > 700 Mio USD until 2025.**



HJT Landscape

Best of the Best from Japan



Latest records

SHJ leads the high efficiency solar cells

	Voc (V)	Jsc (mA/cm²)	FF (%)	Effi. (%)	type※
Panasonic	0.750	39.5	83.2	24.7	SHJ
SunPower	0.737	41.3	82.7	25.2	PC+BC
Panasonic	0.740	41.8	82.7	25.6	HJ+BC
Kaneka	0.738	42.7	84.9	26.7	HJ+BC

※ SHJ: Heterojunction, PC: Passivated contact, BC: Back contact

20 | 26 Feb. 2018 KAUST Research Conference Panasonic

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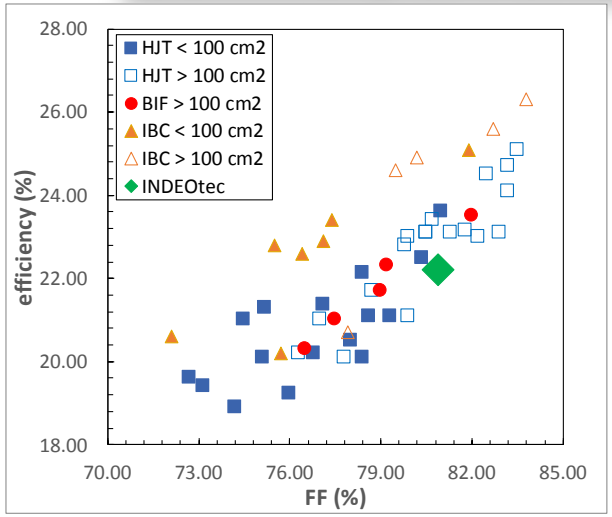
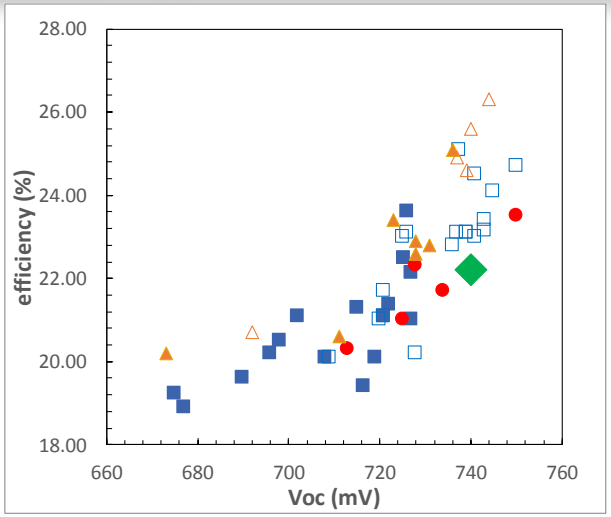
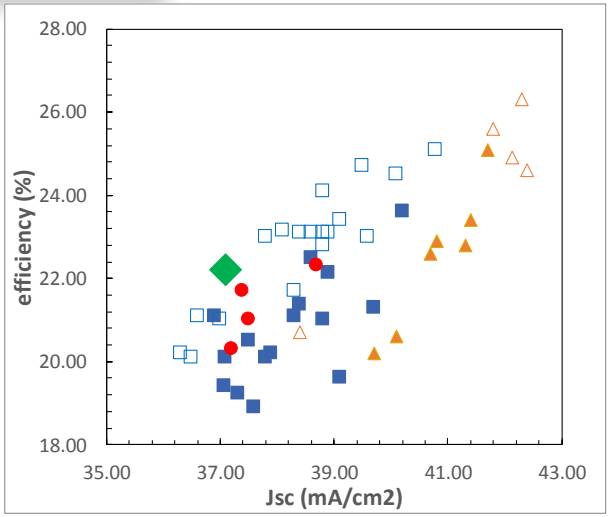
HJT Landscape

Summary of Performance







- HJT cells :
  - Champions: > 26% reported for IBC with Cu plating!
  - Few labs >23% on full cell area with screen printing!
  - Few fabs > 22.5% on full area with screen-printing!
  - Bi-faciality is so easy to integrate!
  - Rather simple manufacturing steps!

