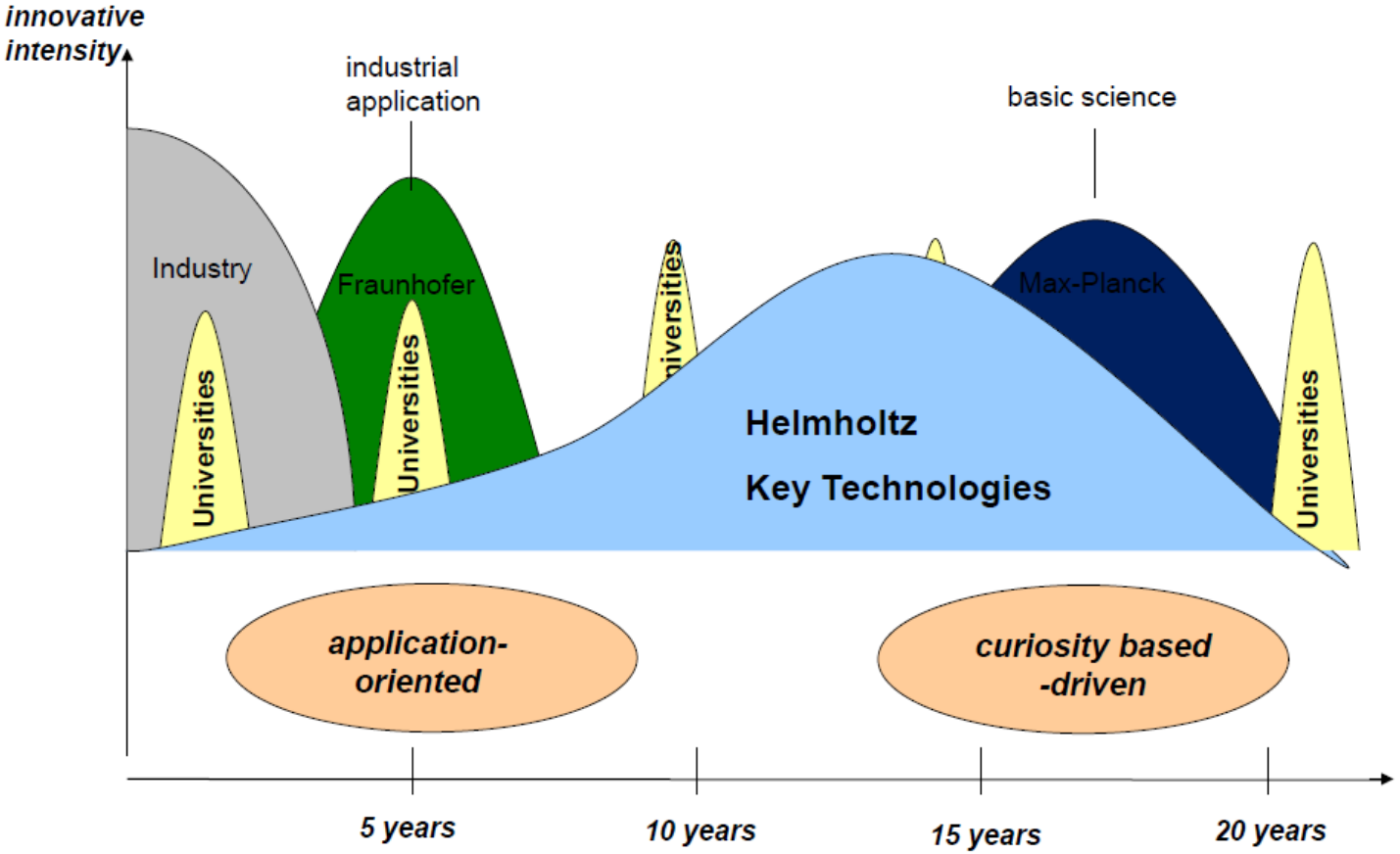
RESEARCH CENTER JÜLICH GMBH, JÜLICH, GERMANY
INSTITUTE OF ENERGY AND CLIMATE RESEARCH 5 – PHOTOVOLTAICS

