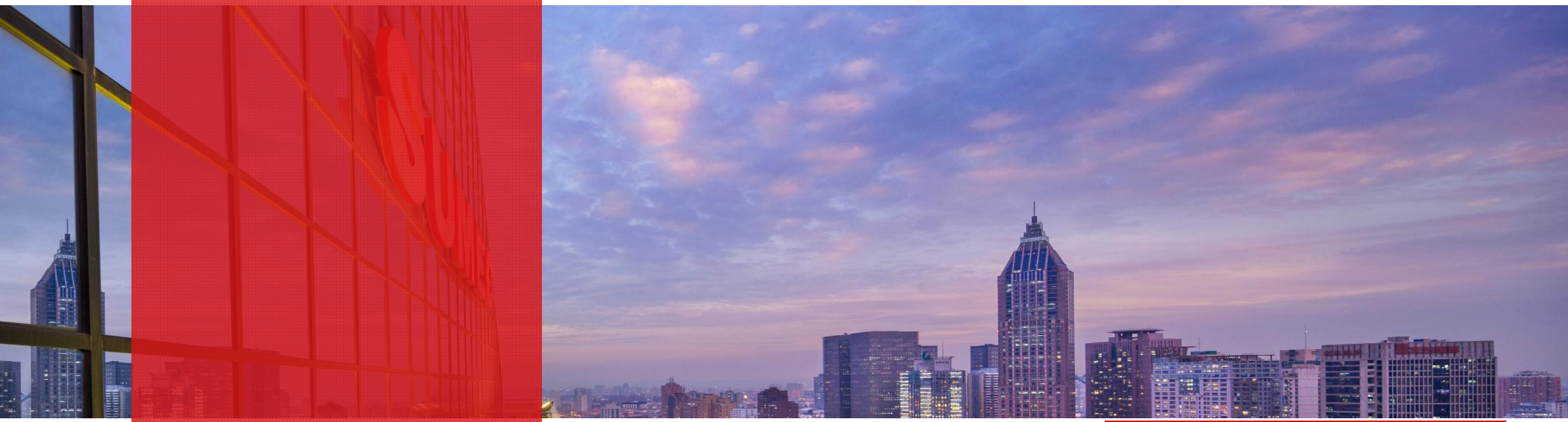
SUMEC
苏美达能源

SUMEC Energy Holdings Co., Ltd.



国机集团 SINOMACH | SUMEC

NANJING . CHINA 2017.03

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苏美达能源

Research and development of advanced photovoltaic technologies at Phono Solar: Black silicon, MWT and SHJ

PART 1
About us

PART 2
R&D Progress

PART 3
PV Plant case

PART 1. About us

- SINOMACH
- SUMEC Group & SUMEC Energy Holdings Co., Ltd.
- SINOMACH New Energy Research Institute

About SINOMACH

国机集团 SINOMACH

- Established **in January 1997**
- **A class** state-owned enterprise
- Fortune Global **500** enterprises
- **180+** overseas branches
- **35.1 billion** USD business revenue
- **Over 120,000+** employees

Core business

About SUMEC

SUMEC

- Established **in 1978**
- A **key member** of SINOMACH
- **Central government-owned** enterprises in Jiangsu province
- **5.7 billion** USD business revenue
- **10,000+** employees

Core business

Trade & service

R&D & Engineering

Investment & development

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About SUMEC

Globalized Industry Platform

About SUMEC


Solar Energy

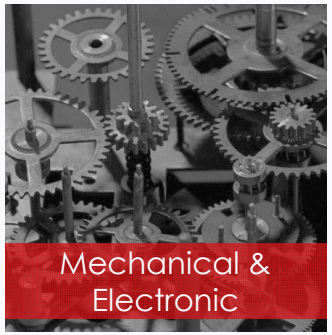

Marine Engineering

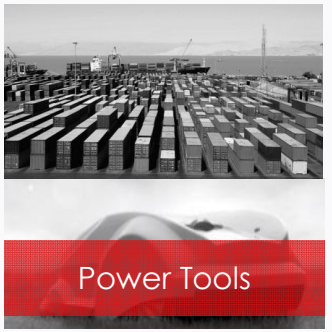

Complete Sets of Engineering

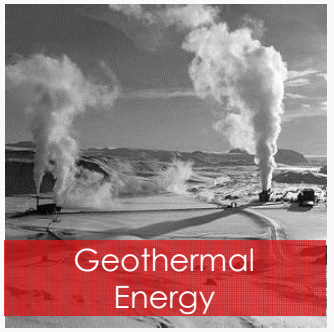

Power Generation Equipment


Textile & Apparel


Wind Energy


Mechanical & Electronic


Power Tools


Geothermal Energy

About SUMEC Energy

SUMEC Energy, a leading global provider of clean energy solutions, committed to customer centered solutions for Energy Supply, Energy Management, Energy Saving and Energy Storage

SUMEC Energy in order to provide efficient and economically sustainable solutions, uses extensive and innovated supply chain strategies, principles and techniques

3500MW	1500MW
Global shipments	Domestic projects
3.5 billion kwh/y	3.9 million tons/y
Generating capacity	Reduction of standard coal

About SINOMACH New Energy Research Institute

A **close loop capability system** for **reducing the cost per kilowatt hour** of PV generated power

TRiED 天津电气科学研究院有限公司 TIANJIN RESEARCH INSTITUTE OF ELECTRIC SCIENCE CO.,LTD.