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Contents

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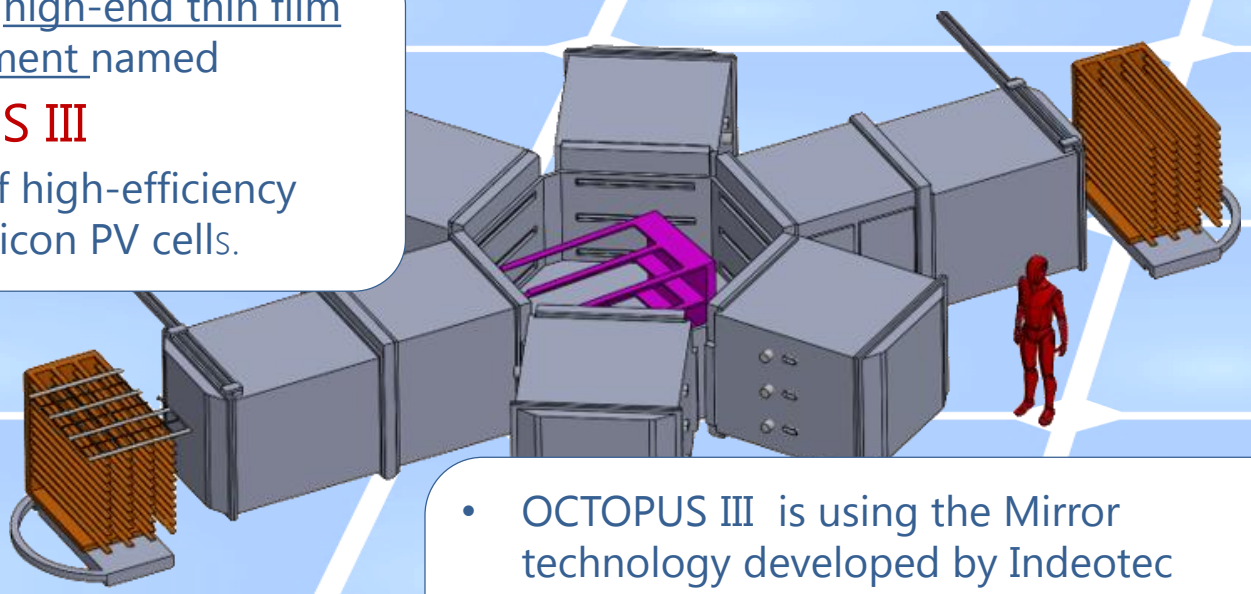
The Product

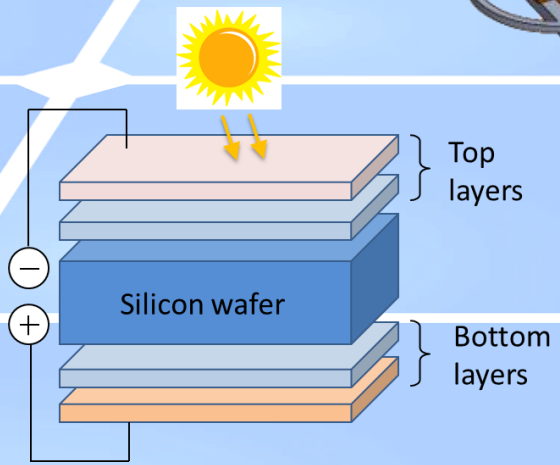
INDEOtec manufactures high-end thin film deposition equipment named

OCTOPUS III

for the manufacture of high-efficiency (Heterojunction) silicon PV cells.



- OCTOPUS III is using the Mirror technology developed by Indeotec
- This machine combines very high throughput and lowest cost of aquisition and operation.



OCTOPUS III deposits ultra thin layers (few nm) on the top and bottom side of silicon wafers, thus generating a PV cell device. > 3'000 wafers per hour can be processed.

