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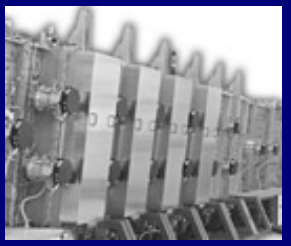

Will Si-Thin Film PV be superior?

Snapshot Business Units

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BU Optics

Precision Optics

Ophthalmics

3D Coating

Flexible

BU Solar

Glass

Solar

The business is grouped around the core fields Optics and Solar

All major TF fields are covered by LO

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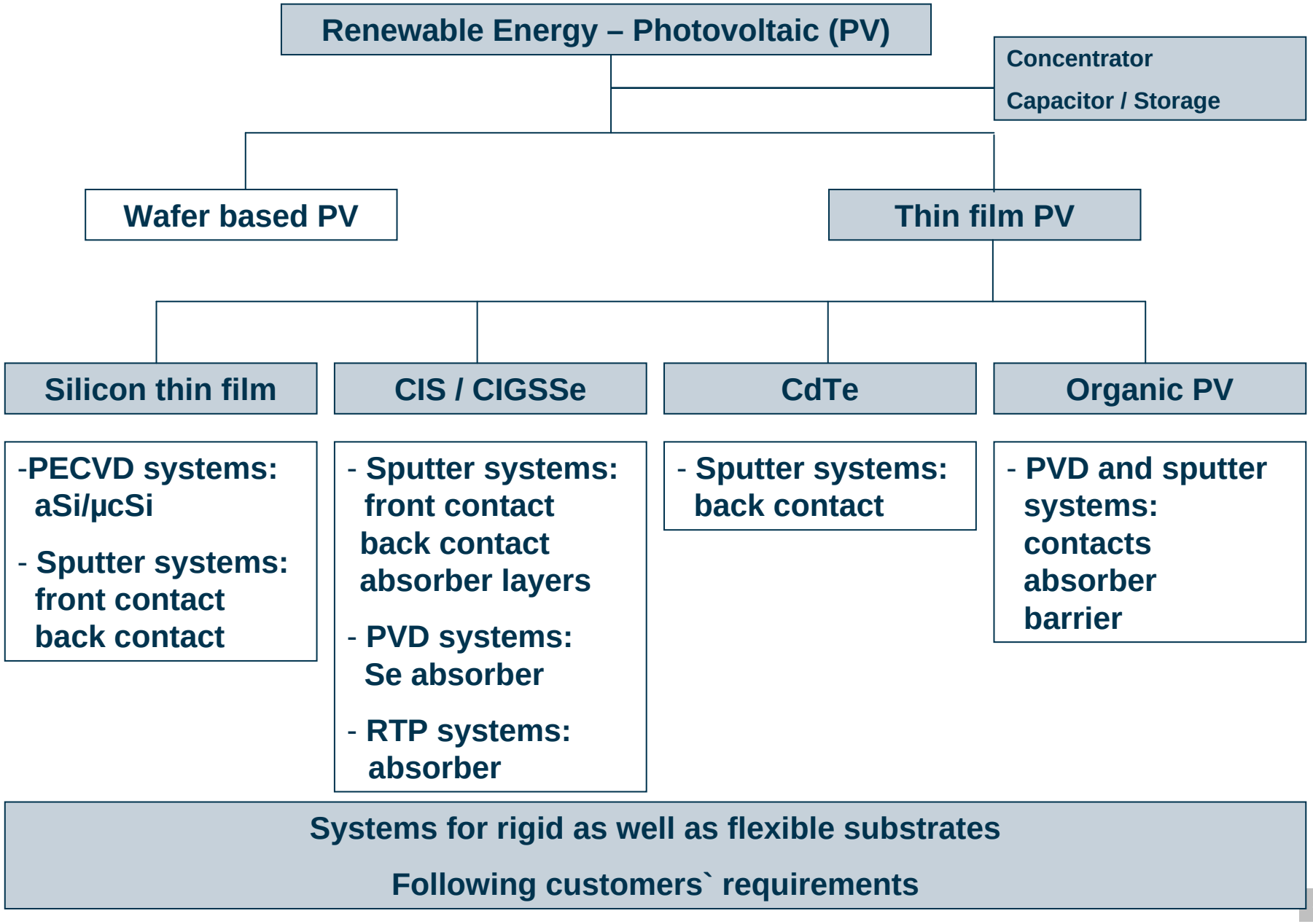