CEI 中国电器院

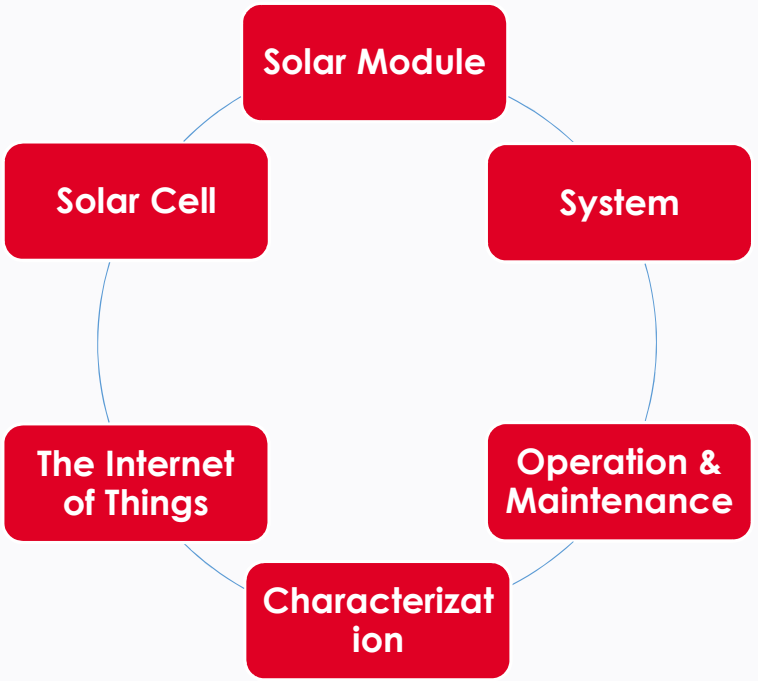
HUAWEI

UNSW THE UNIVERSITY OF NEW SOUTH WALES

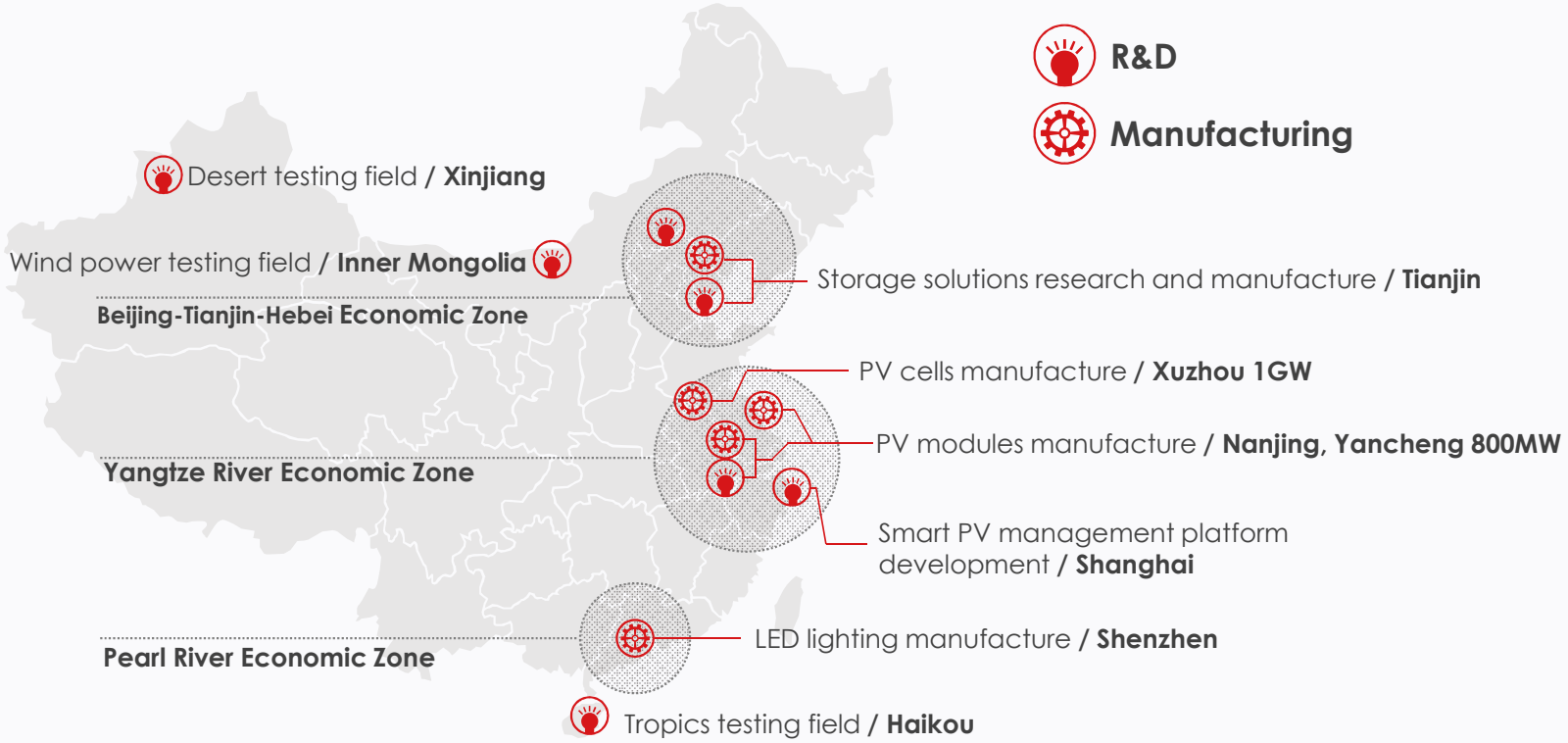
ECN

南京大学 NANJING UNIVERSITY

南京航空航天大学



R&D and Manufacturing Base



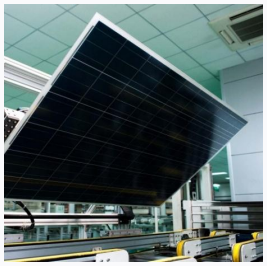
Manufacturing

Tier 1
Bloomberg
NEW ENERGY FINANCE

PV Module Maker Tiering System

Phono® Solar

1000MW
Production capacity



3500MW
Global shipments

Phono Solar Technology Co., Ltd., was founded by SUMEC Group Corporation. Phono Solar is leading brand in the clean energy industry, providing high efficiency PV modules since 2004.

PART 2. R&D Progress

- Strategy & Technology Roadmap
- Nano-Texturing
- Metal Wrap Through Technology
- HJT Technique & Performance
- PERC+ Research
- PV System Forecasting

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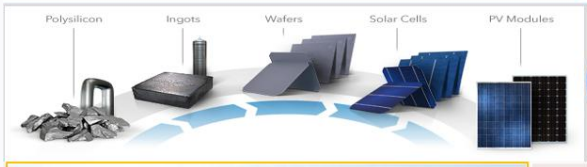
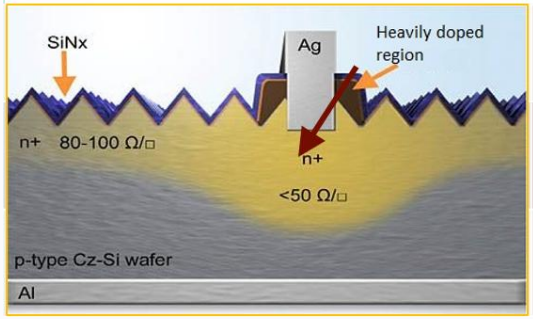
Strategy & Technology Roadmap

Classical Silicon based Solar Cell	Wafer	Texturing	Diffusion	PSG/ISO	Passivation	Printing /Firing
	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
						
Front	DSW	Nano Texturing	Selective Emitter			Double Print/Multi Busbar
Emitter	Pure Material/N type wafer		Ion Implantation			
Rear			Bifacial Diffusion	Rear Side Polishing	Rear Side Passivation	MWT

Proven Technique, Cost Effective, Lots of Mass Production Data, Highly Material and Tools Dependent

Pilot Technique, Strong Potential of Cost Down & Efficiency Gain, Small Scale of Investment

Lower Risk, Cost Effective

More Cost, Higher Efficiency Gain, Cost of Ownership Still in Proving

Higher Risk Worse CoO

RD Stage Technique or Failed Technique, Future Technique

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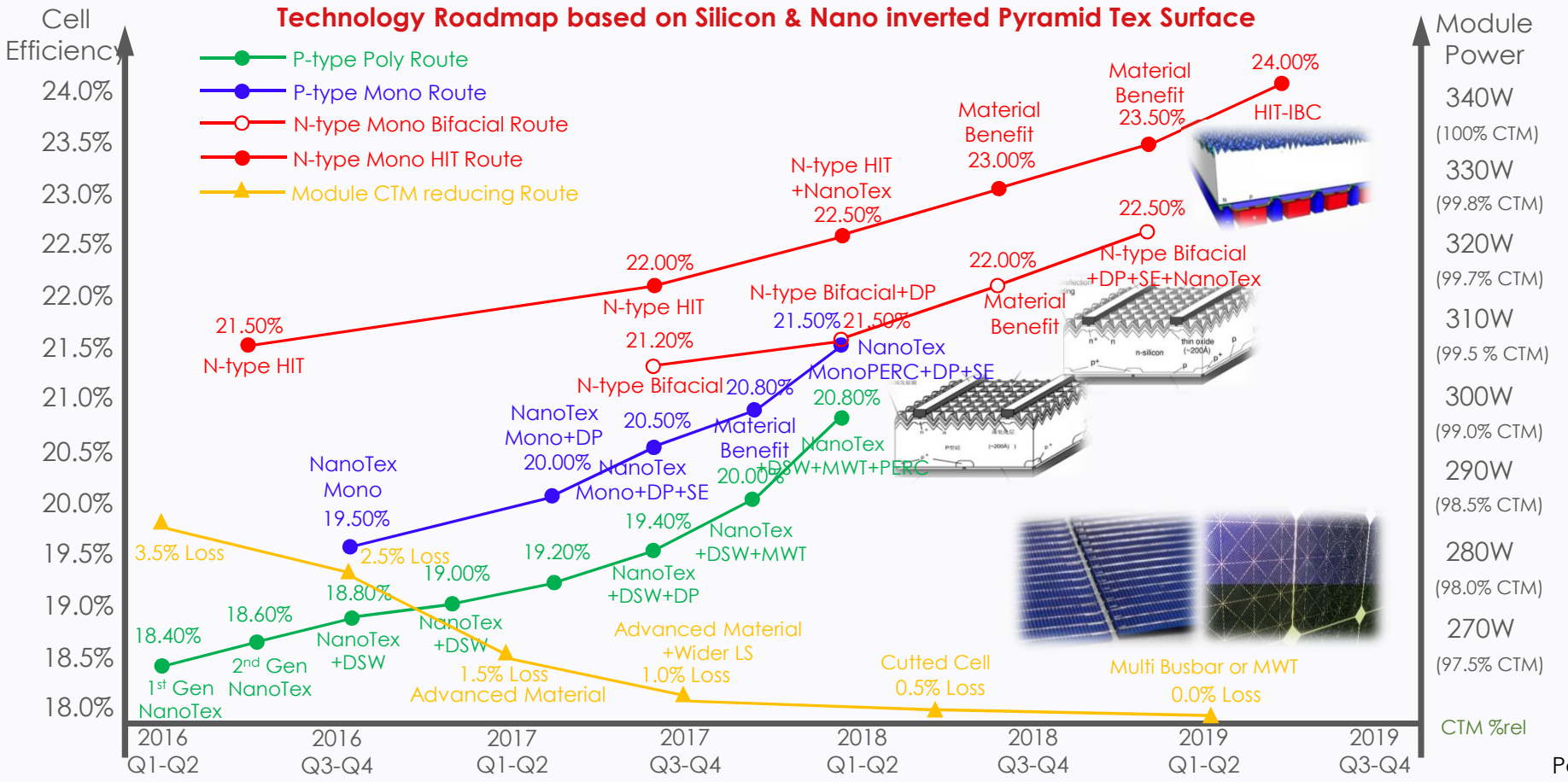
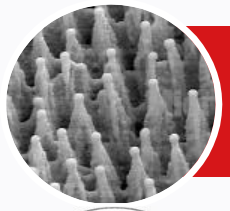
Strategy & Technology Roadmap