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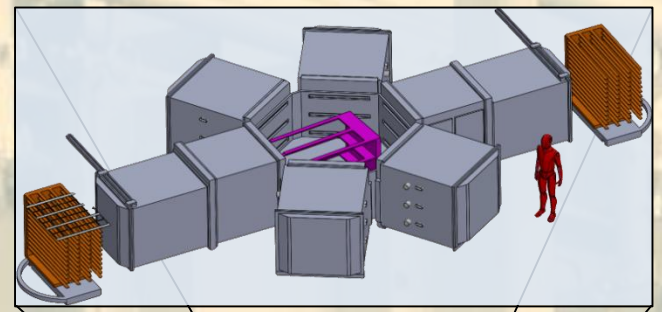
The Product environment

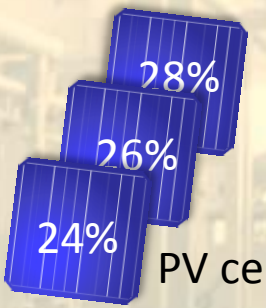


With OCTOPUS III the line output is **approx. 140 MW p.a.**

The cell efficiency potential is 30% and higher.

Wafers

Cleaning / Texturing → Passivation / Device → TCO → Curing /Contacting



PV cells

Heterojunction PV cell manufacturing line

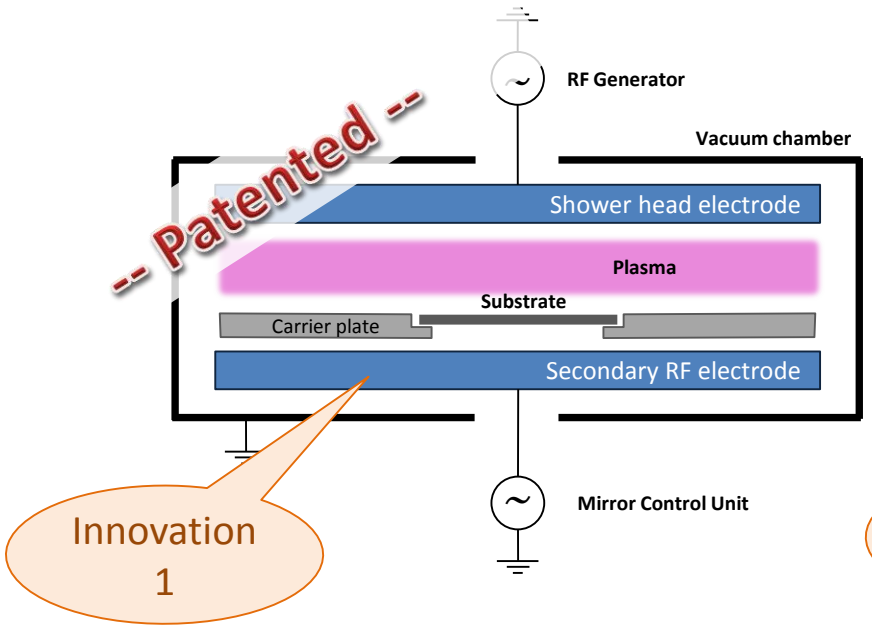
- Texturing is mature: chemistry control and Ozonator
- PECVD is by far the most complex machine and represent 50% of line's CAPEX
- PVD is mature: new materials, double side deposition
- Screen printing machine is mature: double side, adequate paste, lower down Ag consumption, combine with annealing