a-Si / µc-Si Production Line

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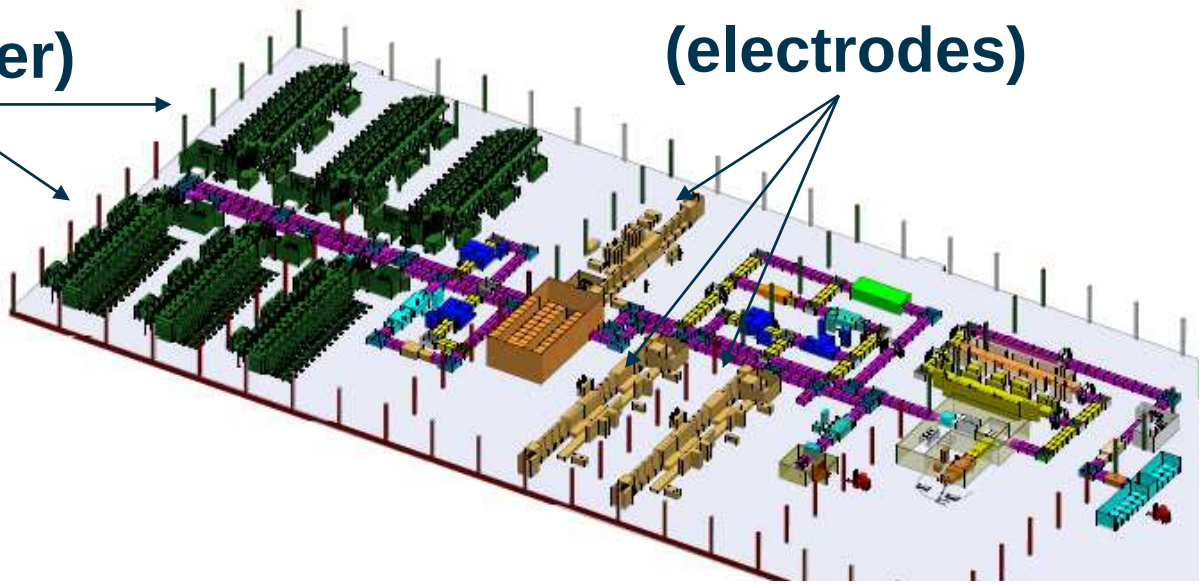
Leybold Optics‘ core competences are vacuum systems and processes for:

PECVD

(absorber layer)

PVD

(electrodes)



PVD: Magnetron Sputter Systems

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Advantages of PVD Photovoltaic system:

- Easy handling due to 7° system
- No back side coating due to carrier concept
- Particle insensitive due to vertical
- Easy / fast maintenance due to cathode concept
- Low CoO due to rotatable cathodes

PECVD: The Linear Cluster Tool „ Phoebus©“

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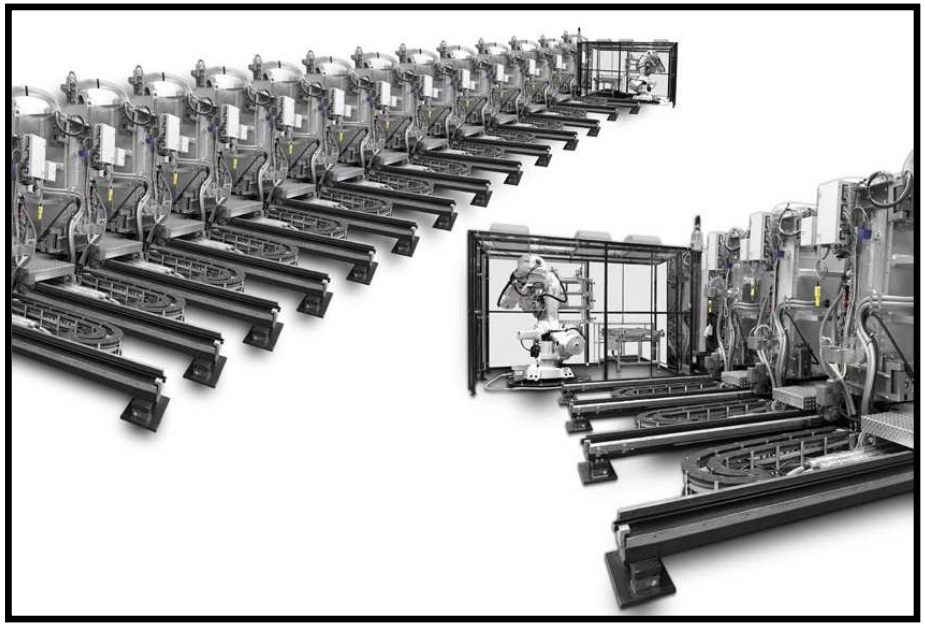
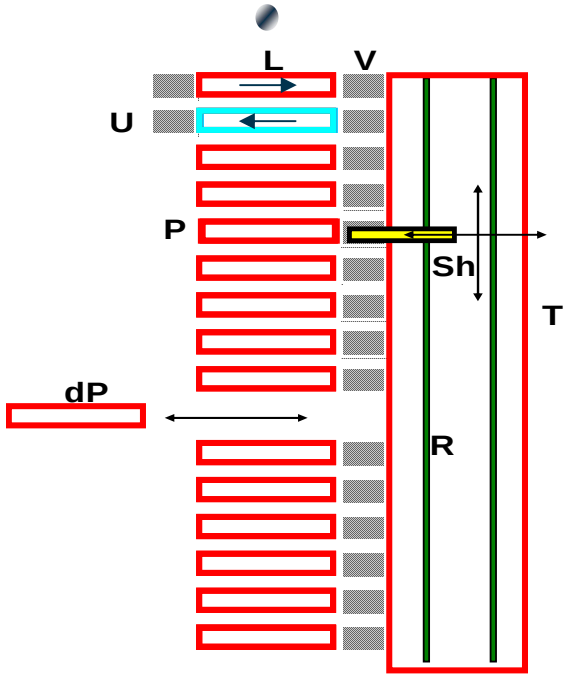
- Maintaining substrate temperature
- No vacuum break during process
- Carrier free
- Rigorous gas separation
- High flexibility in process sequence
- Manufacturing friendly
- Self cleaning with environmentally gas





