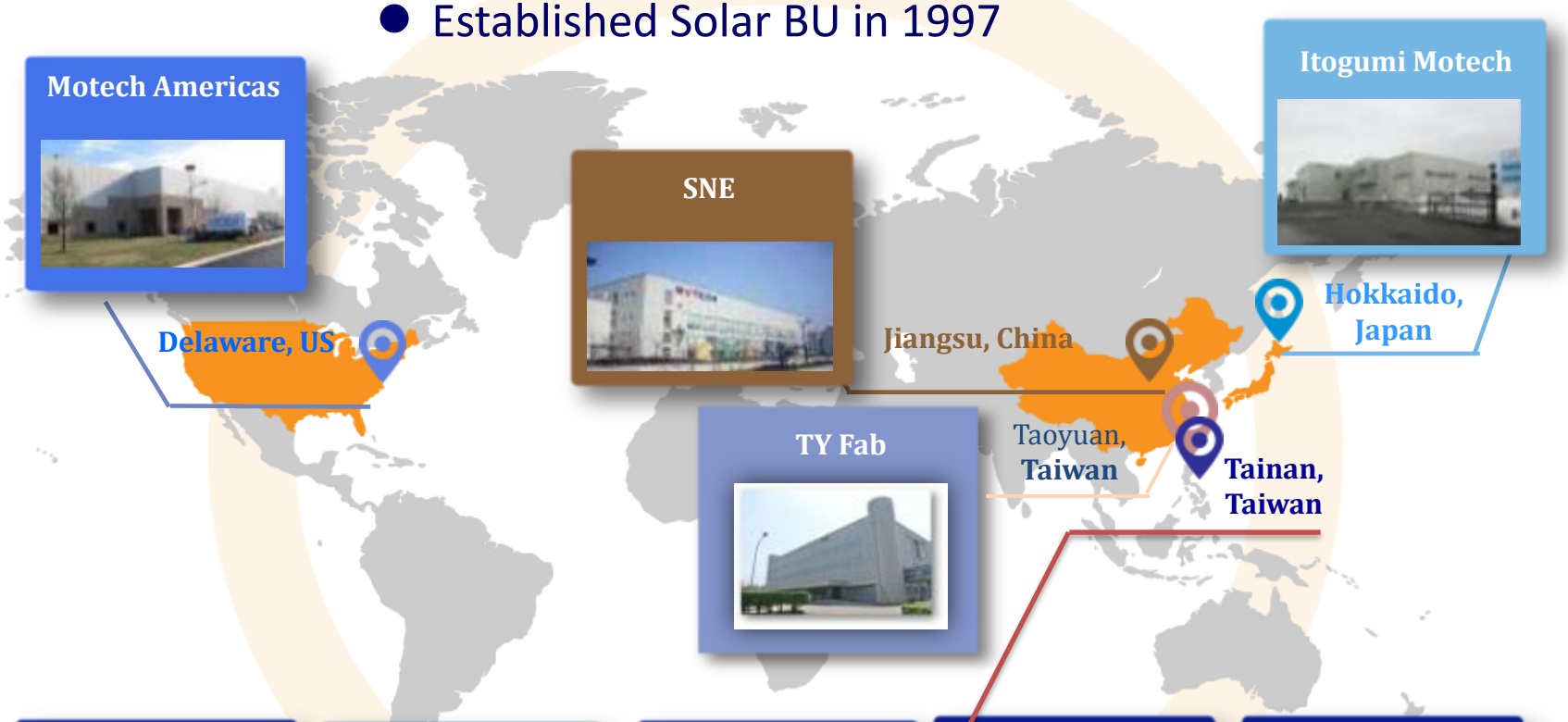
Cu-plated electrodes with green ns laser opening on n-type silicon solar cells

Kuang-Chieh Lai, Shu-Yen Liu, Yueh-Lin Lee, Ming-Shiou Lin, Yun-Kuo Tsao, Chia-Chih Chuang, Chi-Chun Li and Chien-Chun Wang

Advance Technology Development Department
Motech Industries, Inc.