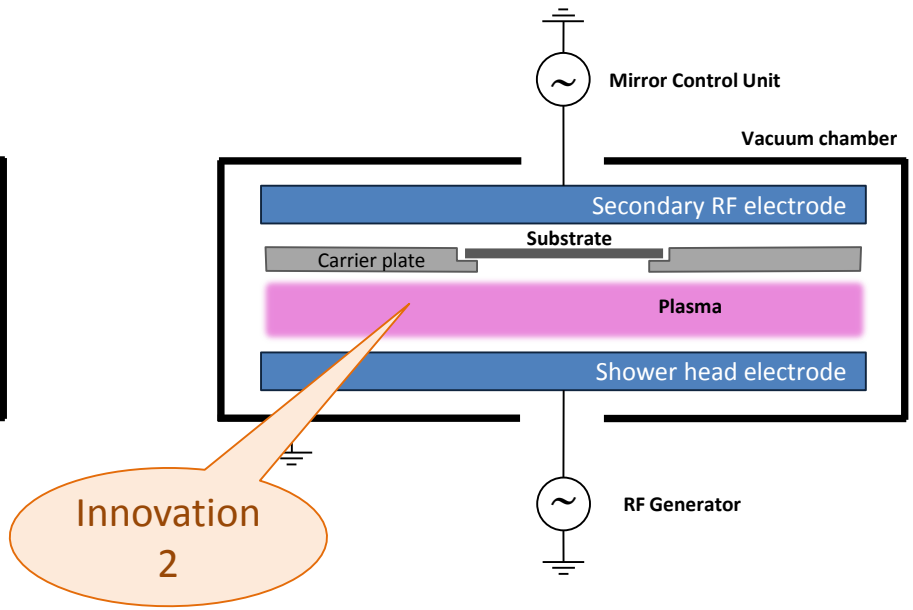
OCTOPUS - Mirror-PECVD

Mirror concept introduction

i/p – layers in top side reactor

i/n – layers in bottom side reactor

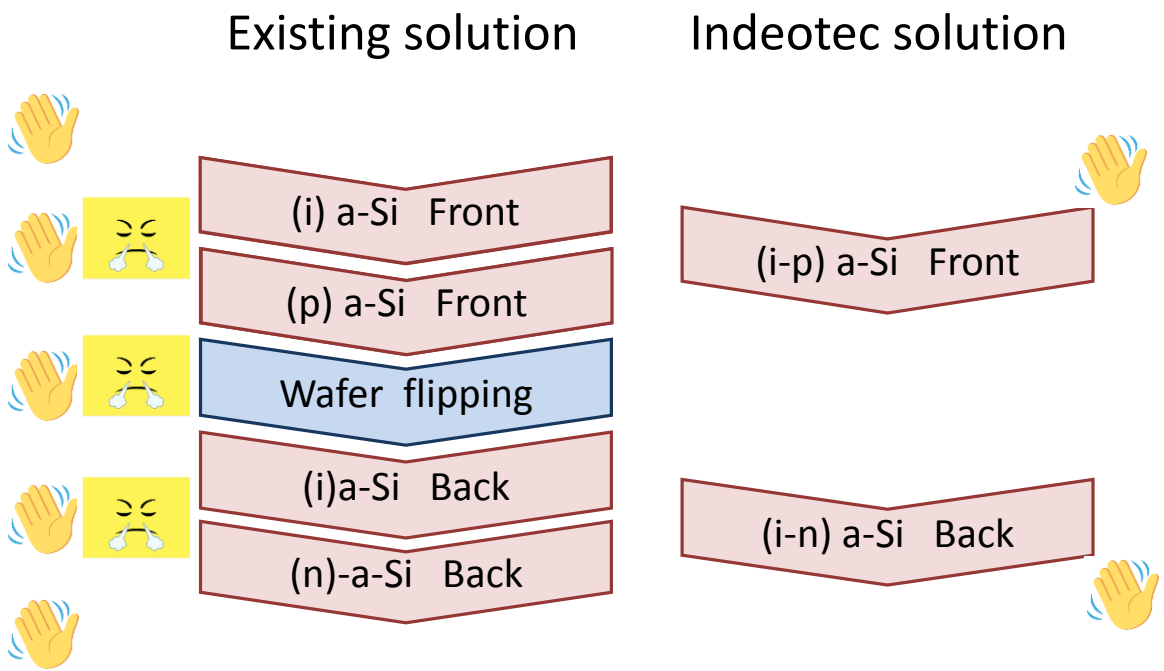




.. Additional electrode (3rd electrode) for enhanced plasma tuning