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Phoebus© excellent uniformity

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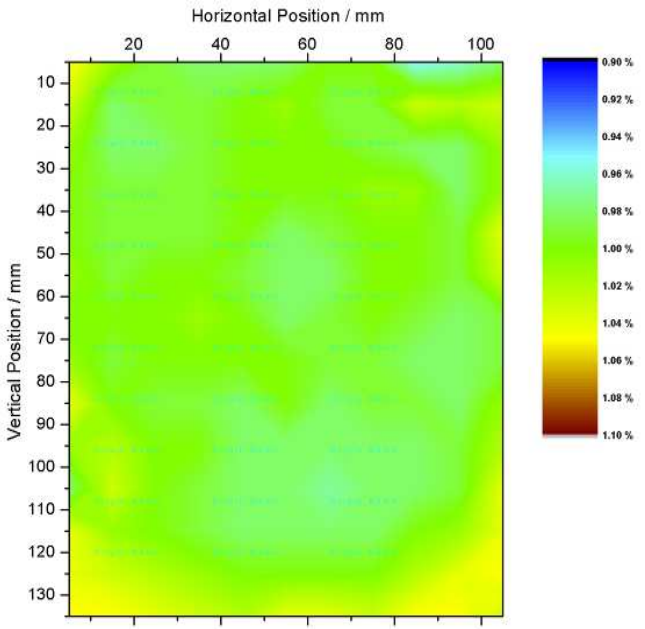

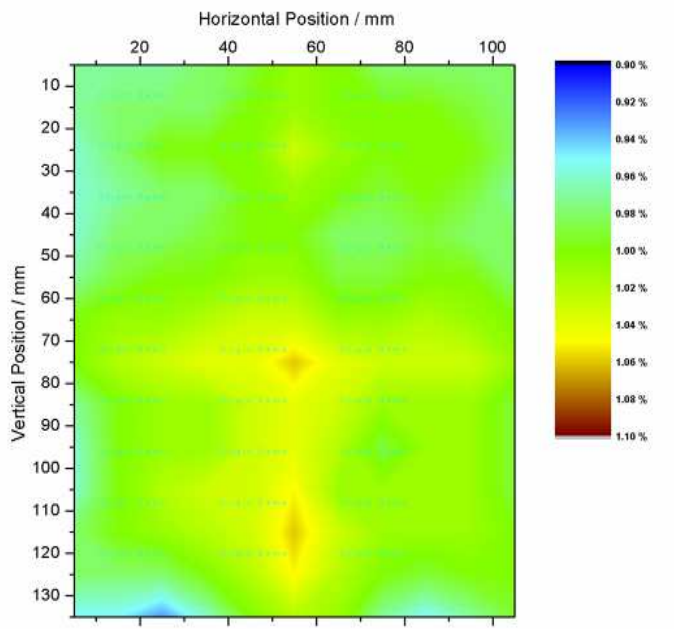

a-Si single junction solar cell:

max/min deviation from average cell thickness: 4,7%

Sigma: < 2,0%

µc-Si single junction solar cell:

max/min deviation from average cell thickness: 6,4%

Sigma: < 2,3%

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Excellent uniformity in crystallinity

