HERCULES

HIGH EFFICIENCY REAR CONTACT SOLAR CELLS AND ULTRA POWERFUL MODULES

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5th Silicon PV – HERCULES project Workshop

HERCULES – EC funding

Programme: FP7-ENERGY-2013-1

In this theme determined for the Community action, the overarching aim is to: - research activities carried out in different forms of trans-national cooperation in different forms across the European Union and beyond, and address major challenges confronted by energy systems; - adapt the current fossil-fuel-based energy system into a more sustainable one, less dependent of imported fuels, based on multiple and in particular renewable and non-polluting energy sources and carriers. Emphasis will be placed on developing less- and non-CO2 emitting energy technologies and on enhancing energy efficiency by rationalising use and storage of energy. The pressing challenges of energy supply security and climate change will be adressed, whilst increasing the competitiveness of Europe's energy industries.

Subprogramme: ENERGY.2013.2.1.1 - High efficiency c-Si photovoltaics modules

Record Number: 110845

Project overview

- HERCULES: **H**igh **E**fficiency **R**ear **C**ontact solar cells and **U**ltra powerful modu**LES**

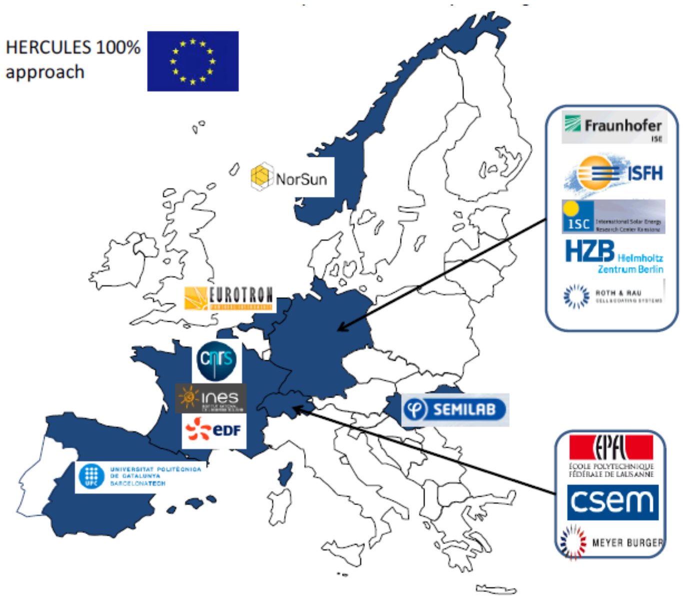
- Gran agreement: **FP7-ENERGY-2013-1 608498**

- Project duration: **36 months (01/11/13-30/09/2016**)

- Budget: **10,263,640.77 €**

- EC contribution: **7,000,000.00 €**

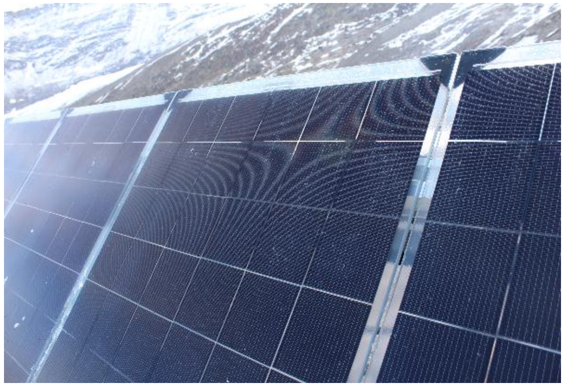
- **16 partners** from 7 countries



HERCULES concept

- Develop innovative n-type monocrystalline c-Si device structures based on back-contact solar cells with alternative junction formation, as well as related strutures including hybrid concept (homo-heterojunction)

- The HERCULES strategy is to transfer the developed processes to the industrial scale by considering all major cost drivers of the entire manufacturing process chain of modules