.. **Carrier on top** and **plasma from bottom** for bottom-side deposition

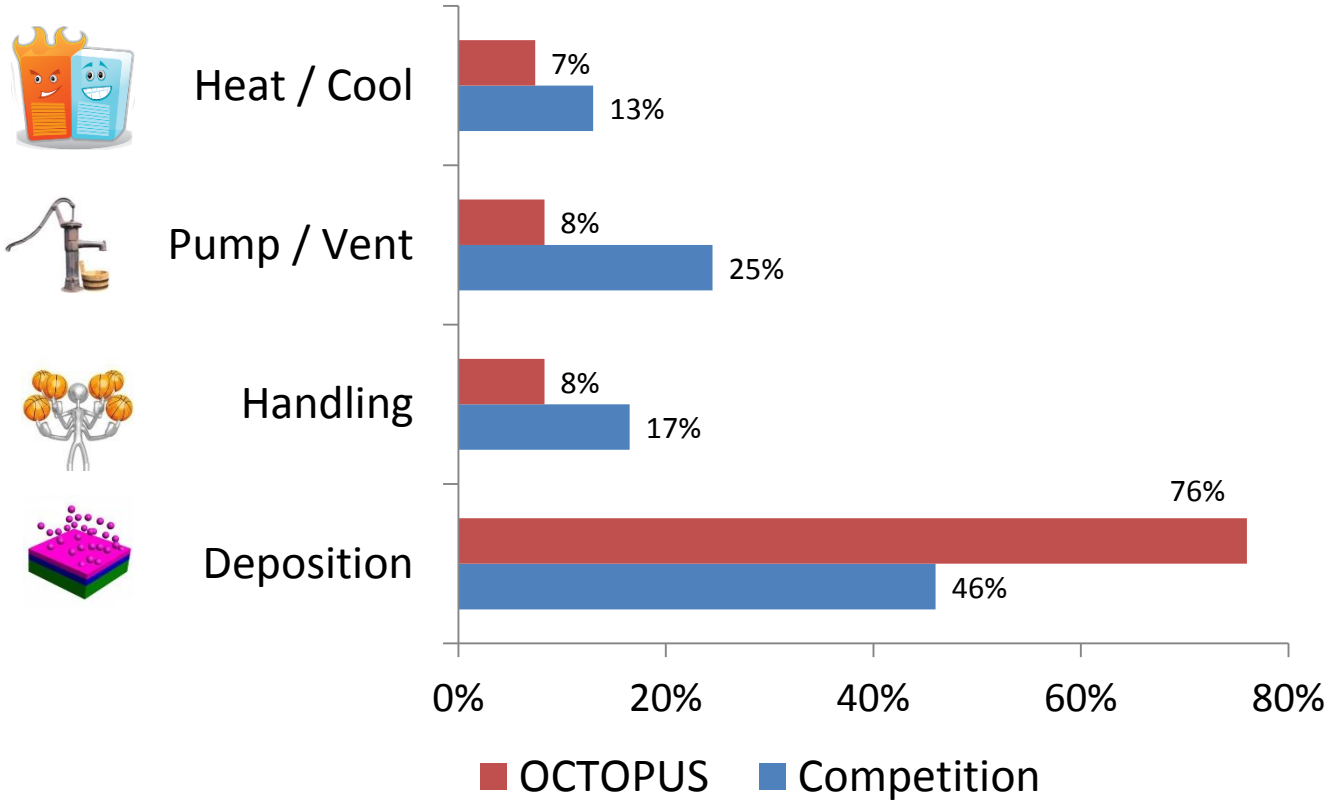
PECVD value proposition: simplification



- ✓ intrinsic and doped in same reactor
- ✓ NO flipping
- ✓ NO external handling
- ✓ NO in-between vacuum break