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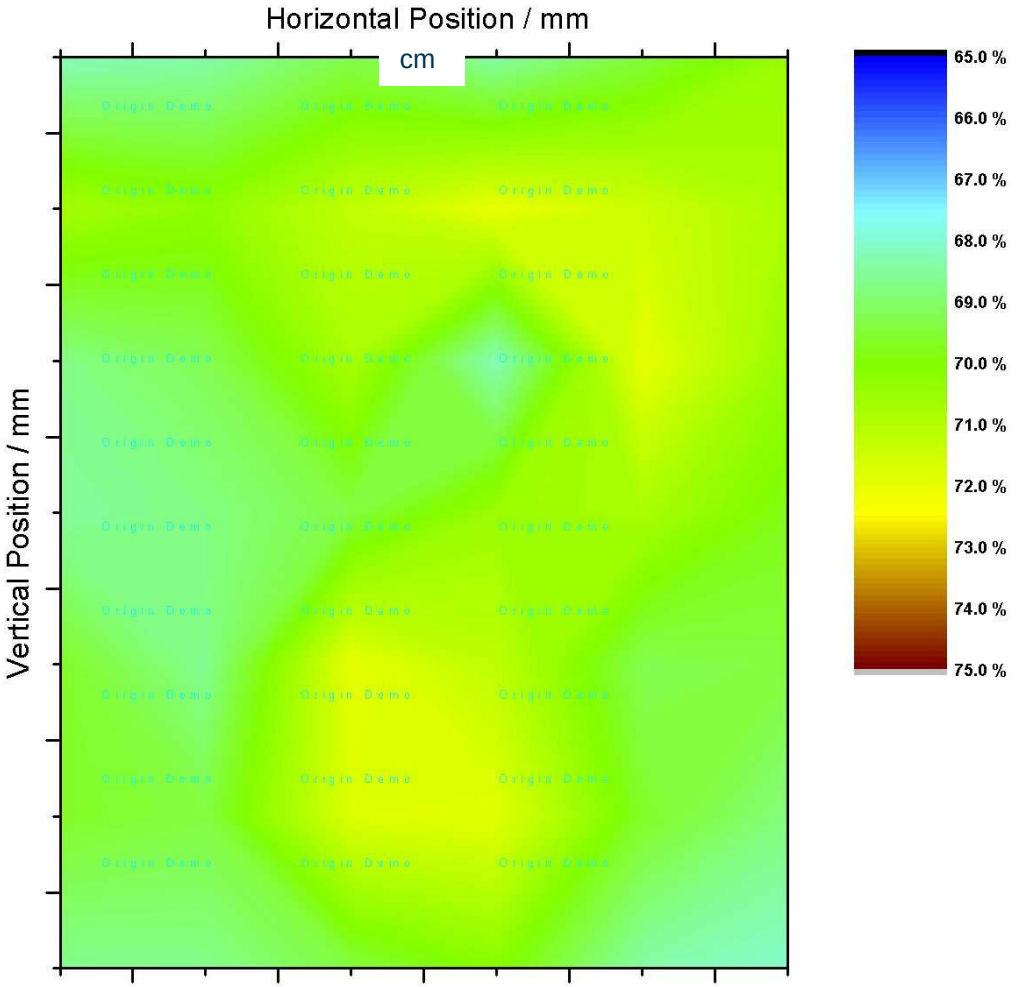
Gen 5 µc-Si solar cell:

crystallinity
measured by Raman probe
(ratio [abs(%)]

Sigma: 1,73%



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Rate improvement without sacrificing Si-layer quality

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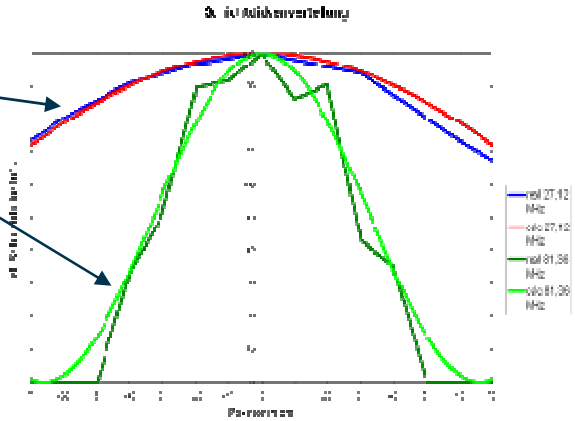
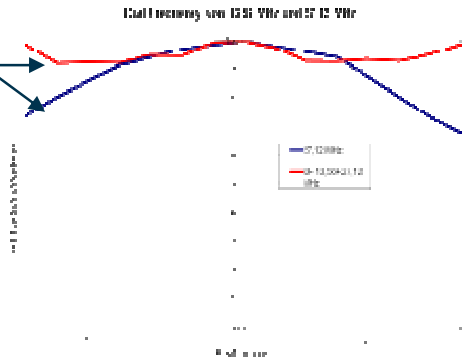
Fact:

- rate improvement by higher frequency
  13,6MHz > 27MHz > 40MHz > 80 MHz
- reduction of Ion bombardment with higher frequency



- But higher frequency results in worse uniformity!

- Solution: Dual Frequency (13,6 MHz + 27 MHz)
  - Ion energy and ion density separately controllable
  - bias controllable by phase shift
  - Uniformity not corrupted VHF!!