INNOVATION IN THIN-FILM MATERIAL AND PROCESSING FOR SILICON SOLAR CELL

25.02.2019 K.DING, A.LAMBERTZ, W.DUAN, M.POMASKA, A.GAD, K.BITTKAU

RESEARCH IN GERMANY



RESEARCH CENTER JUELICH

JÜLICH Forschungszentrum

Finance

- Budget: 550 Mio. €
- Third Party: ~ 190 Mio. €

Personnel

- Staff: 5.800
- >890 PhD students

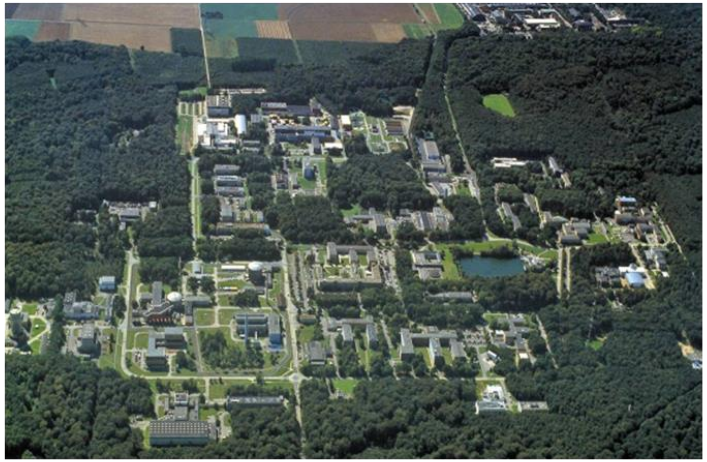
Scientific Output

- 2.100 articles/year

Research Area

- Energy and Climate
- Information and Brain
- Key technologies

HELMHOLTZ ASSOCIATION



IEK-5 PHOTOVOLTAICS

Research groups: 6

Staff: ~100

Helmholtz

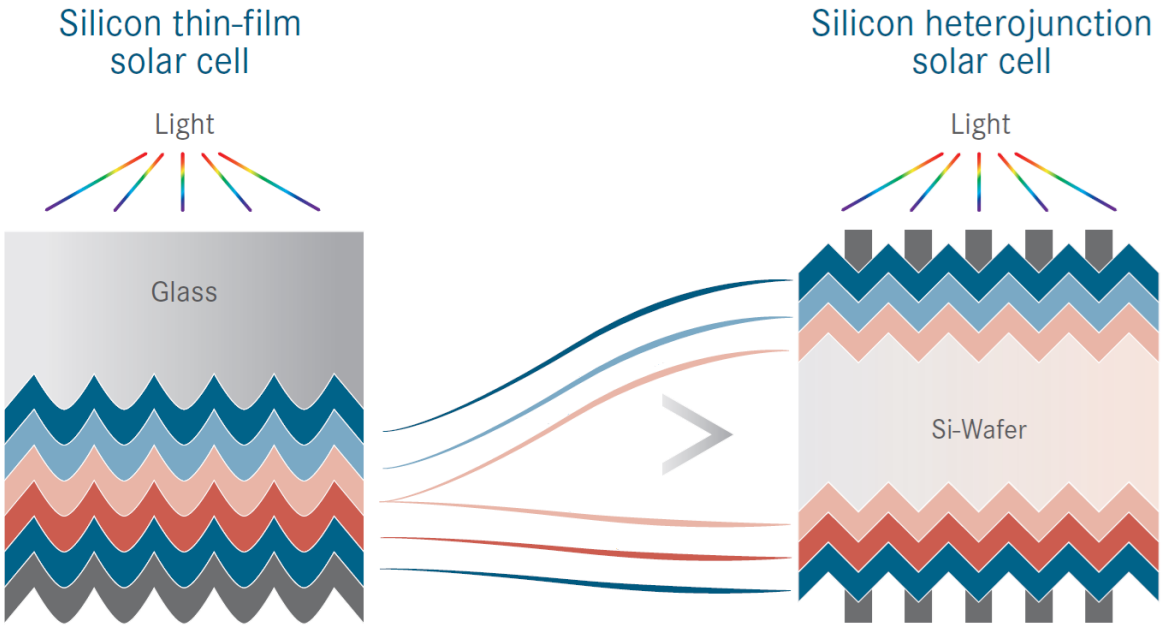
RC Jülich

IEK-5 PV

MOTIVATION SHJ

Silicon thin-film „DNA“ at IEK-5

- Si thin-films
- Si alloys
- TCO films
- Multijunction
- Light management
- Laser processing
- …