Wafer manipulation Vent/vacuum sequence

Wafer Residence time – Process step breakdown



Design target

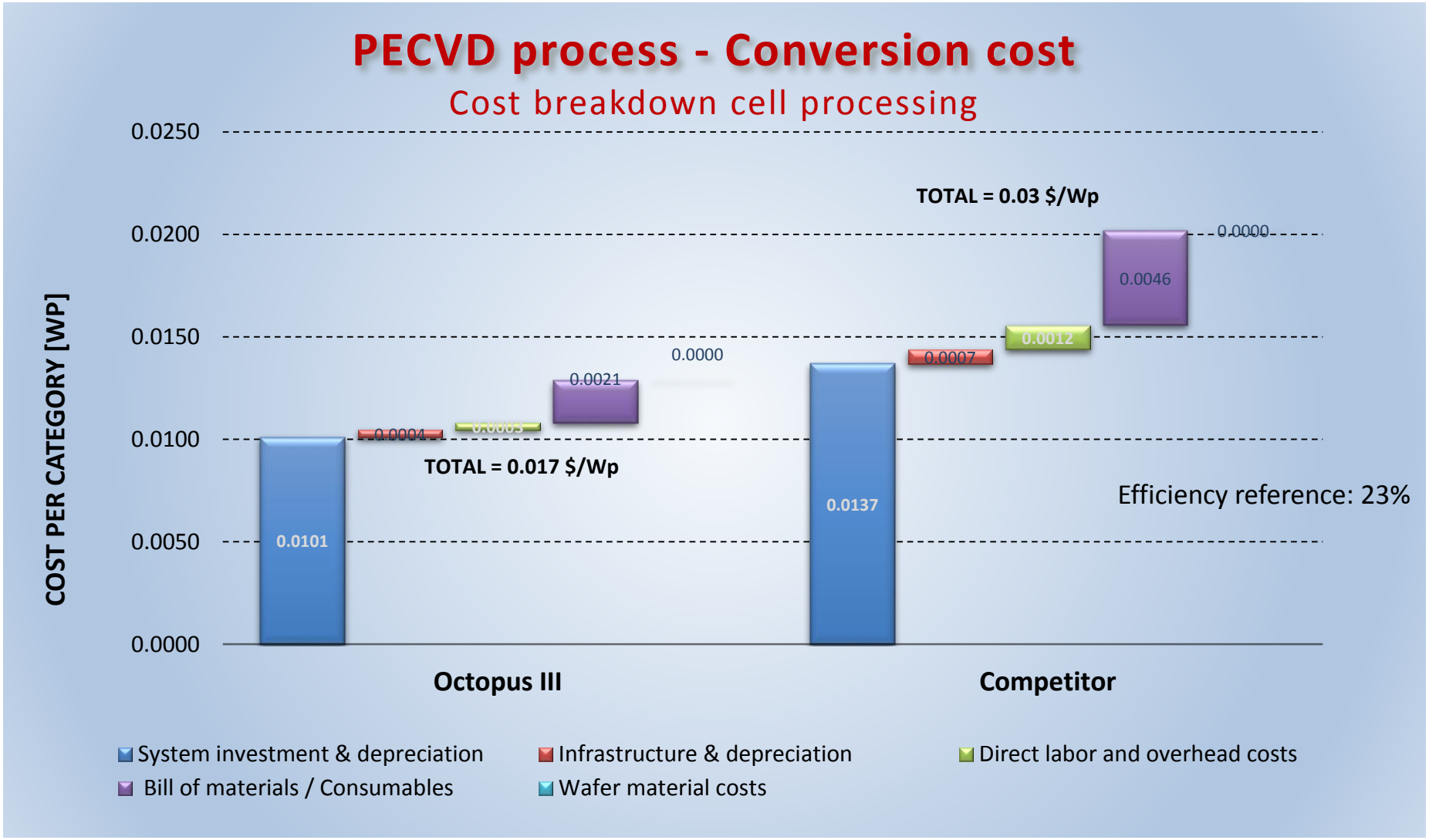
Minimize every step, which does not add value !

Tremendous OPEX savings compared to other manufacturers. (> 30%)

Data baseline: PECVD process only, deposition time identical

OCTOPUS – CoO

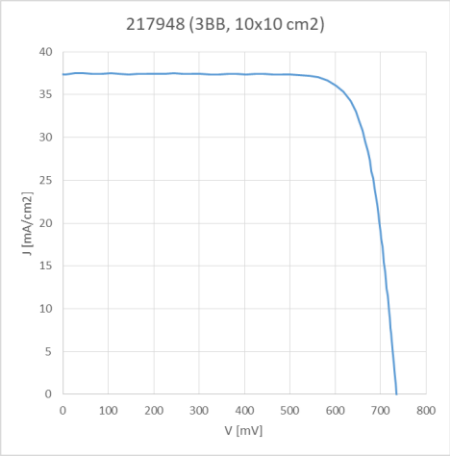
OCTOPUS is well below 2 cent/Wp for PECVD conversion costs. Future improvements promise to come close to the 1-cent-benchmark.