Consortium

	Institute/Company	Country	Role
1	CEA - INES	France	Coordinator, IBC HET solar cells and module fabrication
2	Fraunhofer ISE	Germany	HET, IBC development
3	ISC Konstanz	Germany	IBC solar cells and modules, pilot line and characterisation
4	EPFL	Switzerland	HET development
5	CSEM	Switzerland	HET development
6	ISFH	Germany	implantation and IBC solar cells
7	Helmot-Zentrum Be	Germany	characterization and HET solar cells
8	CNRS	France	characterisation and simulation
9	UPC	Spain	new laser processes
10	MB	Germany	HET pilot line production
11	Roth & Rau AG	Switzerland	HET pilot line production
12	Norsun AS	Norway	materials for high efficiency
13	EDF	France	costs and industrialization
14	Eurotron BV	Netherlands	module fabrication
15	Semilab ZRT	Hungary	characterization
16	ALMA CG	France	Administrative support and coordination

Objectives

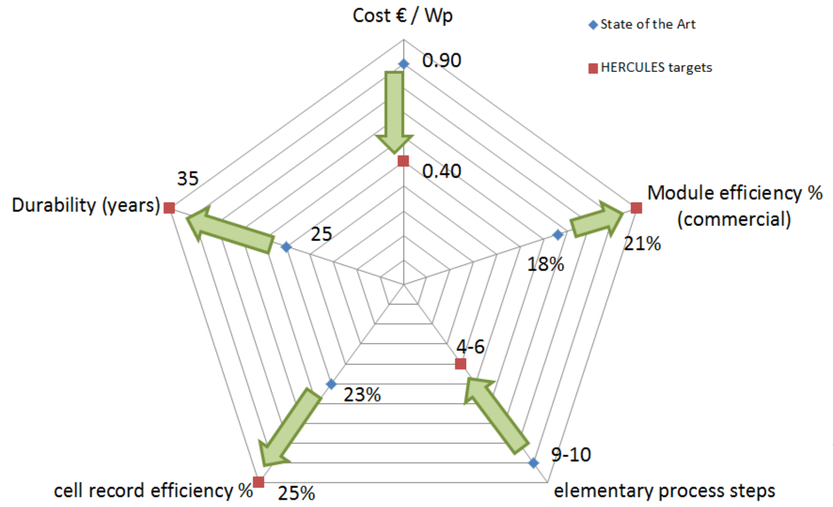
The key objectives of the HERCULES project are to:

1) Develop ultra-high-efficiency (η > 21%) modules at the pilot line scale

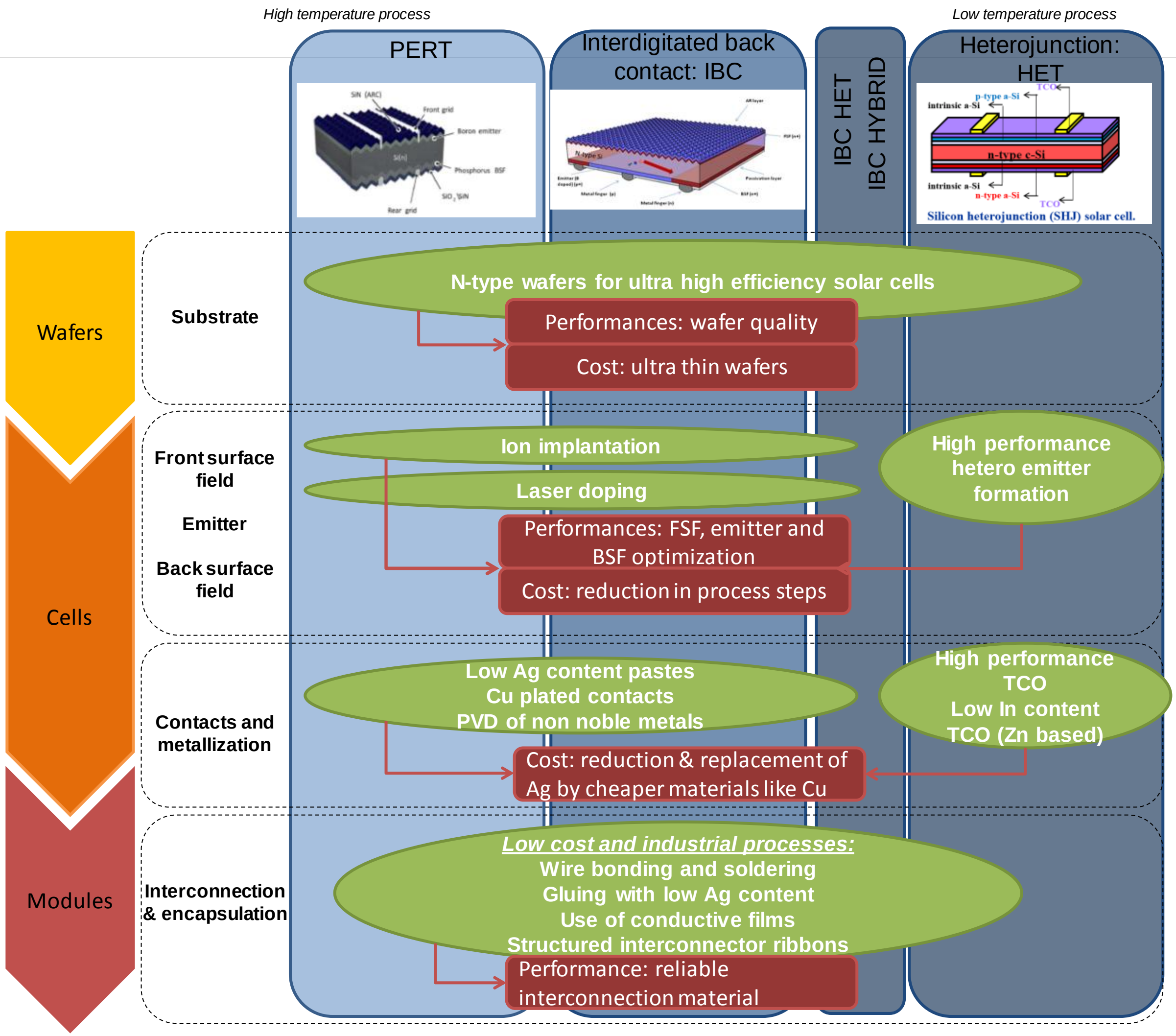
2) Reduce production and investment complexity and demonstrate costs of 0.4 €/Wp at a 500 MW/year commercial plant level