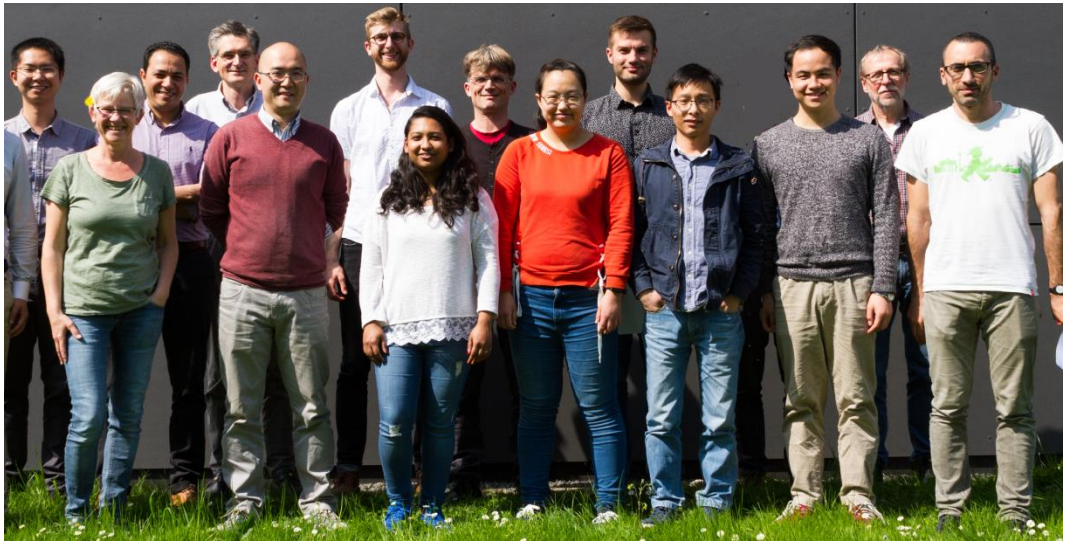


Key expertise is application of novel material and process in SHJ solar cells

SHJ (c-Si) GROUP

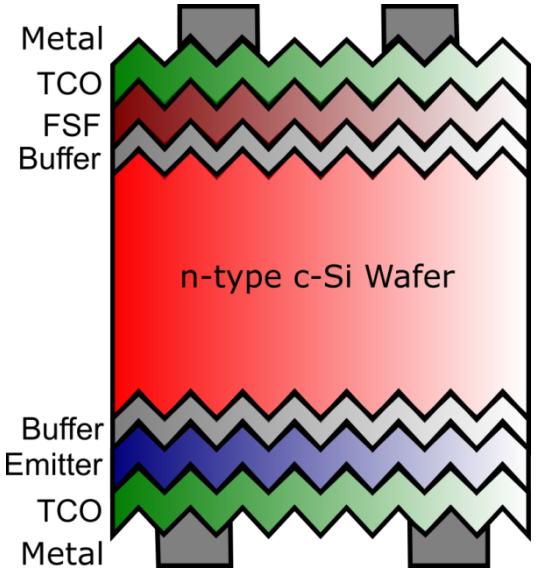
Main collaborator for c-Si activities

- Establishing a baseline for industrial sized (156 x 156 mm²) SHJ solar cells
- Establishing a baseline for silicon solar modules for vehicle integrated PV
- Establishing a process and characterization standard for passivated contact solar cells
- Application of silicon alloys and HWCVD processes in SHJ solar cells



DEVICE TYPE

„Rear emitter M2 size SHJ solar cell



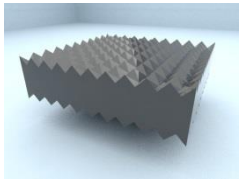
- µc-Si:H and µc-SiOx:H etc.
- IWO, ITiO, AZO etc.
- Smartwire
- Thin wafers (<40 µm)
- Pero-Si-Tandem