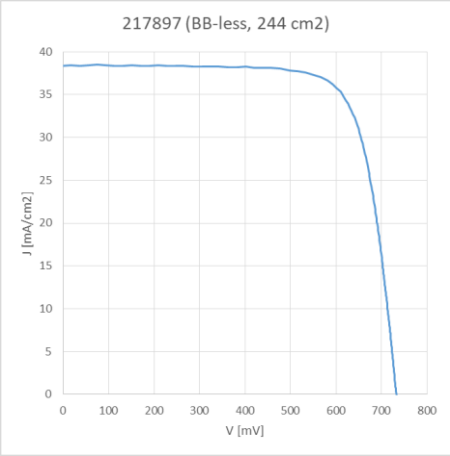


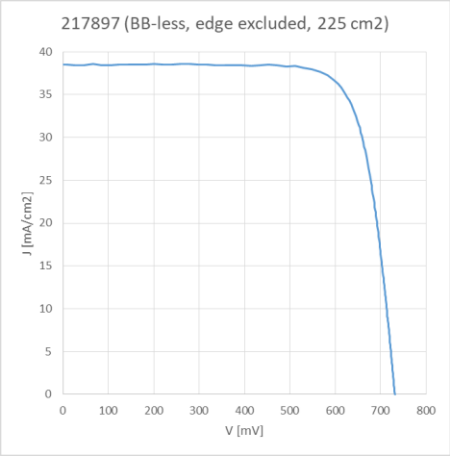
Results – Complete HJT in Mirror Top & Bottom

Cell	Jsc	Voc	FF	Efficiency
100 cm^2, 3 BB	37.4	735	79.3	**21.8**
Full-area 6'', BB-less (244 cm^2)	38.3	736	76.5	**21.6**
Des.-area 6'', BB-less (225 cm^2)*	38.5	735	78.1	**22.1**

*designated-area with masking edges during IV measurement (3 mm exclusion)





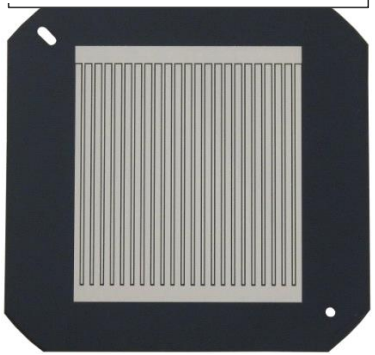


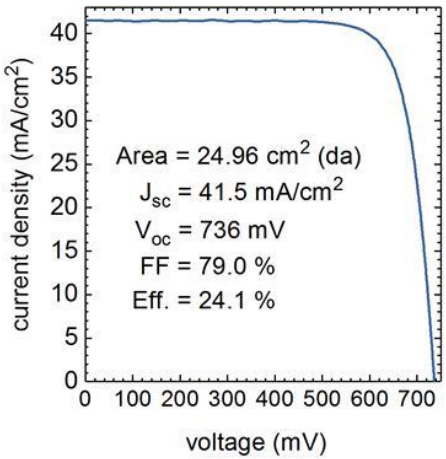
Performed at

Capability proof for >24%
IBC-HJT device produced with Octopus PECVD & PVD

Champion-cell result with PECVD on Octopus II in classic reactor

25 -cm ^{2} tunnel -IBC





«tunnel IBC concept» : lean and simple process flow based on advanced thin film silicon layers management.

- **24 % IBC-HJT cell EFFICIENCY demonstrated w.**
- **CSEM processes**

Performed with Octopus PECVD & PVD

OCTOPUS III - Start safe & Expand to very High Throughput > 3300 wph double side

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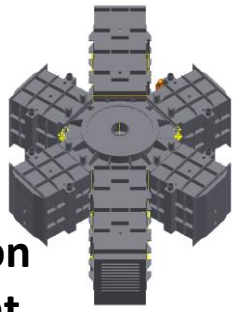
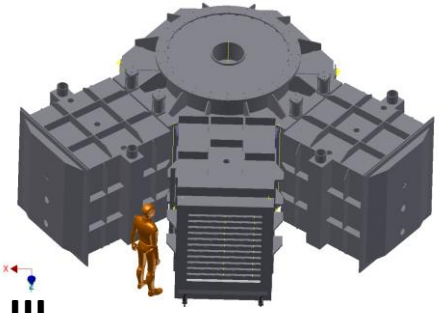
POINT OF ENTRY FOR OCTOPUS III 2018 …