3) Increase the lifetime of modules up to 35 years

4) Demonstrate ultra-high-efficiency solar cells with η > 25%

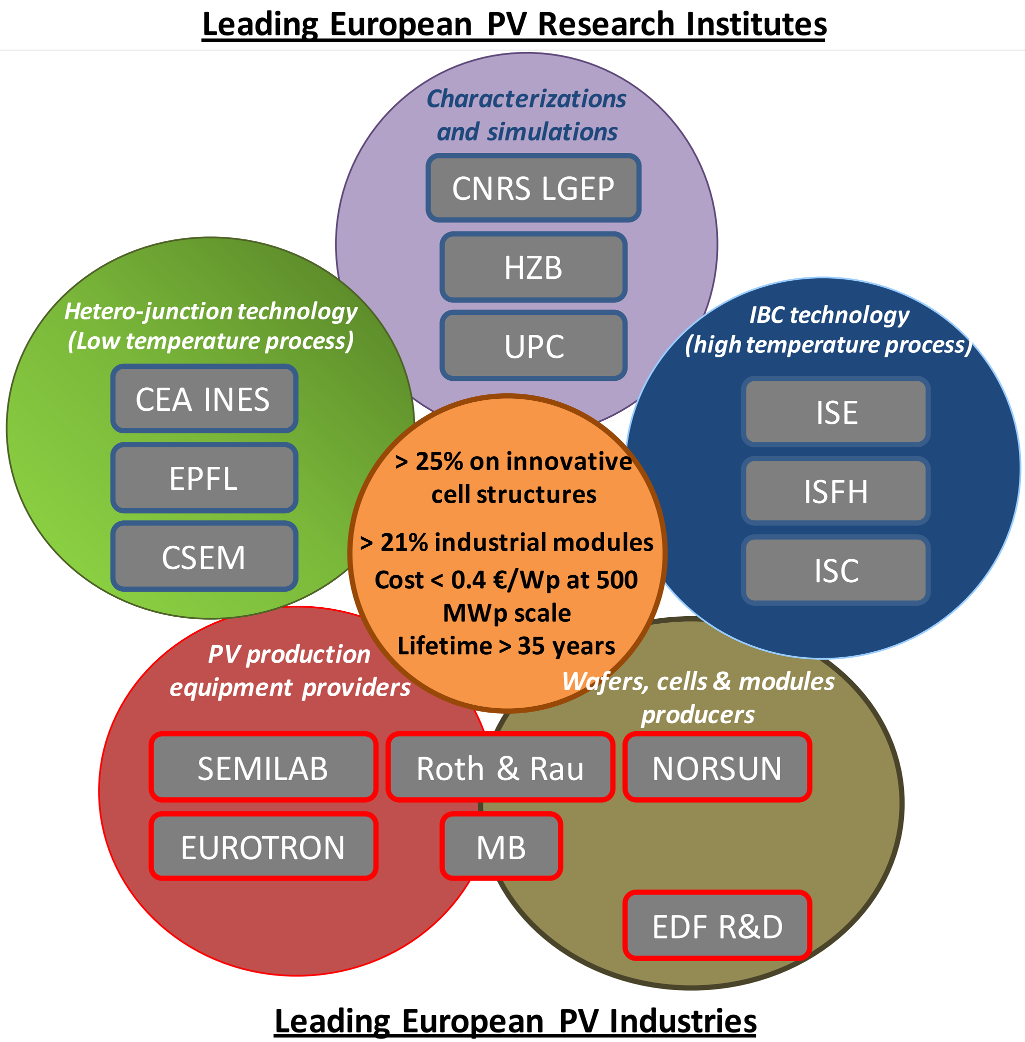


HERCULES work

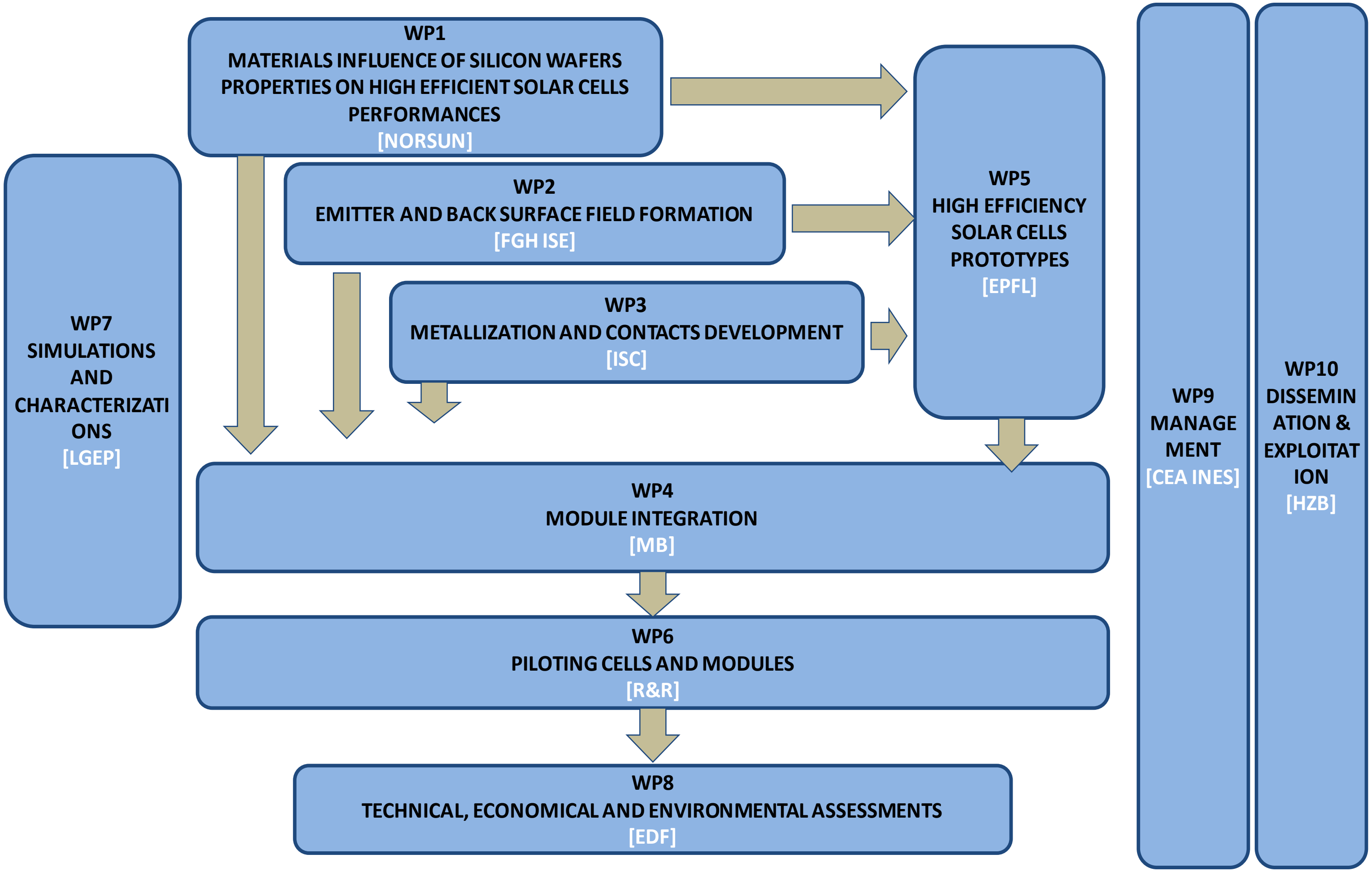


HERCULES

HERCULES synergies



Description of work

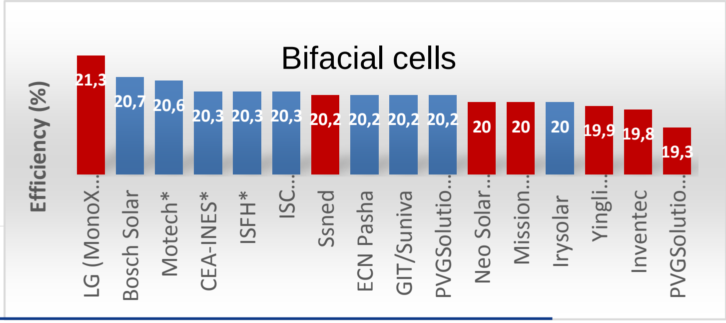


State of the art low cost PERT n-typec-Si cells

As it was in 2012…

Institute/Industry	Technology	Efficiency (%)	Surface (cm^2)	HERCULES
Q-cells	BBr3	19.8	243	No
SUNIVA (Georgia Tech)	Implant	19.8	239	No
Ying -li	BBr3	19.9	239	No
PVGS	BBr3	19,6	239	No
BOSCH Solar	BBr3	20.1	239	No
ECN	BBr3	20.0	239	No

State of the art n-type



As it is now…

Institute/Industry	Technology	Eta (%)	Surface	HERCULES
Q-cells	Rear emitter + PVD FAR	21.3	239	no
LG	MonoXNeon implanted	21,3	239	no
PVGS	Bifacial (19.4% prod) BSF selective	20.2	239	no
Tetrasun/First Solar	Bifacial plated	21	148	no
ISE	**PassDop (passiv FAR a-Si:H)**	**21.3**	**4**	**yes**
	Rear Tunnel ox + poly Si « Topcon »	**24.4**	**4**	**yes**
IMEC	Rear B emitter Cu-plated	22	239	no
ISFH	**PERT - bifacial**	**20.5**		**yes**
Motech	PERT - bifacial	20.6	239	no
ECN	Pasha (bifacial) Ag <70mg	20.2	239	no
CEA-INES	**PERT - bifacial**	**20.3**	**239**	**yes**
ISC	**PERT – bifacial BiSoN**	**20.5**	**239**	**yes**