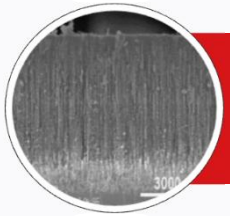


Nano-Texturing



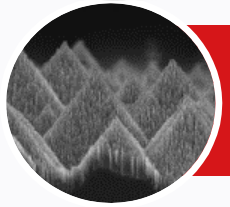
Femtosecond Laser Etching

Nano spike structure , high cost , surface damage



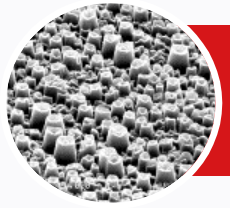
Electrochemical Etching

Porous structure , complex process



Metal Assisted Chemical Etching (MACE)

Nanowires or nanopores , anisotropic etching , low cost

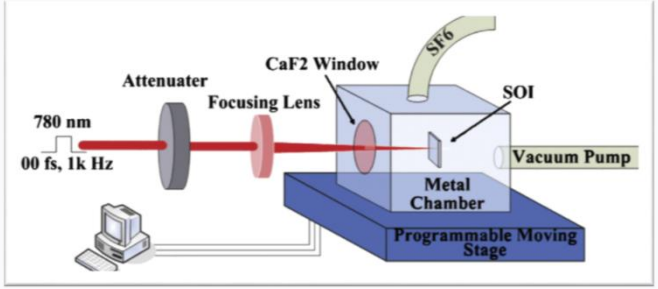


Reactive Ion Etching (RIE)

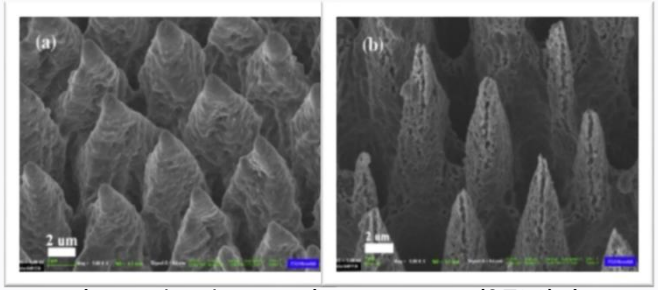
Nanocones or nanopillars , plasma etching , high equipment cost

Nano-Texturing

Femtosecond Laser Etching

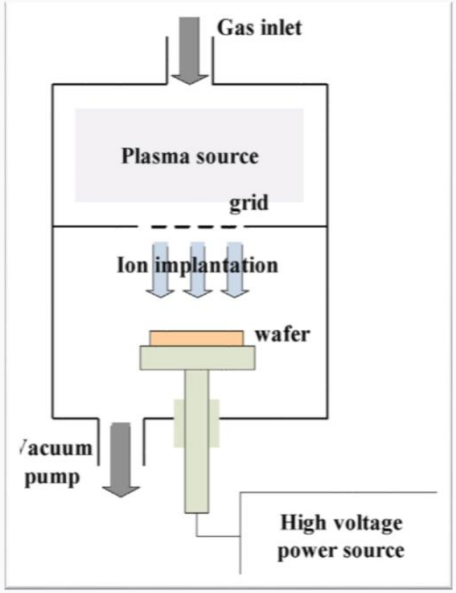


Schematic diagram of the experimental setup for the flexible black silicon fabrication

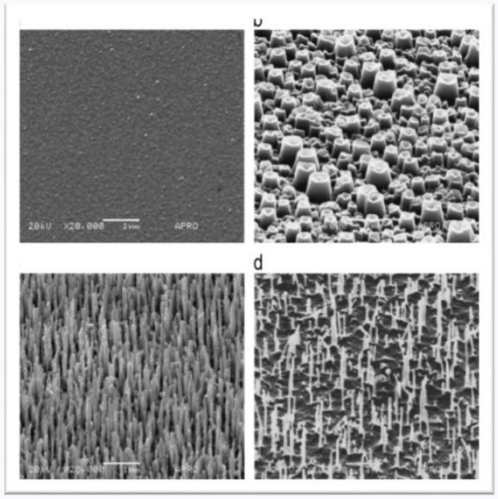


Scanning electron microscope (SEM) image of the micro spike structure of the fabricated flexible black silicon

Reactive Ion Etching (RIE)



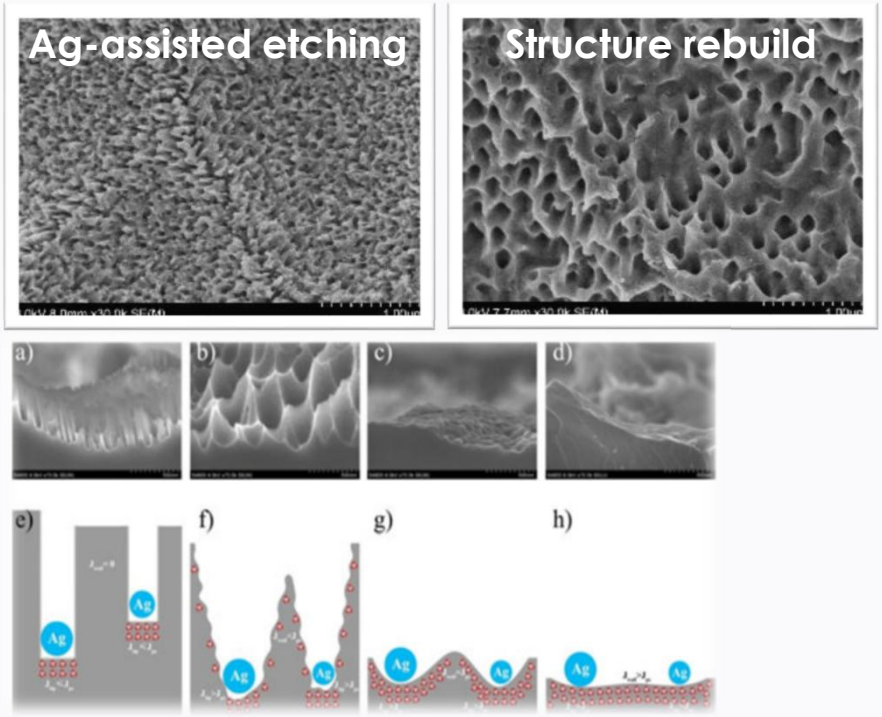
Schematic illustration of a DC-plasma immersion ion implantation apparatus

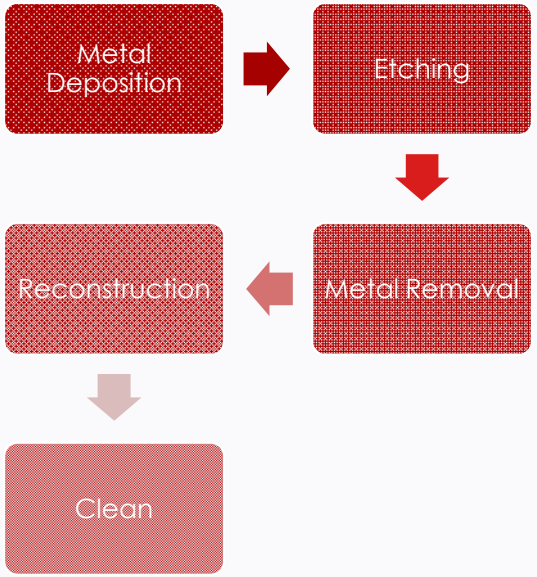


SEM images of silicon surface structures formed by RIE processing with different SF_6/O_2 gas flow ratios

Nano-Texturing

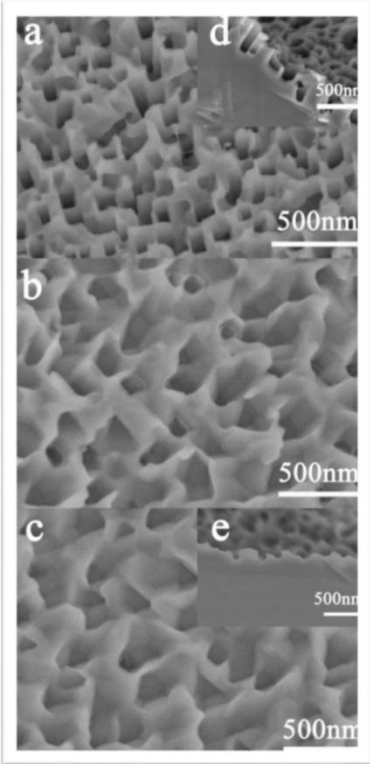
Metal Assisted Chemical Etching (MACE)



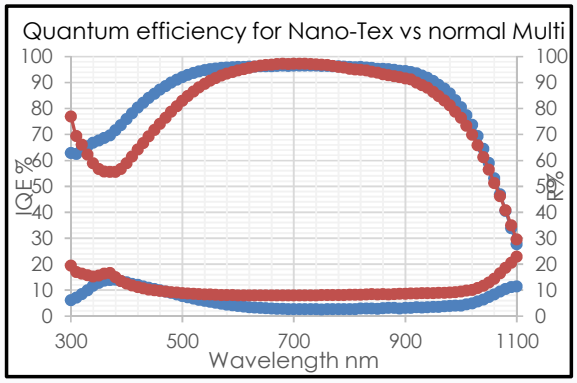


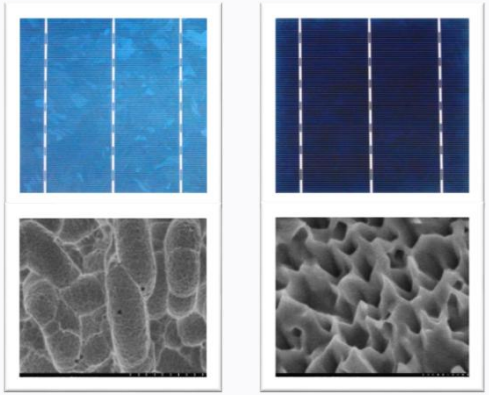
Schematic of Nano-textured silicon processing steps.