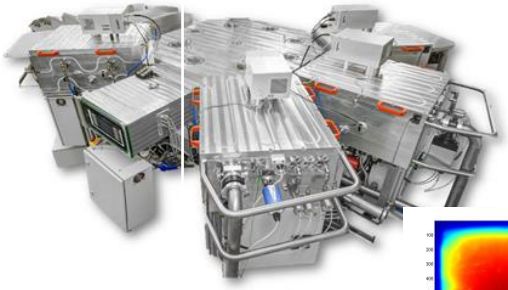
OCTOPUS III

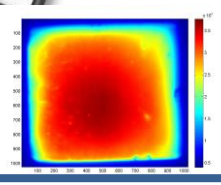
2018 – Qualification
2019 – Deployment





OCTOPUS III
Alpha tool - Qualification





OCTOPUS II
Process
&
Sampling

OCTOPUS III
Gama tool – PRODUCTION

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Take aways:

- Our PECVD technology is the bench-mark for passivation job.
- Mirror-PECVD received Mios of investment so far.
- Mirror-PECVD patented world-wide.
- First order received for mass-production machine Octopus III for qualification.
- > 700 Mio US$ possible turn-over within 5-6 years.
- LOI in hand for 30-40 machines and many more to come after the first qualification.
- We are raising funds to bridge-finance the big growth!!!!!

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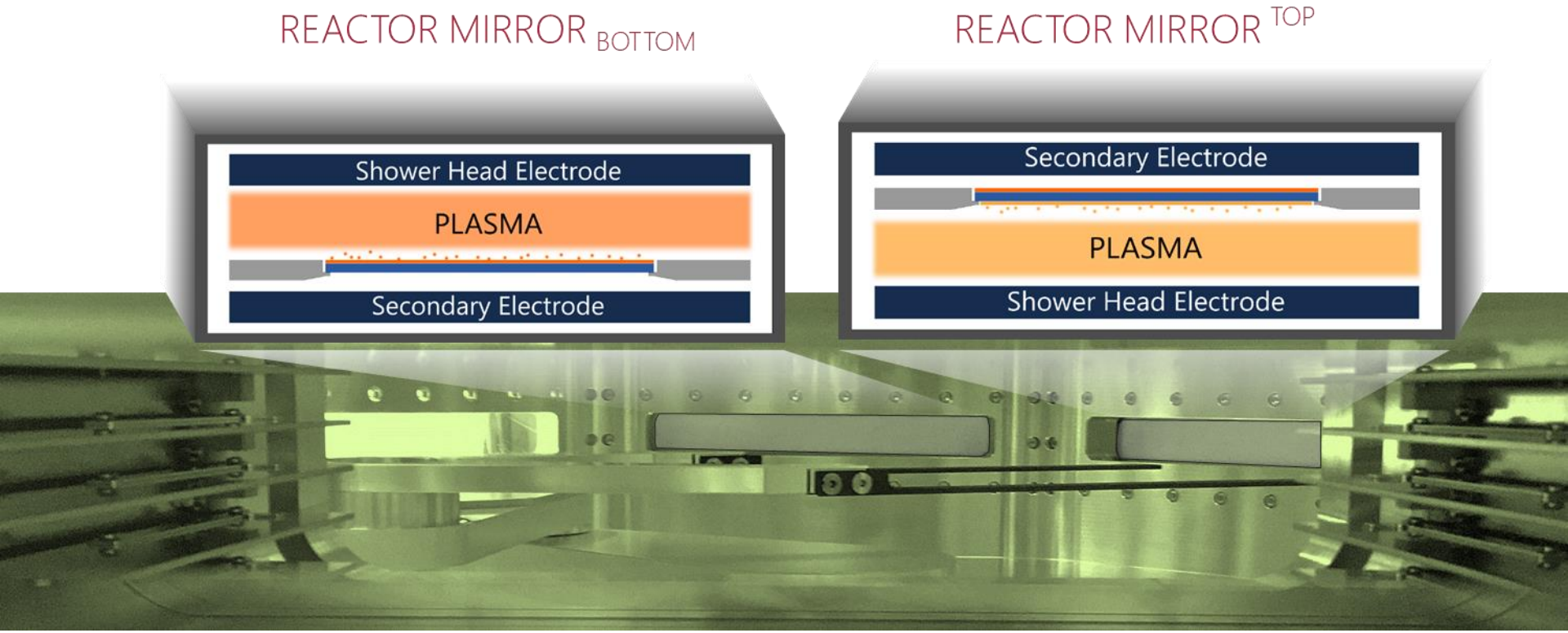
You are welcome to visit the Mirror-PECVD demonstrator in our Lab!