SILICON HETEROJUNCTION BASELINE

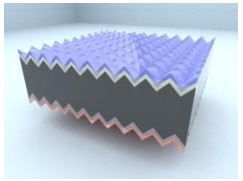
For industrial sized SHJ solar cells

JÜLICH Forschungszentrum

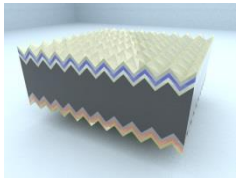
STEP 1 Wafer pretreatment



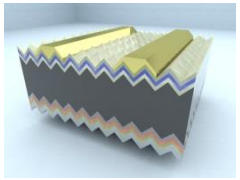
STEP 2 Silicon deposition



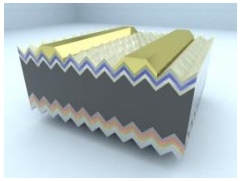
STEP 3 TCO sputtering



STEP 4 Silver screen printing



STEP 5 Cell characterization

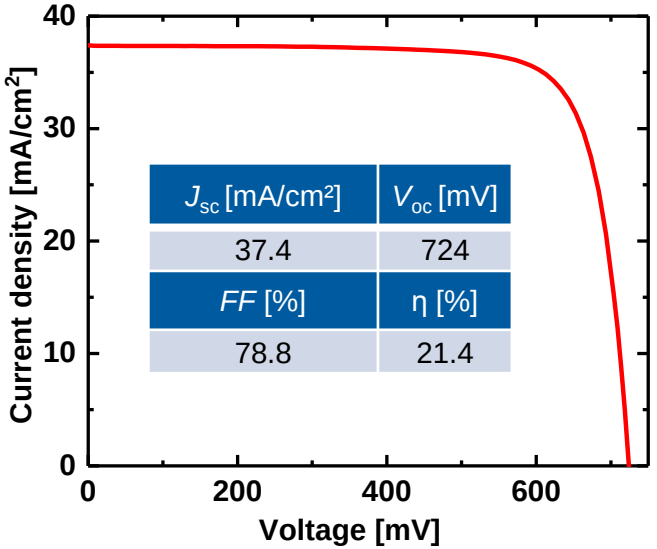


SILICON HETEROJUNCTION BASELINE

For industrial sized SHJ solar cells

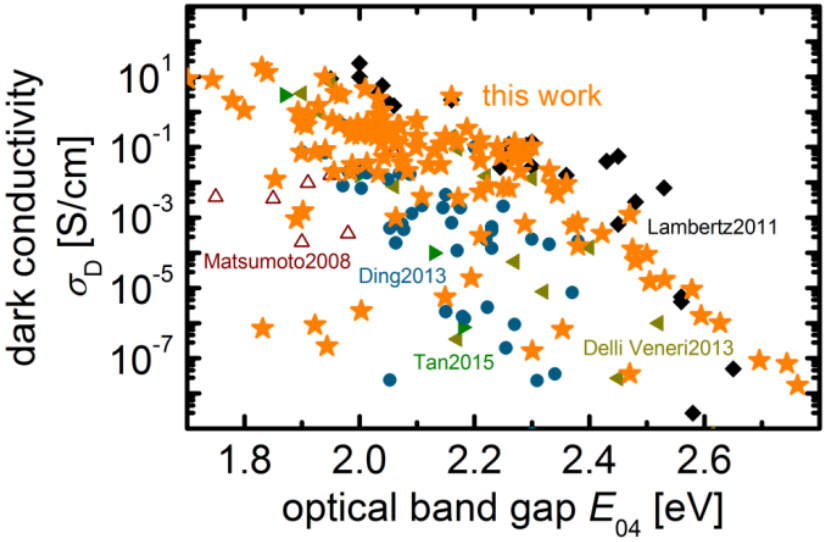
- High solar cell efficiency
- Reproducible and homogeneous process
- High throughput
- Fast feed back
- Industrial scalable tools
- Established platforms

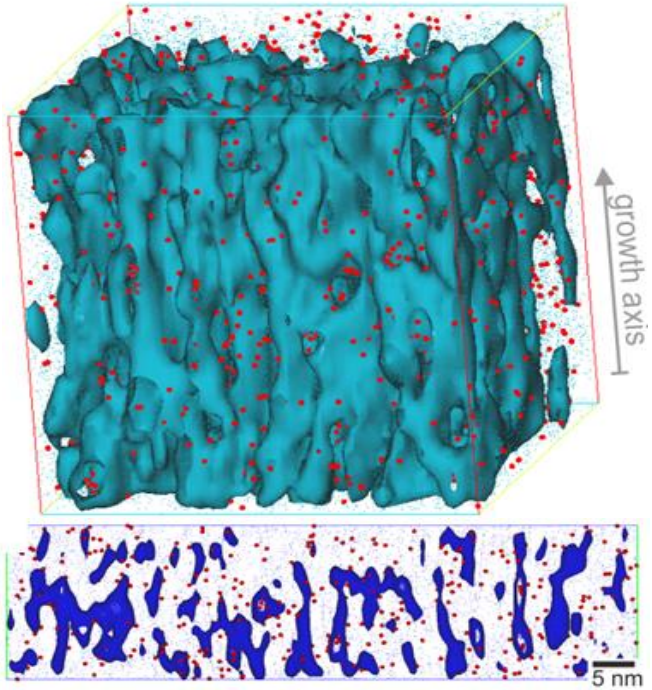
→ Test materials and processes for η > 25%