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State-of-the art IBC/IBC HET cells

As it was in 2012

Institute/Industry	Technology	Efficiency (%)	Surface (cm^2)	HERCULES
Sunpower/TOTAL	IBC/Cu	24.2	243	no
ANU	IBC	24.6	4	no
IMEC	IBC/Cu	23.3	4	no
ISE	**Back-contacted back-junction**	**23**	**4**	**yes**
ISFH	**IBC**	**22.3**	**239**	**yes**
ISC	**IBC ZEBRA**	**21**	**243**	**yes**
SHARP	IBC HET	24.7	1	no
LG	IBC HET	23.4	4	no
HZB-ISFH	**IBC HET**	**20.2**	**1**	**Yes**
CEA-INES	**IBC HET**	**19**	**25**	**yes**

State-of-the art IBC/IBC HET cells

As it is now…

Institute/Industry	Technology	Efficiency (%)	Surface (cm²)	HERCULES
Sunpower/TOTAL	IBC/Cu	25	121	no
ANU	IBC	24.6	4	no
IMEC	IBC/Cu	23.3	4	no
ISE	**Back-contacted back-junction**	**23**	**4**	**yes**
ISFH	**IBC**	**22.3**	**239**	**yes**
ISC	**IBC ZEBRA**	**21.5**	**243**	**yes**
PANASONIC	IBC HET	25.6	143	no
SHARP	IBC HET	25.1	1	no
LG	IBC HET	23.4	4	no
EPFL-CSEM	**IBC HET**	**22**	**9**	**yes**
HZB-ISFH	**IBC HET**	**20.2**	**1**	**yes**
CEA-INES	**IBC HET**	**20**	**25**	**yes**

State of the art: Heterojunction cells

As it was in 2012…

Institution	η [%]	area [cm^2]	HERCULES
Panasonic Solar (Japan)	23.7	**100, Cz**	No
Kaneka (Japan)	23.5	**~90**	no
CEA INES (France)	22.2	**105, FZ**	yes
EPFL (Switzerland)	22.1	**4, FZ**	yes
Roth and Rau (Switzerland)	22	**4, Cz**	yes
Hyundai (Korea)	21.1	**220**	no
CIC Solar (Japan)	20	**243, Cz**	no
HZB (Germany)	19.8	**1, FZ**	yes

State of the art: Heterojunction cells

As it is now

Institute/company	Efficiency (%)	area (cm2)	HERCULES
Panasonic	24.7	100; thickness 98mm	no
Kaneka	24.2	171	no
Choshu	24.1	156PSQ grid touch bus bar less	no
AUO	23.1	240	no
SILEVO	23.1	240	no
R&R MB	**22.8**	**240**	**yes**
CSEM	**22.8**	**156PSQ grid touch bus bar less**	**yes**
CEA - INES	**22.8**	**239**	**yes**
EPFL	**22.4**	**4**	**yes**

Strategic impact

- **Solutions going well beyond the state of the art in terms of investments costs (target below 1 €/Wp) and efficiency targets at module level η > 21% on mono c-Si**

Currently, manufacturing/investments costs for c-Si modules are in the range of 0.8-1.0 €/Wp depending on the technology. We mentioned in section 1.1 the specific case of China selling at 0.6 € /Wp which is below production costs, and represents a very aggressive strategy in order to compete with the other technologies especially on the European market.