Innovation Prize 2010 for “Dual-Frequency-technology”

LEYBOLD OPTICS

Leybold Optics has an exclusive license of the Dual Frequency technology

Informationsdienst Wissenschaft

Sie sind hier: Home > Pressemitteilung: Bochumer Physik-Dekan erhält ...

Pressemitteilung

Bochumer Physik-Dekan erhält Plasma-Innovationspreis

Dr. Josef König, Pressestelle
Ruhr-Universität Bochum

17.12.2009 08:42

Entdeckung des "Elektrischen Asymmetrie-Effekts" wird gewürdigt
EPS Plasma Physics Innovation Prize 2010 für Uwe Czarnetzki

Prof. Dr. Uwe Czarnetzki

Prof. Dr. Uwe Czarnetzki, Dekan der Fakultät für Physik und Astronomie der Ruhr-Universität Bochum, wird für die Entdeckung des "Elektrischen Asymmetrie-Effekts" von der Europäischen Physikalischen Gesellschaft (EPS) mit dem "Innovationspreis für Plasmaphysik" ausgezeichnet. Seine Entdeckung führte letztlich zu einem innovativen Verfahren zur Kontrolle von industriellen Plasmen. Das Anwendungsspektrum der aufgrund dieser Entdeckung entwickelten Technologie reicht von der Solarzellenproduktion über Oberflächenfunktionalisierung

bis zum Halbleiterätzen in der Mikroelektronik. Der mit 3.000 Euro dotierte Preis wird im Juni 2010 bei der EPS Konferenz verliehen.

Zwei neuartige Charakteristika

Der Elektrische Asymmetrie-Effekt wurde erstmals in symmetrischen kapazitiv gekoppelten Radiofrequenzentladungen bei der Überlagerung der Grundfrequenz (f = 13,56 MHz) mit einer geradzahligen Harmonischen (2f, 4f, etc.) untersucht. Die gezielte Erforschung der zugrundeliegenden Physik dieses Effektes und die aus diesem Verständnis erfolgte Optimierung führten schließlich zu einem innovativen Verfahren zur Kontrolle von industriellen Plasmen. Das neue Verfahren zeichnet sich vor allem durch zwei neuartige Charakteristika aus: Zum einen ist erstmals eine wirklich unabhängige Regelung der beiden wichtigen Prozessparameter Ionenenergie und Ionenfluss möglich. Zum anderen ist das Verfahren vor allem anwendbar auf großflächige Entladungen, die für moderne industrielle Anwendungen bedeutsam sind. Das Verfahren ist über RUBITEC, die RUB-Verwertungsgesellschaft, patentiert und an der Umsetzung zur effizienteren Produktion von Solarzellen wird mit einem industriellen Partner (Leybold Optics GmbH) gearbeitet. An der Erforschung waren neben Mitgliedern des Lehrstuhls für Plasma- und Atomphysik, insbesondere Dr. Brian Heil, auch Kollegen aus der Elektrotechnik (Prof. Dr. Ralf Peter Brinkmann, Dr. habil. Thomas Mussenbrock) sowie von der Hungarian Academy of Science in Budapest (Dr. Zoltan Donko) beteiligt.

http://idw-online.de/de/news349305

Leybold Optics Phoebus© PECVD machine

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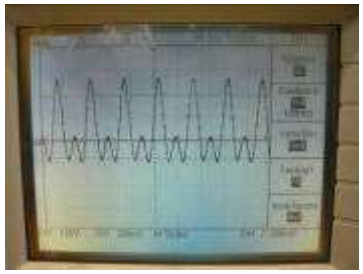
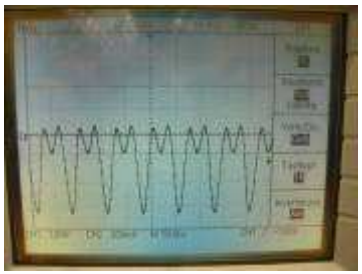
Hardware adoptions for dual frequency technology:

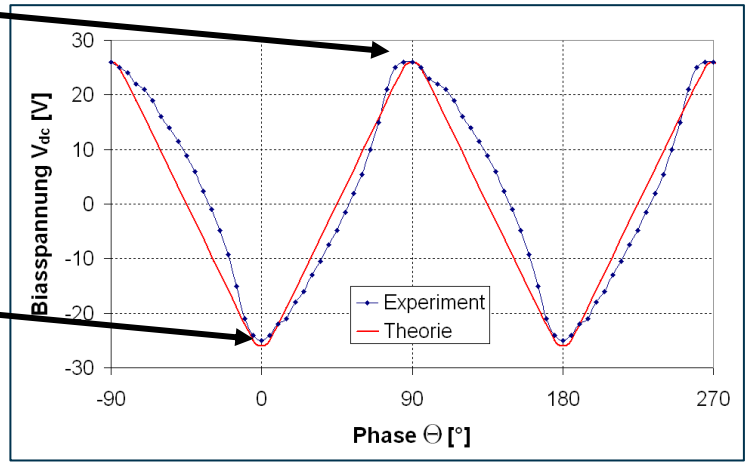
- 2nd power supply and
  2nd matching unit
- frequency generator incl. phase shifter

$U_{Dc} > 0$



$U_{Dc} < 0$





Bias voltage can be switched from positive to negative by turning phase shift.