Nano-Texturing

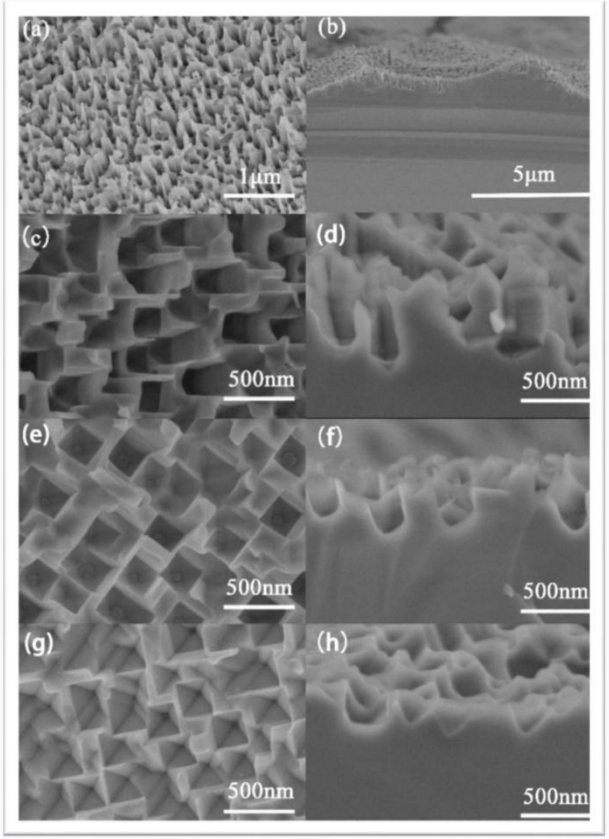


	Voc (V)	Isc (A)	Rs (mΩ)	FF (%)	Eff (%)
Acid textured (avg.)	0.630	8.647	0.0029	78.61	17.59%
Alkaline treatment Nano-mc-Si (avg.)	0.629	8.738	0.0024	79.19	17.89%
Round treatment Nano-mc-Si (avg.)	0.630	8.764	0.0029	79.02	17.94%
Best Nano-mc-Si	0.634	8.882	0.0023	79.78	18.47%





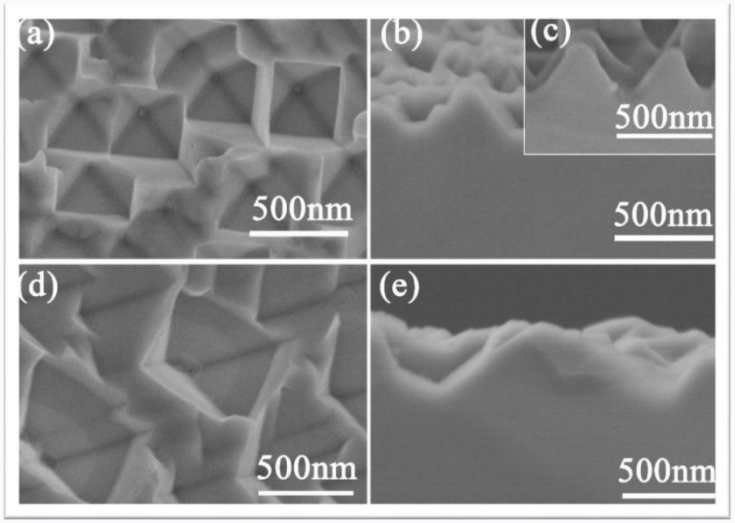
Nano-Texturing



SEM images of the nanostructure after NSR treatment under different time

Inverted pyramid structure by NSR

Nano Structure Rebuilding (NSR) solution
Based on acid system
H_2O_2 and additive



SEM images of the inverted pyramids with further NSR treatment

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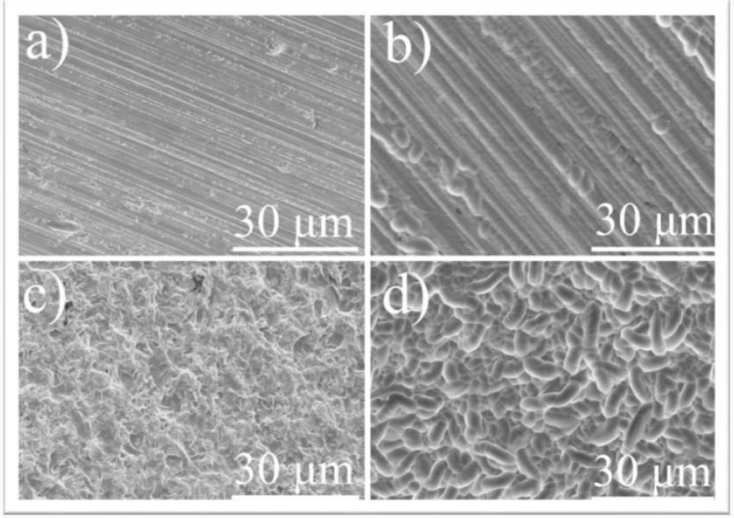
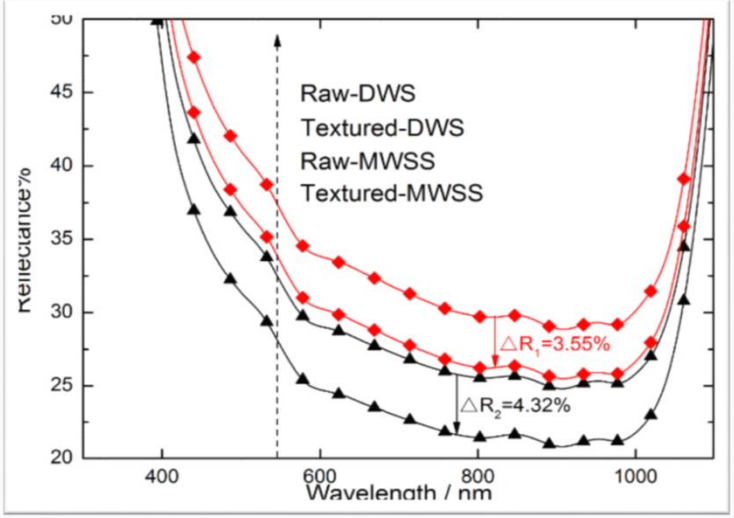
Nano-Texturing