NANOCRYSTALLINE SILICON OXIDE

Transparent and conductive window layer



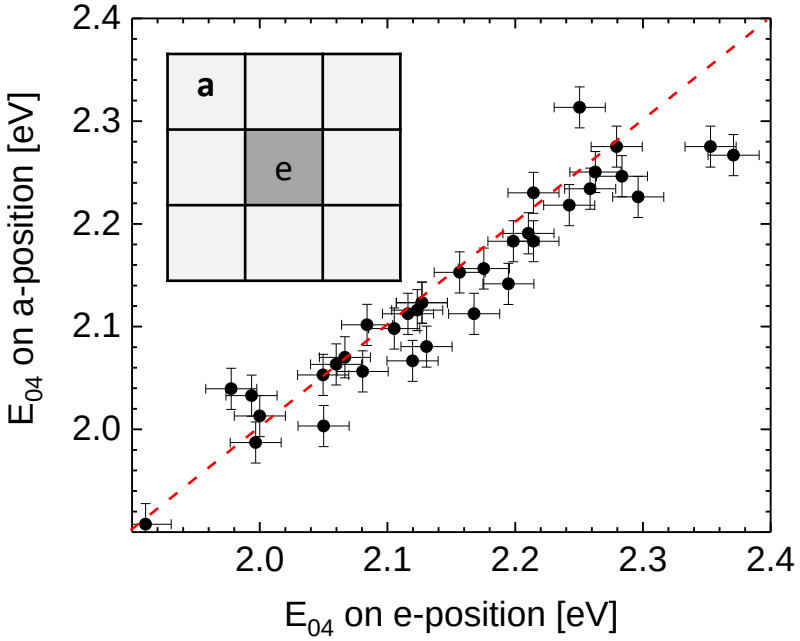


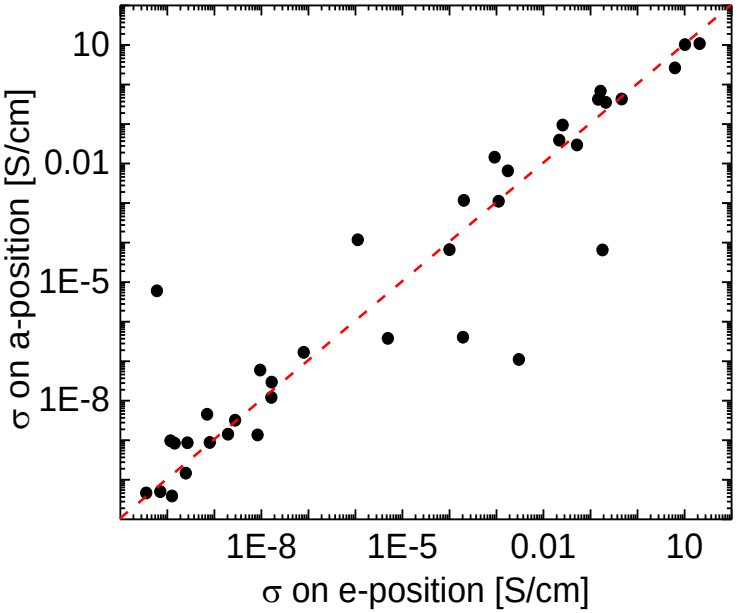
- Deposited by PECVD, both n- and p-type possible
- Industrial compatible/transferable process
- Fully compatible with SHJ solar cell technology

A. Richter, et.al. (2017) Sol. Energy Mater. Sol. Cells, 174, 196–201.

NANOCRYSTALLINE SILICON OXIDE

Good uniformity of material properties





VEHICLE INTEGRATED PV

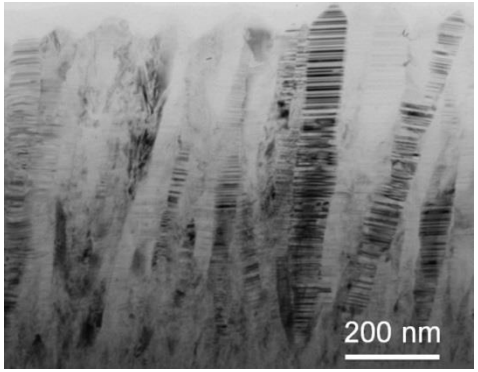
SHJ solar cell for integration in automobile industry

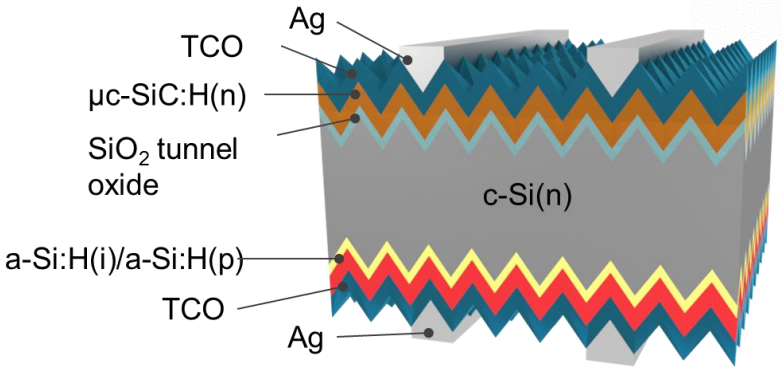
New aspects on cell requirement:

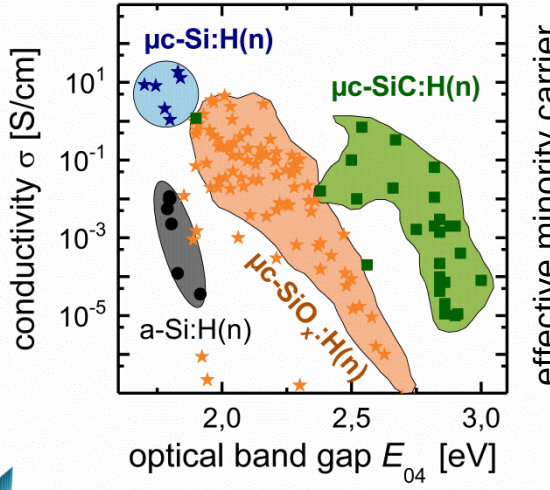
- High demand on aesthetics
- Flexibility in cell size required