Dual Frequency results

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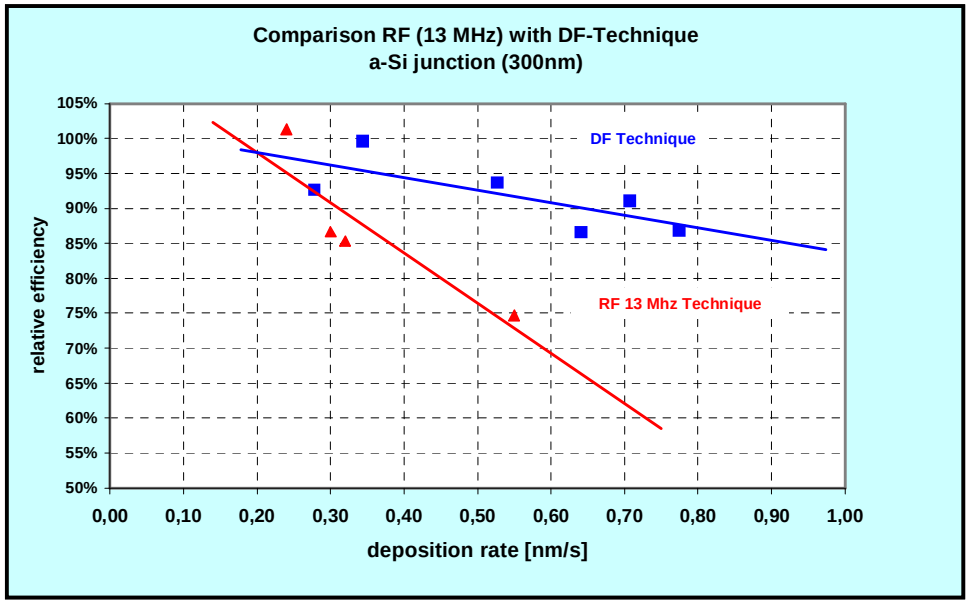
Results for a-Si (1400mm * 1100mm substrate)

- higher efficiencies at high deposition rates (2*times higher)
- same uniformity than 13.56 MHz process



	50	150	250	350	450	550	650	750	850	950	1050
50	473	478	481	482	482	483	484	481	480	476	471
150	473	483	487	488	496	497	498	496	493	485	478
250	482	495	501	503	503	507	510	513	512	500	484
350	486	502	507	509	510	517	521	521	520	508	487
450	491	507	512	514	517	518	522	523	523	513	493
550	493	506	510	513	516	523	524	524	524	513	494
650	491	503	508	511	513	523	524	524	524	515	496
750	489	500	503	504	509	521	525	524	524	518	496
850	490	498	500	498	505	519	523	523	524	518	496
950	489	494	496	494	493	510	515	518	521	512	494
1050	487	489	492	491	492	505	511	513	517	508	497
1150	485	487	488	488	491	497	505	509	510	503	494
1250	480	489	488	487	493	496	499	503	504	496	483
1350	476	482	487	491	500	504	504	501	498	484	479

	1	2	3	4	5	6	7	8	9	10	11
	50	150	250	350	450	550	650	750	850	950	1050
50	651	649	634	632	626	641	658	674	667	646	628
150	644	657	666	666	657	633	627	627	636	642	643
250	653	675	679	668	660	650	637	627	631	628	634
350	630	659	658	640	646	648	640	627	637	646	648
450	651	641	631	649	667	674	657	639	648	652	631
550	652	636	636	664	669	662	654	640	635	634	626
650	651	628	647	662	672	671	671	654	633	637	626
750	645	628	656	655	653	662	664	642	635	648	626
850	644	630	659	651	639	651	647	626	629	637	635
950	626	641	683	668	640	655	643	628	627	636	650
1050	647	670	688	669	650	660	633	630	641	634	651
1150	661	686	678	659	652	649	631	634	645	647	646
1250	657	668	664	675	659	643	644	654	674	644	641
1350	663	683	699	659	641	654	675	666	661	655	645

13.56 MHz	13.56MHz + 27.12 MHz
2,8%	Standard deviation **2,4 %**

Basic procedure of chamber cleaning

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Regular chamber cleaning to guarantee stable production

Others:

- cleaning after each deposition
- hazard mechanical cleaning

Leybold Optics:

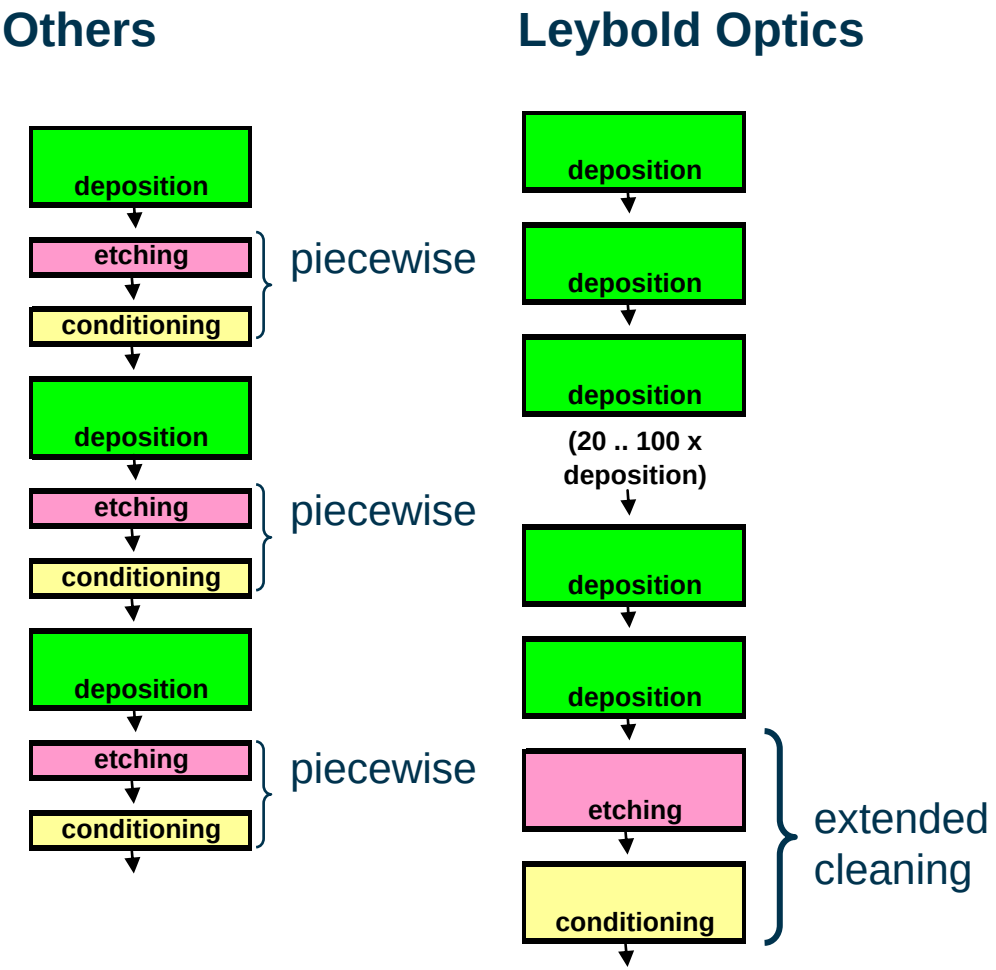
- cleaning after several deposition cycles

Advantages:

- reduced total cleaning time
- better HF-gas pumping
- effective conditioning

> **higher throughput**

stable processes



New cleaning process: “Green process” using F_2

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What happens if the use of NF3 is banned?

Switch to F_2? → **Yes!**

Toxicity matter:

Either low % mixtures or on-site generation (e.g. available from Linde*) is a proven safe and reliable supply mode.

Up to 20% F_2 dilution in N_2 or Ar is easier handable

Possible activation of F2 (20%):

remote plasma system

or

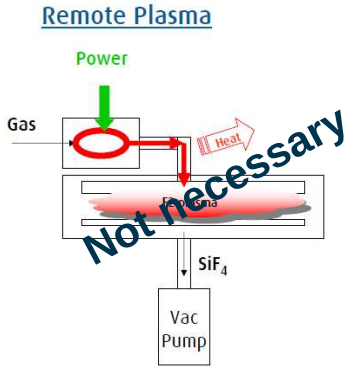
thermal activation

Clean Gas	Atmospheric Lifetime (years)	Global Warming Potential $(GWP)_{100}$
CF_4	50000	6500
C_2F_6	10000	9200
C_3F_8	2600	7000
SF_6	3200	23900
NF_3	740	17200
F_2	0	0

NF_3 and SF_6 on 2007 ITRS Chemical Restrictions Table

Comparison of Toxicity of Electronic Gases	
Gas TLV/TWA[1]	(ppm)
Arsine	0.05
Diborane	0.1
ClF_3	0.1
Germane	0.2
Phosphine	0.3
Fluorine, F_2	1
HF	3
Silane	5
NF_3	10
CO	25

Note 1: TLV/TWA is defined as Threshold Limit Value/Time-Weighted Average. It is the maximum permitted workday exposure recommended by the ACGIH.