Diamond Wire Sawed Wafer

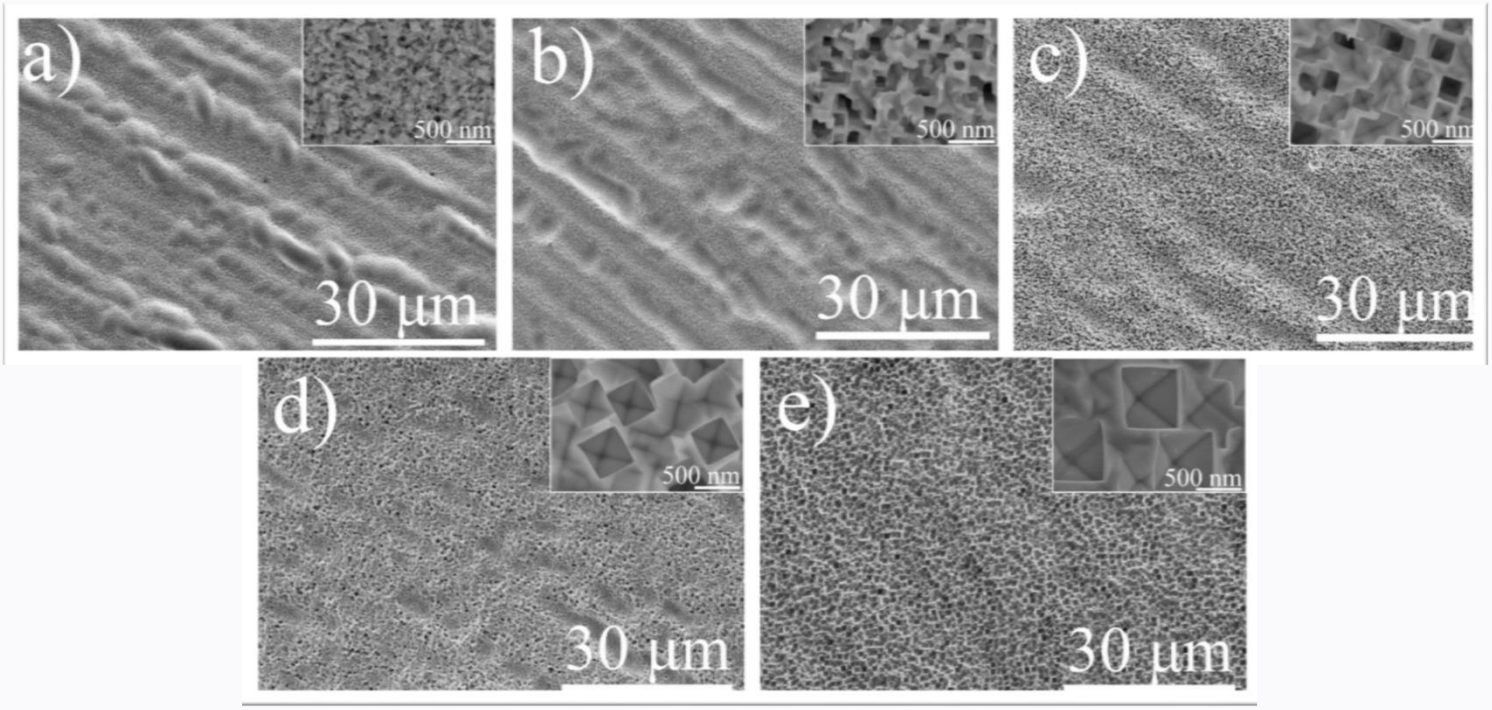


Surface SEM figures of acid texture on DWS and MWSS wafers



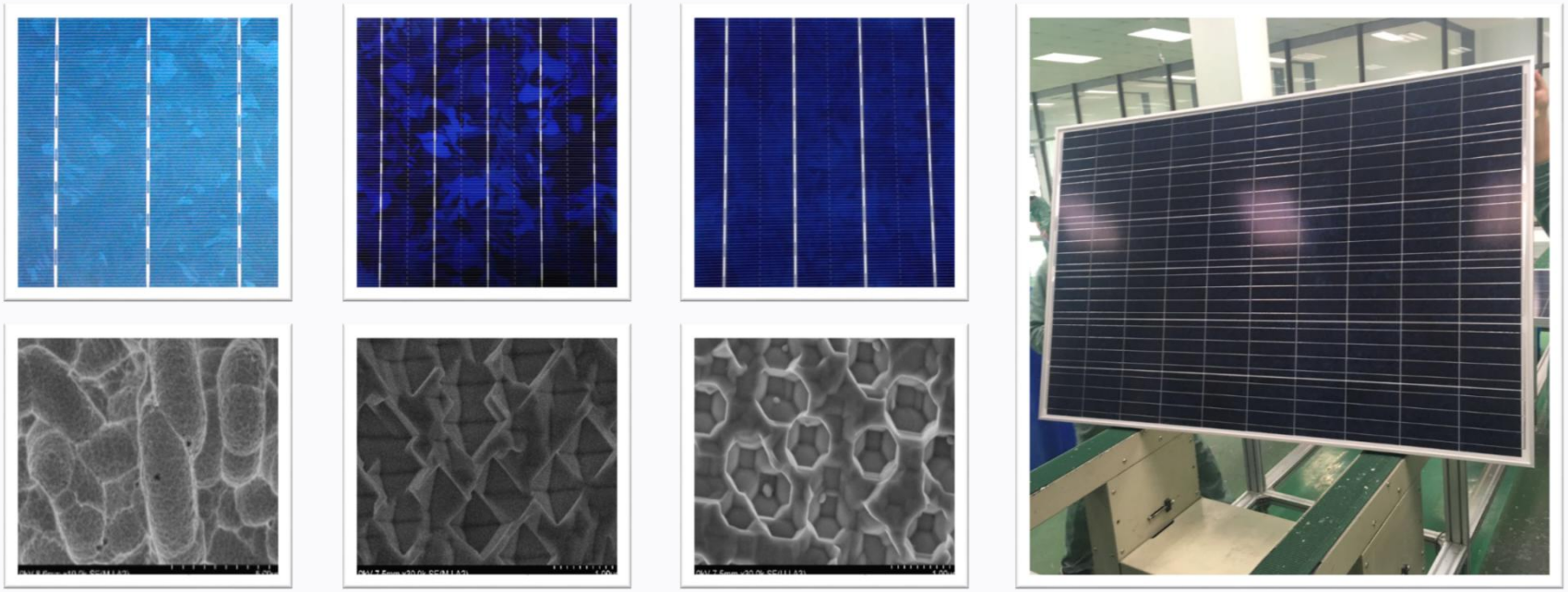
Reflectance of DWS and MWSS wafers before and after acid texture

Nano-Texturing



Surface SEM figures of DWS wafers with different NSR treatment time

Nano-Texturing



Mass Production Nano-Texturing Multi Solar cell & Module based on Dimond Saw Wafer

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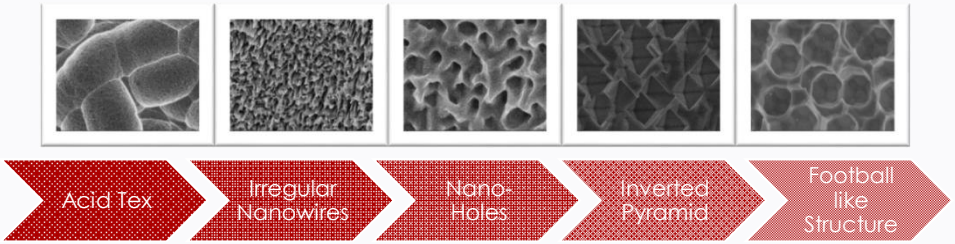
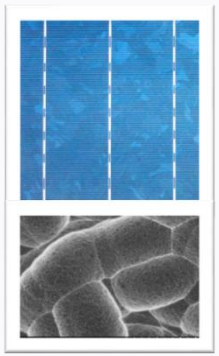
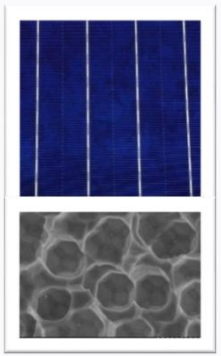
Nano-Texturing



Index for SUMEC's Nano-Tex Solar Cell



- Cell
  1) Cell Cost Down 5%
  2) Compatible with DWS wafer
  3) Compatible with other High Efficiency Technologies
  4) Efficiency Gain 0.4%
- Module
  1) Module Cost Down 4%
- System
  1) Power Output Gain (kwh/kw) is over 3%
  2) System Cost Down 3%

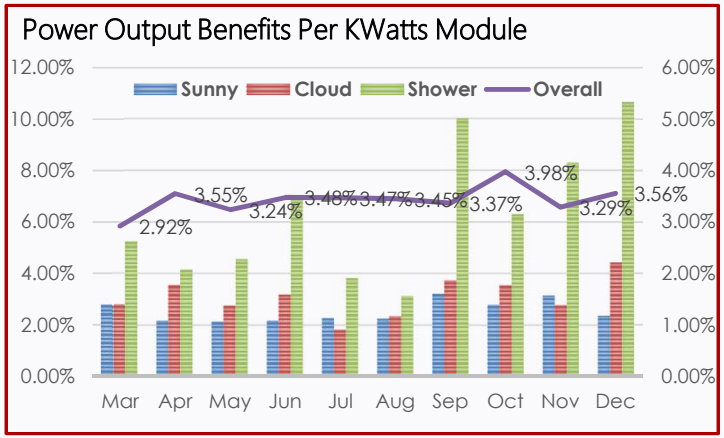


	Acid Tex	Nano-Tex
Chemical ($/W)	0.002	0.006
Tool, Consumption, Labour Cost ($/W)	0.0007	0.002
Total Cost ($/W)	0.0027	0.008
Cost Saving from Wafer ($/W)	0 (Slurry)	0.013 (Diamond)
The Real Cost Down or Increase ($/W)	0.0027 (Increase)	0.005 (Down)
Efficiency Gain	0%	+0.4%
Income ($/W)	—	0.023
Total Income ($/W)	—	0.028
Module Cost	—	3.5% (Down)
System Cost	—	2.4% (Down)
Power Cost per Kwh	—	5% (Down)

Nano-Texturing

Power Plant: SUMEC HQ; Location: Nanjing
Type: distributed system; Capacity: 1.1MW

Power Plant: SUMEC Bao Fengda YangZhou; Location: (33.37786N,119.52888E)
Type: Ground-based solar system; Capacity: 9MW