The target of the project is to demonstrate a cost down to 0.4 € / Wp (in a 500 MWp scale scenario) and therefore a reduction of 30% to 50% while keeping high performances of c-Si modules outputs over 21% on mono c-Si at the pilot scale. In other words, using innovative and high potential cell structures, HERCULES will demonstrate ultra-high efficiency by producing modules of power outputs > 320 Wp at the end of the project.

Another objective will be to demonstrate cell prototype of η > 25% on small areas in order to pave the way for the future ultra high efficient generations of c-Si solar cells.

Strategic impact

- **Stimulation and acceleration of the industrial take-up of promising results beyond laboratory scale**

The scientific developments carried out in HERCULES will benefit from the strong academic-entreprise collaboration capitalizing on existing initiatives. Companies like Roth & Rau already developed pilot scale for the manufacturing of c-Si solar cells & modules. Their participation along with the contribution of leader manufacturing equipment providers (EUROTRON, MB) will ensure a fast transfer of lab results towards industrial take up. Furthermore, as introduced in section 1.1, the European Photovoltaic industry cannot afford leaving promising R&D results at the lab scale: selling more competitive and performing devices are the key for them to remain in the lead of the PV worldwide race.

- **New competitive industrial processes**

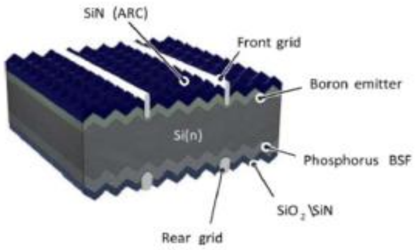
The learning curve of device efficiency vs investments costs is reaching its limits: technological breakthrough such as the novel cells architectures developed on manufacturing processes proposed by HERCULES are needed in the current PV industry paradigm. The development of high performance solar cells is only worth if the process can be easily up-scaled and transferred to pilot line for the development of future competitive industrial processes.

The HERCULES strategy includes the transfer towards industrial processes very early on in the manufacturing process of ultra-high efficient solar cells. The technological “boxes” have been chosen for their industrial friendliness and the demonstration is illustrated by the existing close collaborations of Research Institutes with the project industrials.

Strategic Research Agenda for Photovoltaic Energy

HERCULES will also greatly contribute to the roadmap objectives set by the SRA by 2016:

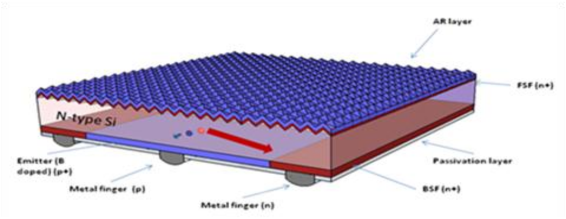
- **Materials :**



Manufacturing aspects: decreasing wafer thicknesses (< 100 µm) will positively impact the material use for a given generated power. Moreover, a reduction of 30% in diamond wire costs is targeted leading to lower material cost and consumption.

Technology aspects: promote the take up of n-type substrates for high efficiency devices with high quality/low defect (average carrier lifetime τ > 10 ms), improved wafering process, low costs adhesives and easy interconnection solutions (back contact modules)

- **Devices:**



Manufacturing aspects: industrial processes for ultra high efficiency module η > 21% (mono c Si n-type)

Technological aspects: module lifetime > 35 years, low costs and easy metal contact processes, improved device interconnection (Icell to module loss < 1% abs)

Scientific aspects: innovative hybrid cells and modules structures leading to ultra high efficiency

Strategic Research Agenda for Photovoltaic Energy

- **HERCULES will contribute to the achievements of the global goals set by the SET2020 initiative**
    - reduction of 20% of GHG emissions vs 1990 level
    - renewable energy represents 20% of the energy mix by 2020
    - reduction of overall energy consumption of 20% by 2020
- **The objective is to reach 12% of produced electricity by solar energy by 2020 and this implies a readily reduction of the cost of solar PV energy (LCOE) to align with the other existing sources of electricity and gain competitiveness.**
- **Other impacts will contribute to the energetic independency of Europe which is strategic especially when industry needs are concerned.**

Thanks for your attention!