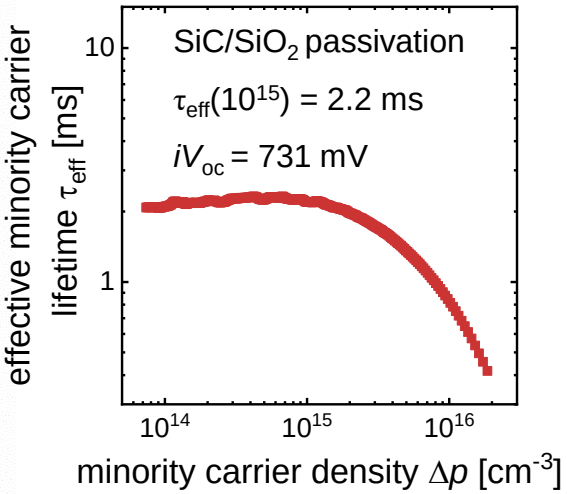
MICROCRYSTALLINE SILCON CARBIDE

Transparent and low-T passivated contact





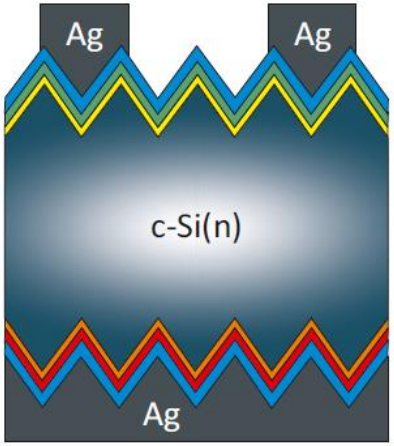




- Deposited by HWCVD
- Low-T process compatible with SHJ
- Highly transparent SiO_2/SiC stack
- High passivation quality

M. Pomaska, et.al. (2015) Thin Solid Films, 595, 217–220.

TRANSPARENT PASSIVATED CONTACT



ITO - 70 nm
µc-SiC:H(n)
SiO_2 - 1.2 nm

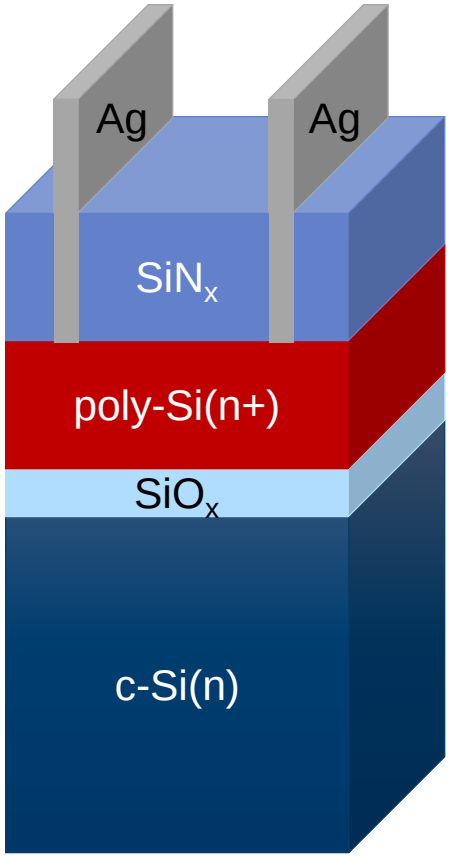
a-Si:H(i) - 10 nm
µc-SiO_x:H(p) - 50 nm
ITO - 70 nm

µc-SiC:H(n)/SiO_2 passivation deteriorated during ITO sputtering
→ iV_{oc} limited
→ J_{sc} decreased

	η (%)	J_{sc} (mA/cm²)	*FF* (%)	V_{oc} (mV)	R_s (Ωcm²)
SiC/SiO_2	19.7	**38.7**	71.5	712	2.1
Ref.	19.9	36.1	75.7	727	1.4

First low-T transparent passivated contact

POLY-SI PASSIVATED CONTACT



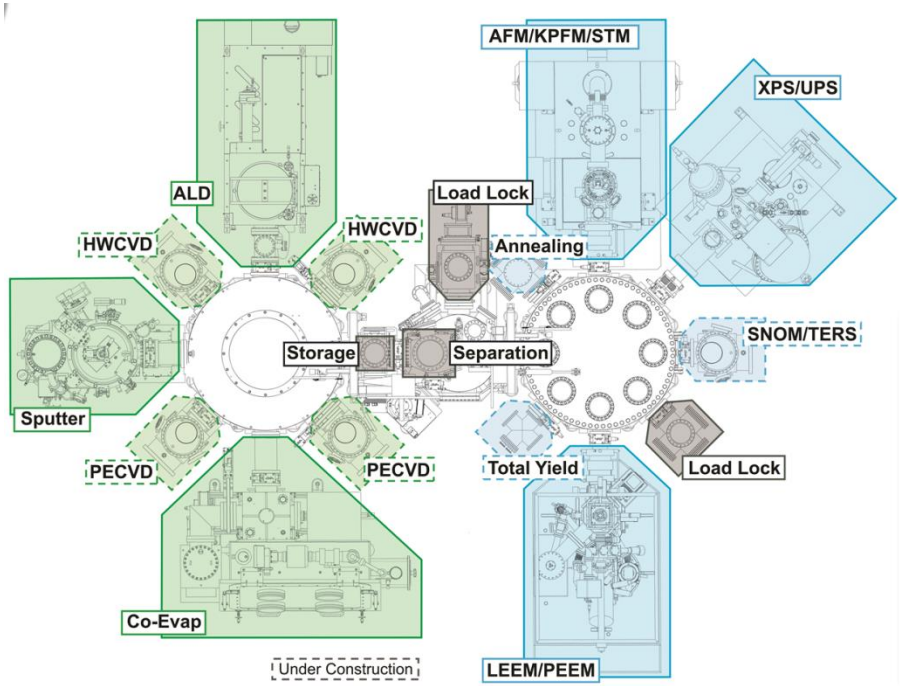
Process chain:

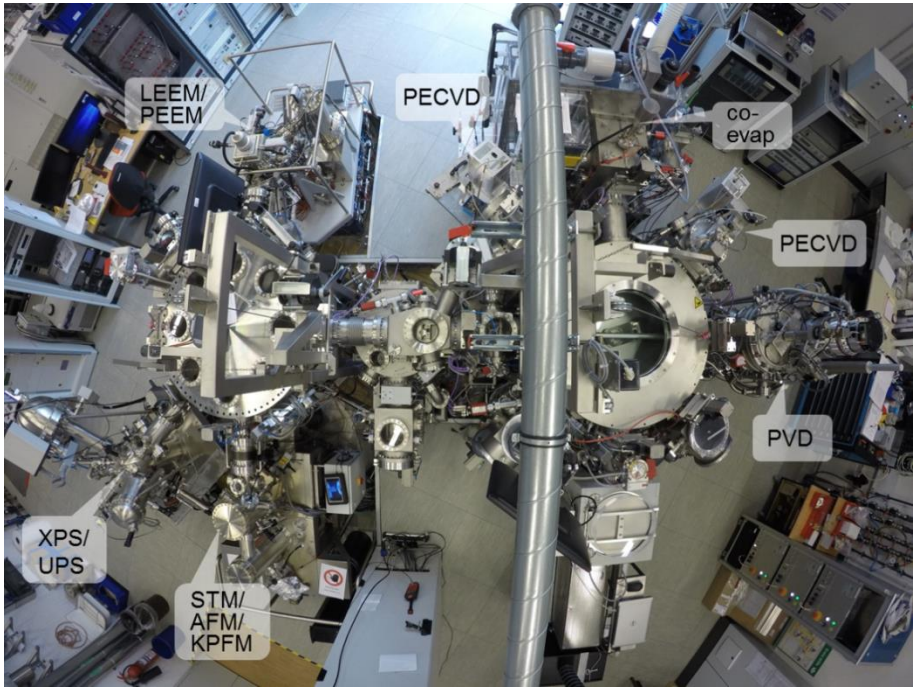
1. growth of ca. 1.5 nm tunnel oxide
2. **HWCVD n-doped layer (Si, SiO SiC)**
3. furnace anneal @ 800-900 °C
4. deposition of ca. 80 nm SiN_x layer
5. Screen print Ag-contacts
6. fire contacts @ 850 °C

Currently best **iV_{oc}: 731 mV** (with **R_{sheet} = 142 Ω$_{□}$** and **deposition rate** of **42 nm/min**

CHARACTERIZATION JOSEPH

Understanding the passivated contact





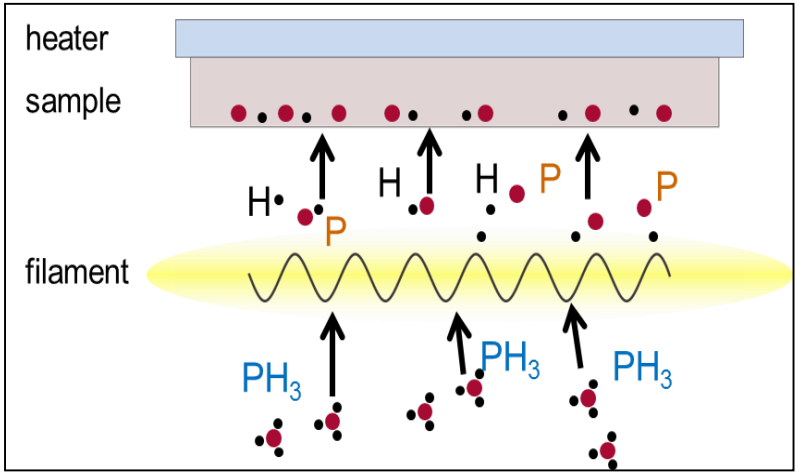
SUMMARY

- Research Center Jülich works on SHJ and Pass. Con.
- Key expertise is thin-film materials and processes for SHJ
- Industrial sized processes
- Unique Si-alloy materials and HWCVD processes