Time/ Capacity	Normal Multi 260P					Nano-Tex 260P	Nano-Tex/ Normal
	Array #1 (1510KW)	Array #2 (1510KW)	Array #3 (1510KW)	Array #4 (1510KW)	Avg (1510KW)	Array #5 (1478KW)	
Jul	110.577	110.065	110.094	108.673	109.852	112.735	2.62%
Aug	114.499	113.878	113.808	111.573	113.440	116.709	2.88%
Sep	128.228	127.055	127.057	122.925	126.316	132.354	4.78%
Oct	103.370	102.733	102.809	100.124	102.259	106.659	4.30%
Nov	43.769	43.510	43.554	42.891	43.431	44.704	2.93%
Dec	73.595	72.822	73.136	71.169	72.680	75.053	3.26%
Sum	647.631	642.884	643.594	628.524	640.658	663.267	3.53%

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Nano-Texturing

Technical Indicator		Mass Production	2nd Generation
Tools	Through put(pc/H)	3400	5000+
	Uptime	88%	92%
	Investment ($)	430,000	580,000
	Automation	fully	fully
Process	Wafer Cutting	Slurry & diamond	Slurry & diamond
	Wafer	multi & mono	multi & mono
	Efficiency Gain(multi)	0.4%(19.00%)	0.4%(19.00%)
Module	CTM	~1.5% , +5 ~ +10W	~1% , +10W
	Reliability & Stability	good	good
	Power Output per KW Gain	+3%	+3%

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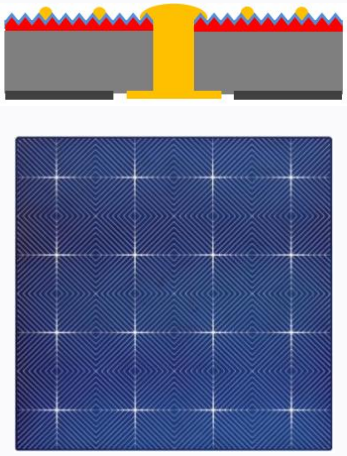
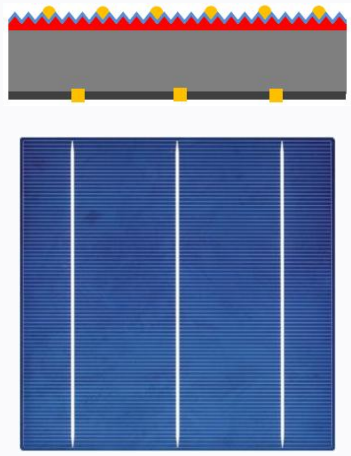
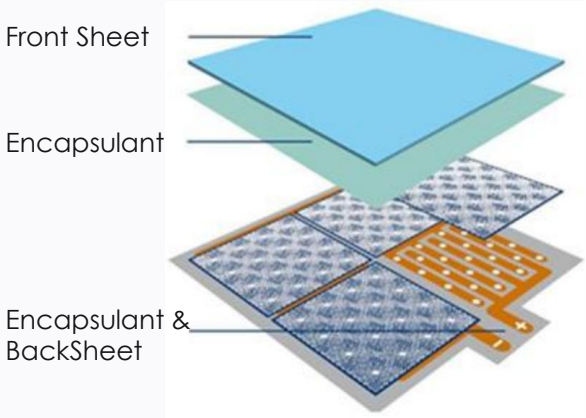
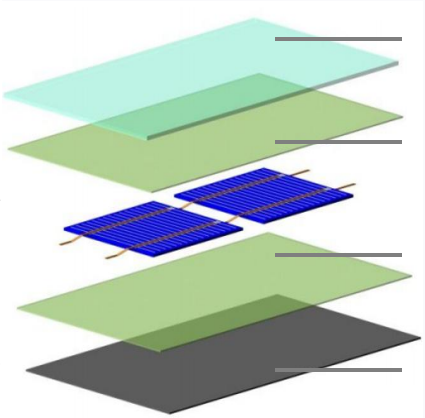
Metal Wrap Through Technology



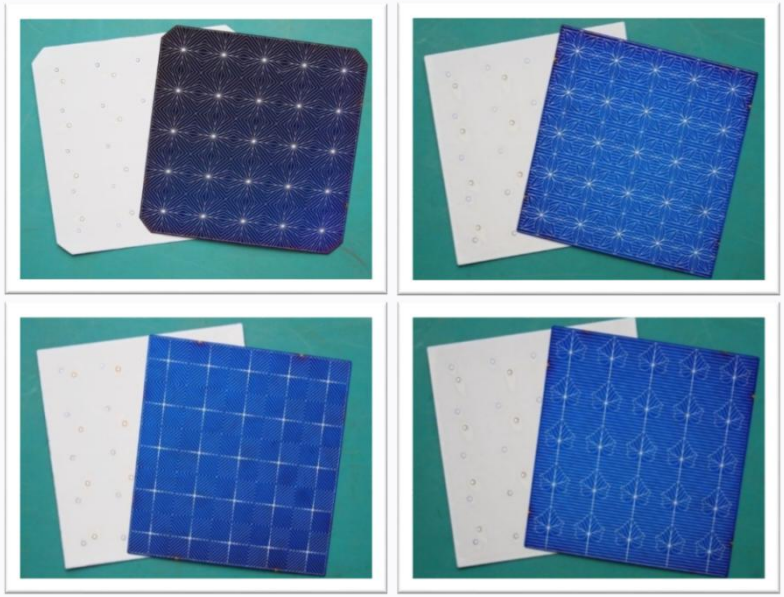
MWT	Contrast items	Normal
Wrapped-through	Cell Structure	Front electrode
No busbar	Front Grid	Busbar
Better appearance		monotonous appearance
Less	Grid Shading	More
+0.3%	Efficiency Gain	0%
Patterned conductive foil integrated backsheet	Module assembling	normal backsheet
Electrical conductive adhesive(Less CTM)		Welding strip(Higher Rs Loss)
Compatible with IBC & thin wafer		None Compatible with IBC & thin wafer



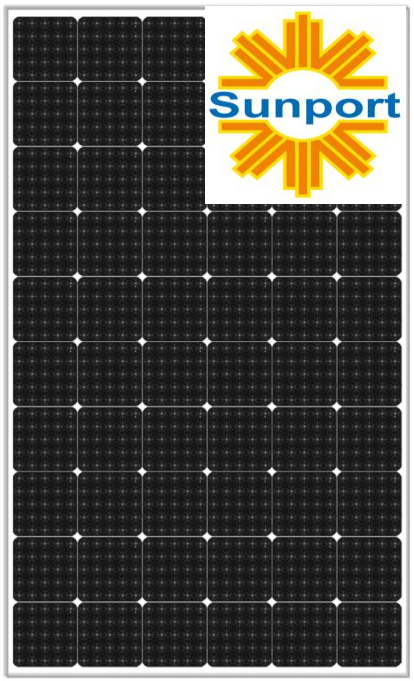




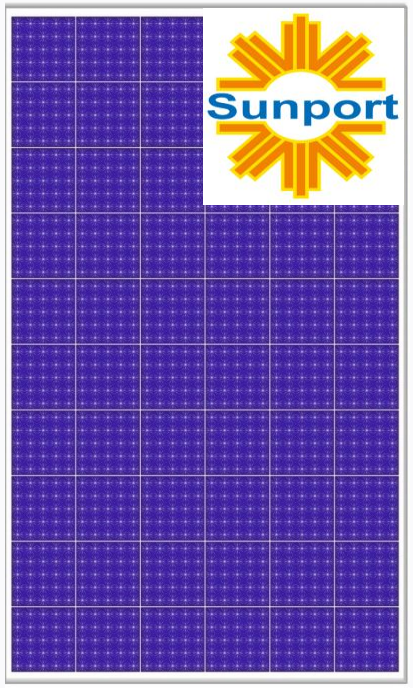
Metal Wrap Through Technology



- Front side 25 holes by laser drilled → Future 36 holes
- Average efficiency for normal multi wafer & process → 19.0%
- We are doing process integration with Nano-Tex multi cells, the average cell efficiency might achieve over 19.5%
- Our power output target for the 60p@module is 300Wp



Mono 60pcs MWT module
（Normal Mono ~ 280Wp, MWT Mono ~ 295Wp ）



Multi 60pcs MWT module
（Normal Multi ~ 270Wp, MWT Multi ~ 285Wp ）

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Metal Wrap Through Technology