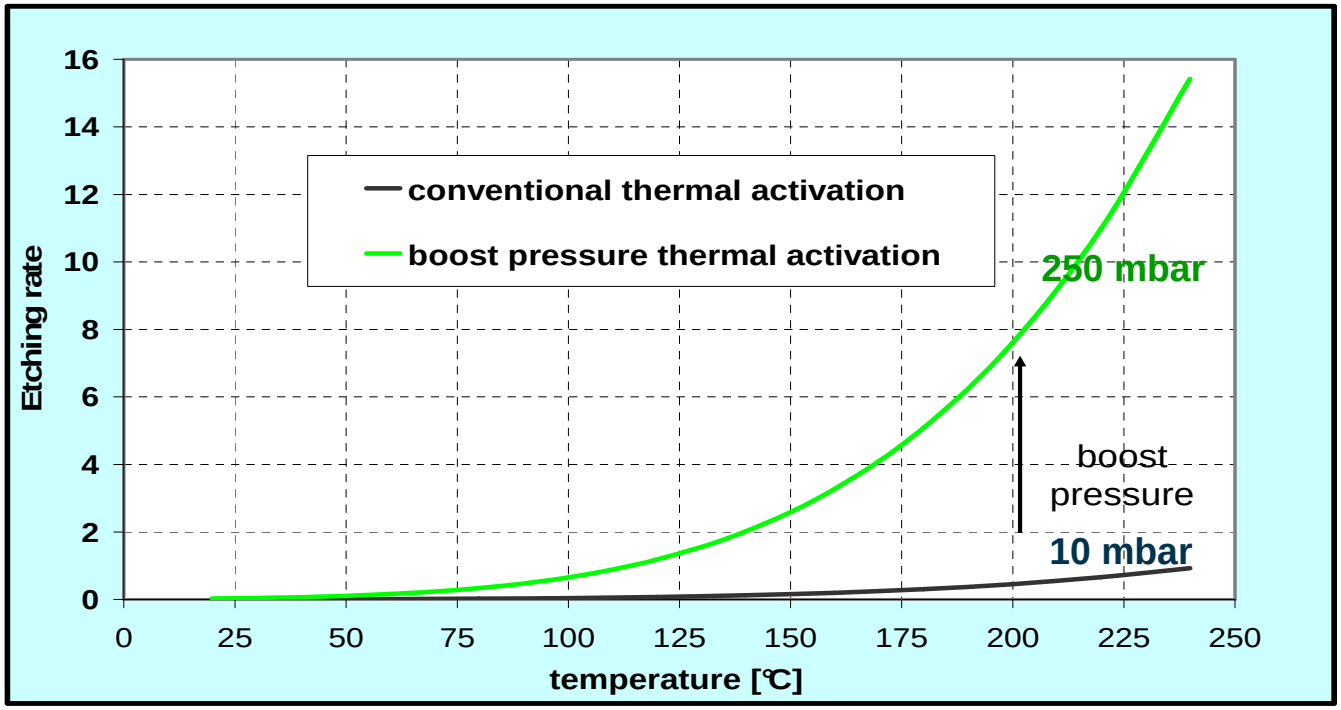
*(see also poster session)

New cleaning process: “Green process” using F2

LEYBOLD OPTICS

We developed *boost pressure thermal activation (BPTA-)* process* because:

- **thermal activation**
- **more reliable than remote plasma (simple thermal principle)**
- **less energy consuming**
- **less hardware necessary (RPS)**



*patent pending

New cleaning process: “Green process” using F2

LEYBOLD OPTICS

Advantages of boost pressure thermal activation (BPTA-) process*

- highly efficient cleaning process (F2 utilization >95%)
- “soft” process avoiding highly excited species
- more homogeneous process and therefore shorter “over-etching time” required
- cleaning /deposition rate > 15
- “green process”
- cost less than NF_3 process

*patent pending

PECVD: The Linear Cluster Tool „ Phoebus©“

LEYBOLD OPTICS

Process Challenge

- Uniform layers over thickness
- Uniform deposition
- Quality µ-Si Layer
- Adaptable to customers TC process

- High rates without sacrificing efficiency
- Stable, reproducible process

Advantage Phoebus

- Linear cluster single stage process
- Excellent electrode design
- Excellent process control
- Fast, flexible µ-Si adoption to customers TC process
- Innovative Dual Frequency technology
- In-situ plasma cleaning with NF_3 as well as F_2 / N_2

Summary

LEYBOLD OPTICS

Advanced process & design for economic high throughput PV manufacturing

- Economic PVD processes
- Advanced PECVD system
  - Rate improvement without sacrificing efficiency
  - Economic cleaning technology (F_2/N_2)
  - Flexible for new or/and additional layer implementation

Economic high throughput equipment is optimum basis for superior production