ACKNOWLEDGEMENT

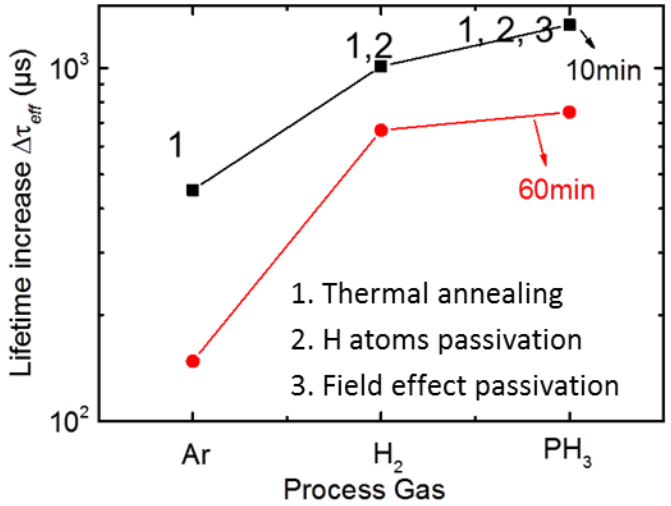
CATALYTIC DOPING

Post deposition treatment for SHJ solar cell



- Good synergy by combining cat-doping and SHJ technology
- Post deposition treatment to engineer the thin-films and the interfaces

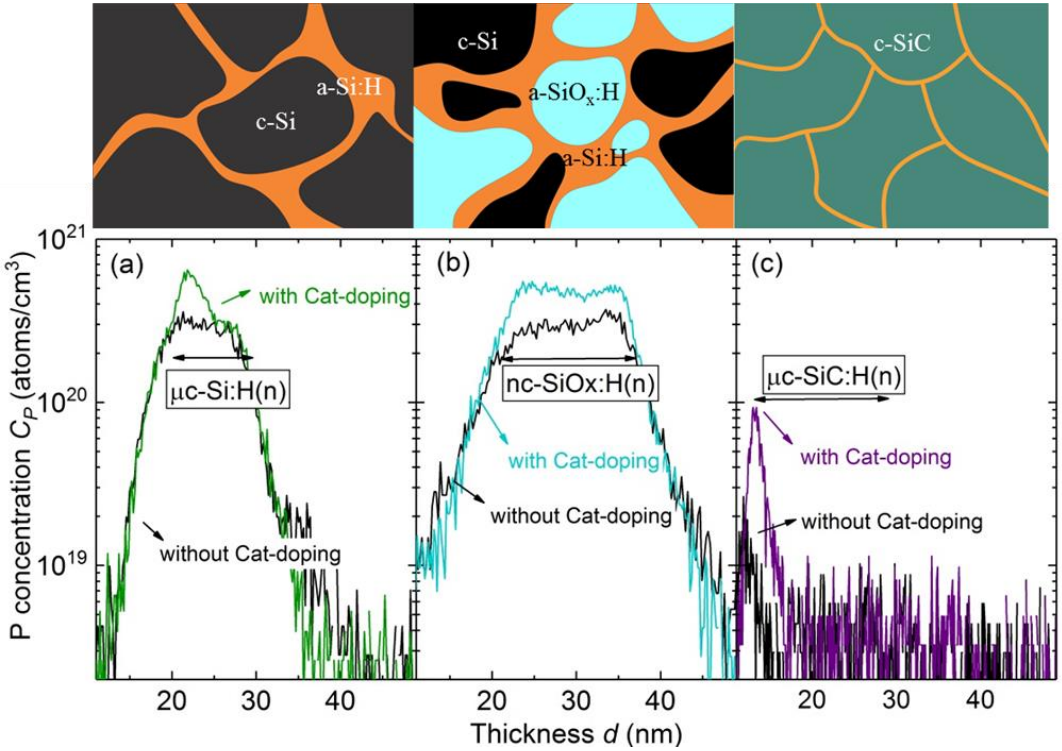
- Increase in P doping (ECV, SIMS)
- Increase in lifetime (QSSPC)
- No impact on optics (PDS)

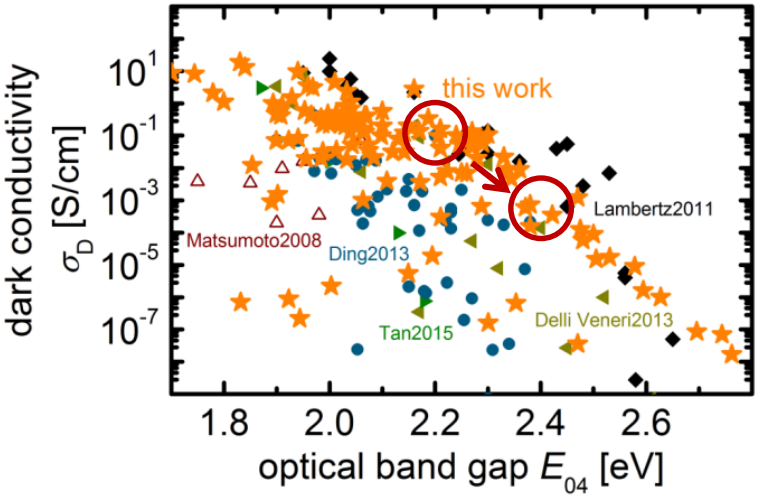


Y. Liu, et.al., (2017) Thin Solid Films, 635, 63–65.

DIFFUSION OF PHOSPHORUS

Doping mechanism and application in cell





+0.3 % absolute