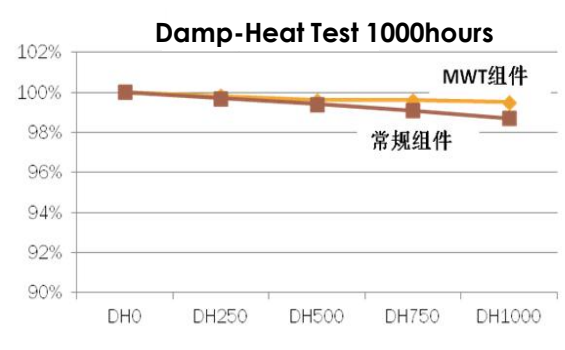
MWT reliability & stability test

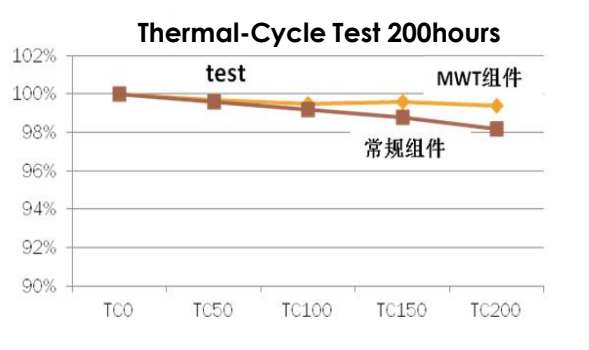
DH Condition:

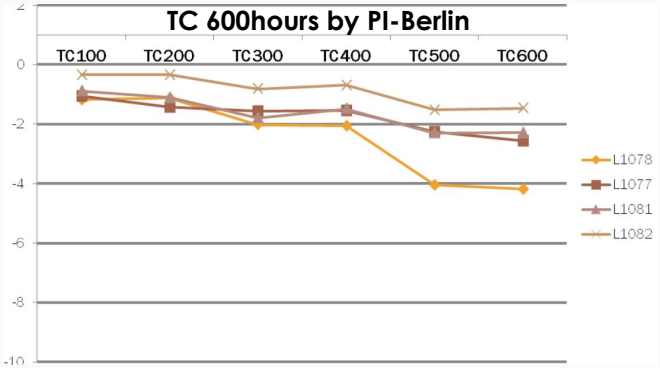
1000hours@85℃ & 85%RH

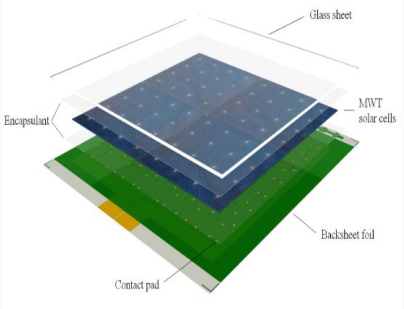
TC Condition:

85 ℃ ~ -40℃ ~ 85℃ @200hours









Metal Wrap Through Technology

Normal Screen Printing Process vs. MWT

P-Type wafer start	P-Type wafer start
	Laser drilling of vias
Damage etching & texturing	Damage etching & texturing
$POCl_3$ diffusion in furnace	$POCl_3$ diffusion in furnace
	Etching paste printing & dry
PSG/rear removal	PSG/etching paste/rear removal
Si_xN_y coating & passivation	Si_xN_y coating & passivation
Screen printing & cofiring	Screen printing & cofiring
Testing & sorting	Testing & sorting

After drilling holes

A big end up holes Is better for paste's filling, which is necessary for hole junction removal step and contact printing process

Metal Wrap Through Technology

“MWT + Nano-Tex” Technology

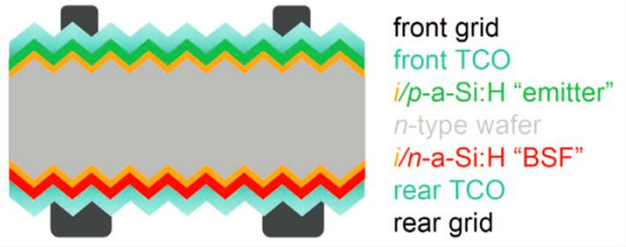
Strategic Partner : Sunport

Module Capacity: 500 GW in Xuzhou City

HJT Technique & Performance

Advantages & Disadvantages between N type HJT & P type

Type	N Type HIT	P Type
Advantages	1. No LID & No PID 2. Lower temperature coefficient 3. Bifacial structure 4. Higher conversion efficiency, easier over 22%	1. Mature process flow 2. More supplier for mass production 3. Lower cost
Disadvantages	1. Higher process requirement 2. Small process windows 3. Cost more for tools and material	1. Some LID & PID issue 2. Hard to achieve efficiency over 22%



Cell Type	P-Poly	P-Mono	N-HIT
Cell Efficiency	19%	21%	22%
Ideal module efficiency	17.22%	18.68%	19.57%
CTM loss	1-2%	3.5-4%	<2%
Real module efficiency	16.87%	17.94%	19.18%
LID	1%	2%	N
PID	Y	Y	N
Temperature coefficient (%/℃)	-0.45	-0.45	-0.27
PTC/STC	89.20%	89.00%	93.00%
Efficient module efficiency	14.60%	15.33%	17.83%

HJT Technique & Performance

- Wet Chemical Etching & Cleaning

- Screen Printing for Metal Contact

- CVD Process for Junction

- PVD Process for ITO

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HJT Technique & Performance

Items	Progress	Result	Comment	Optimization Plan
CTM	Done	Average CTM 3.35% The range is 3.17%~3.74%	For mono P type production, CTM avg is 3.5%	1.Use high transparent glass 2.Optimize the soldering process 3.Refining the sorting BIN
LID	Done	30—35kWh be stable，1.9%，range:1.2%~2.8%	Higher than P mono	1.Retest the sample 2. Change different simulator
Temperature Coefficient	Done	α=0.02%，β=-0.28% δ=-0.32%	Normal P type cell: 0.02%/℃、-0.32%/℃、-0.46%/℃	
Low Irradiation	Done	200W/m²: ↓80.8%	P type average: ↓80.5%	
DH	Done	DH1000, ↓2.19%	IEC61215 & internal control rule: after DH2000, TC400, Power degradation < 5%, no appearance issue	
TC	Done	TC400, ↓3.54%		Some crack happened near the beginning of solder strip

HJT Technique & Performance

HJT bifacial power generating performance testing site

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HJT Technique & Performance

HJT bifacial module power generation site experiment with different landform (one year data)					
Landform	Power output kWh	kWh/W	Power output gain	Analysis	Future Plan
White backsheet	316.99	0.0545	1.15 (15%)	Result highly fit the reflection coefficient of the landform	White paint & white stone might be a cost effective solution for increasing the Rearside light absorbing
White paint	314.21	0.05375	1.13 (13%)		
White stone	309.19	0.0529	1.12 (12%)		
Water	297.26	0.0508	1.07 (7%)		
Cement (baseline)	276.24	0.0474	1.00		
Grass	267.54	0.0461	0.97		
HJT single side module vs. HJT bifacial					
Module type	Power output kWh	kWh/W	Power output gain	Analysis	Future Plan
Single side	176.42	0.0304	1.038(3.8%)	Backsheet reflectance is considerable for single side HJT	Compare black and white backsheet
Bifacial	170.74	0.0293	1.00		
HJT single side module vs. Normal P type poly					
Module type	Power output kWh	kWh/W	Power output gain	Analysis*	
HJT single side	176.42	0.0304	1.045(4.5%)	1、gain from the backside (backsheet reflectance) 2、lower temperature coefficient. (HIT-0.32%)(P type-0.46%)。	
Normal	155.03	0.0291	1.00		

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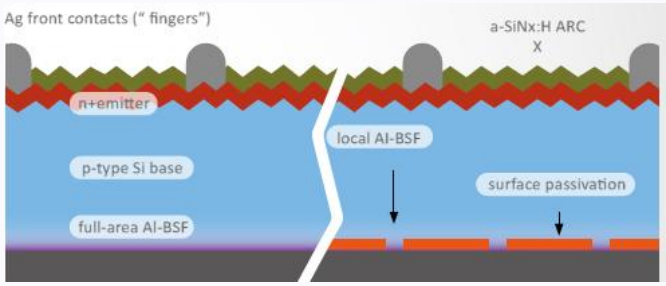
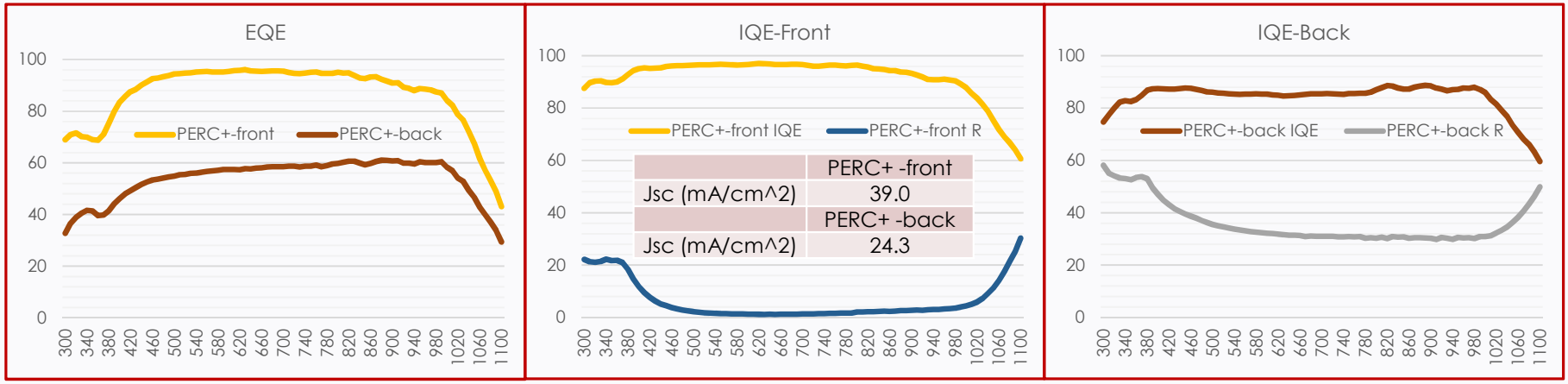
PERC+ Research

PERC+ process and performance research

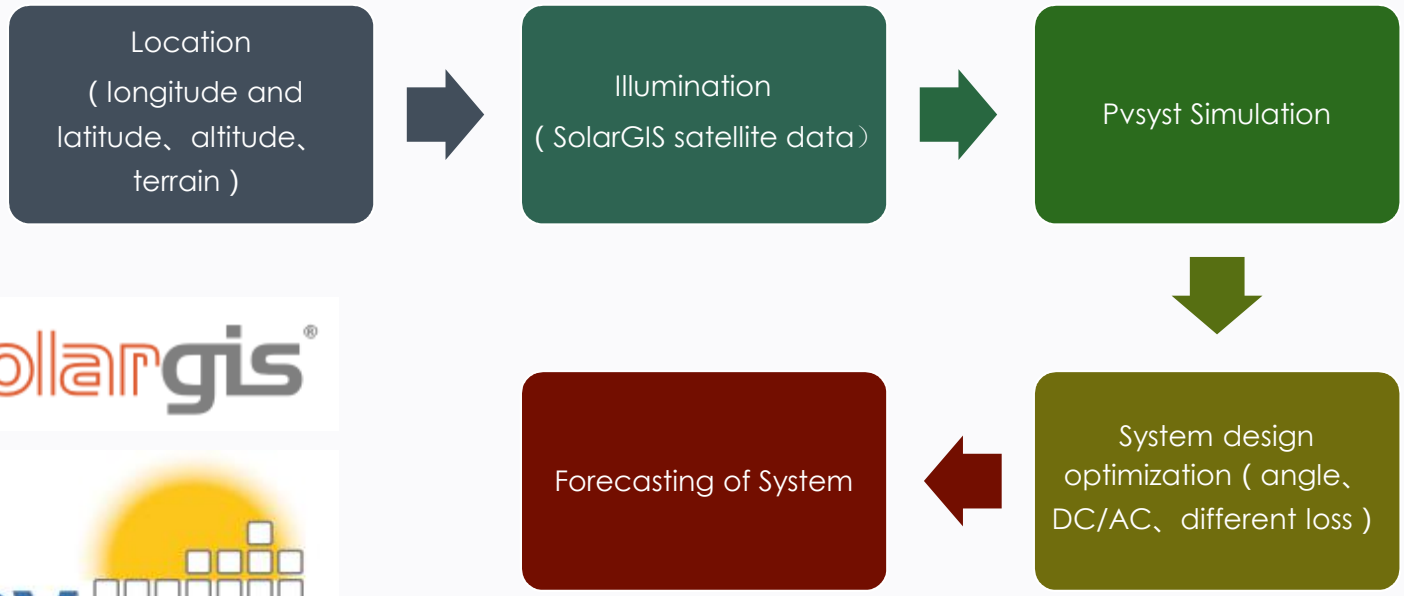


p-PERC	Contrast items	PERC+
Yes	Rear SixNy layer	No
Yes	Laser grooving	No
About 20nm (TMA consumption higher)	Al2O3 (TMA consumption)	About 6nm (TMA consumption lower)
No	Bifacial cell	Yes (bifacial coefficient>75%)
20.5%	Conversion efficiency	20.3% (lab result)
Full print , high	Al paste consumption	Grid print ,low

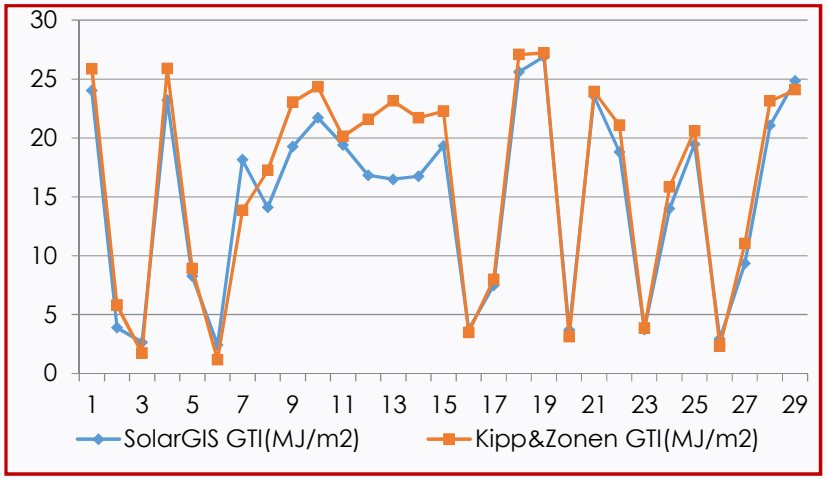


PV System Forecasting

SolarGIS Data + Pvsyst Simulation + Empirical Correction



PV System Forecasting



The Satellite Data is not very accuracy especially there is any microclimate change ate the location.
So, we installed high accurate Solar radiation measurement tools to fix SolarGIS' data.

PART 3. PV Plant case

- Ground Mounted PV Plant
- Distributed Power Plant
- Others

Marketing Strategy

上屋顶

Distributed Systems on Rooftops

下农田

Abandoned Ground-Mounted (seashore, coal-mining subsidence area)

达用户

Standalone System

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Ground-Mounted PV Plant

Project Overview

Location: Dongtai, Jiangsu

Project Type: Ground-Mounted

System Size: 50 MW

Completion Date: December 2013

Construction Period: 14 months

Generating Capacity: 58,613 MWh/year

China largest tidal-flat PV power plant

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Distributed Power Plant

Project Overview

Location: Hefei, Anhui

Project Type: Distributed Rooftop

System Size: 100 MW

Completion Date: May 2016

Construction Period: 24 months

Generating Capacity: 48,930 MWh/year

China largest Distributed PV power plant

Others

Xuyi, 9.8MW.
hilly area, sheep farming

Peixian, 15.8MW.
Coal mining subsidence area

Others

Germany

America

Austrilia

Japan

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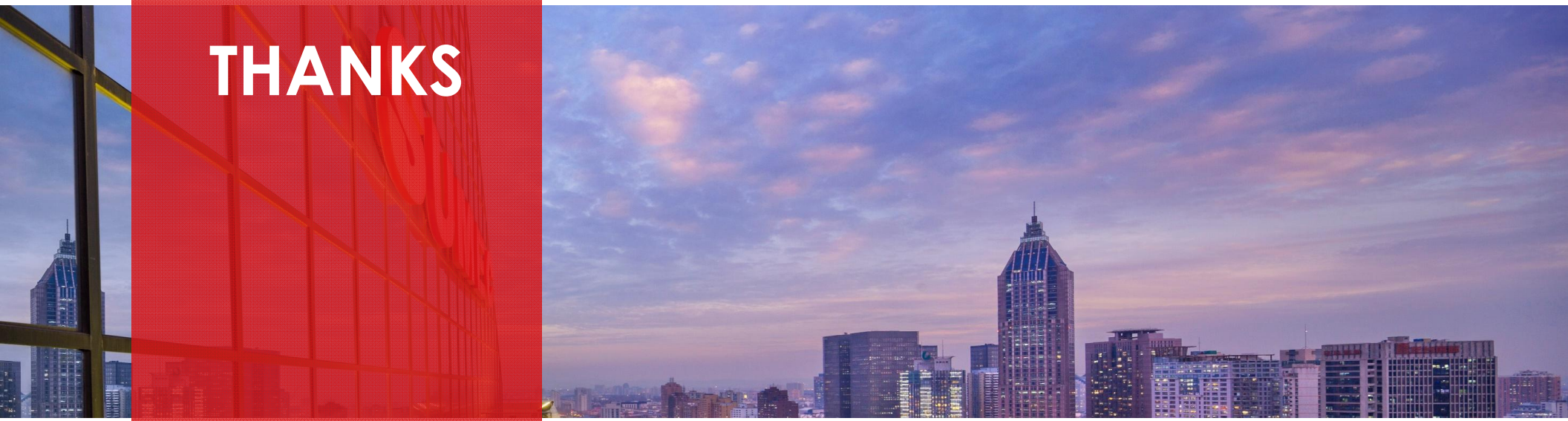
苏美达能源

THANKS



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