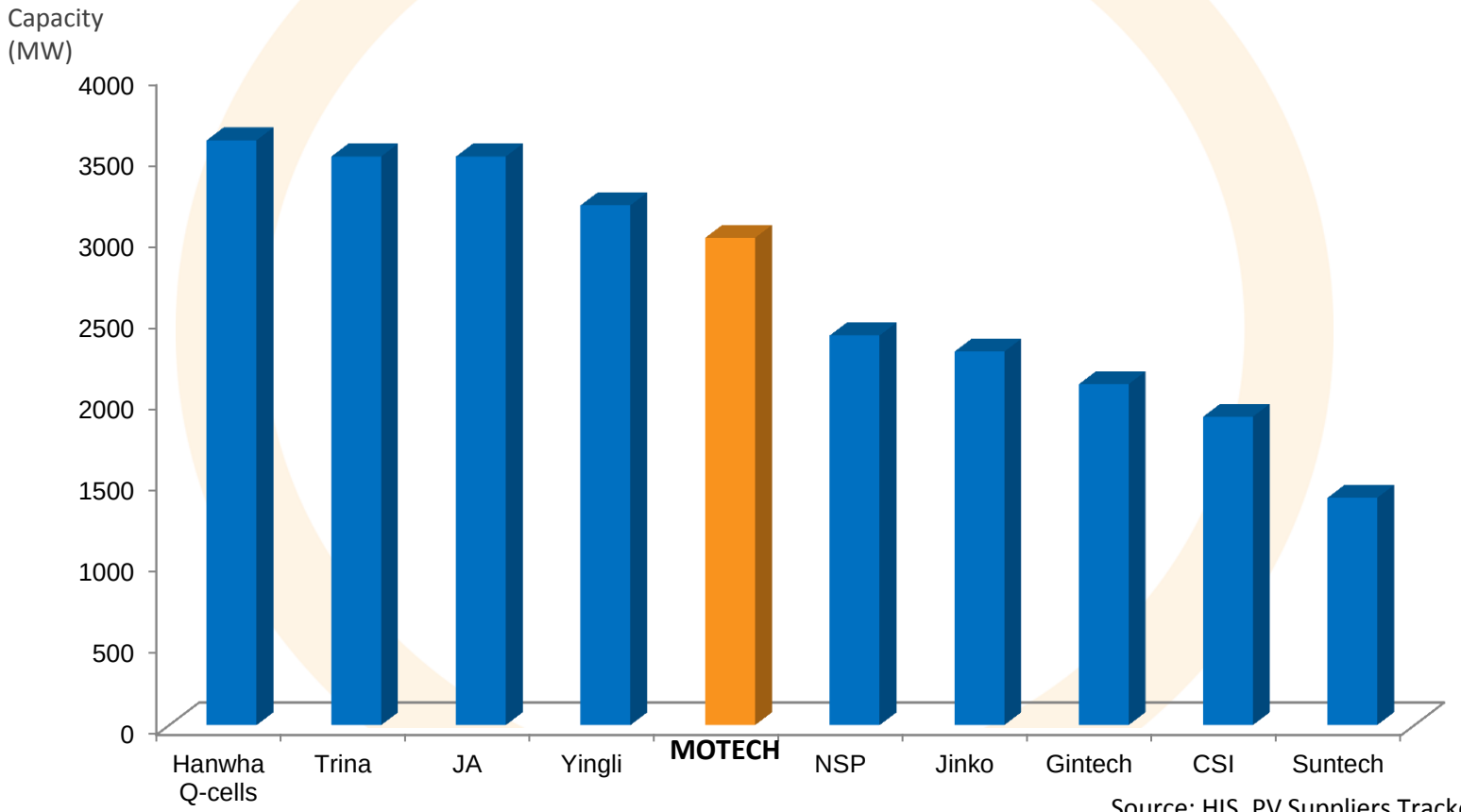
Motech Industries, Inc.

- Founded in 1983
- Established Solar BU in 1997



A Leading Solar Cell Manufacturer

- 3.2GW cell production capacity in 2015
  - No.5 in the world
- Smaller capacity of ingot growth, wafer slicing, module

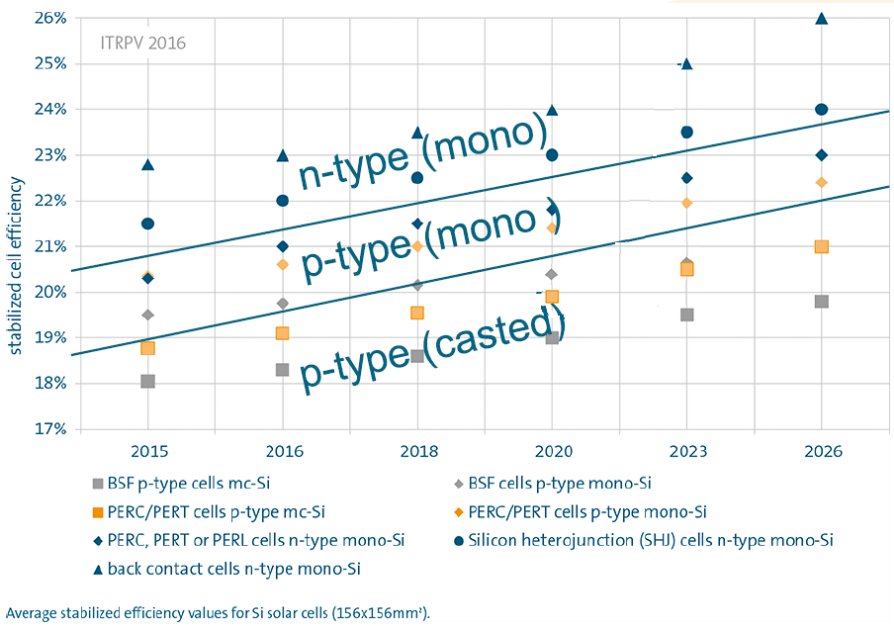


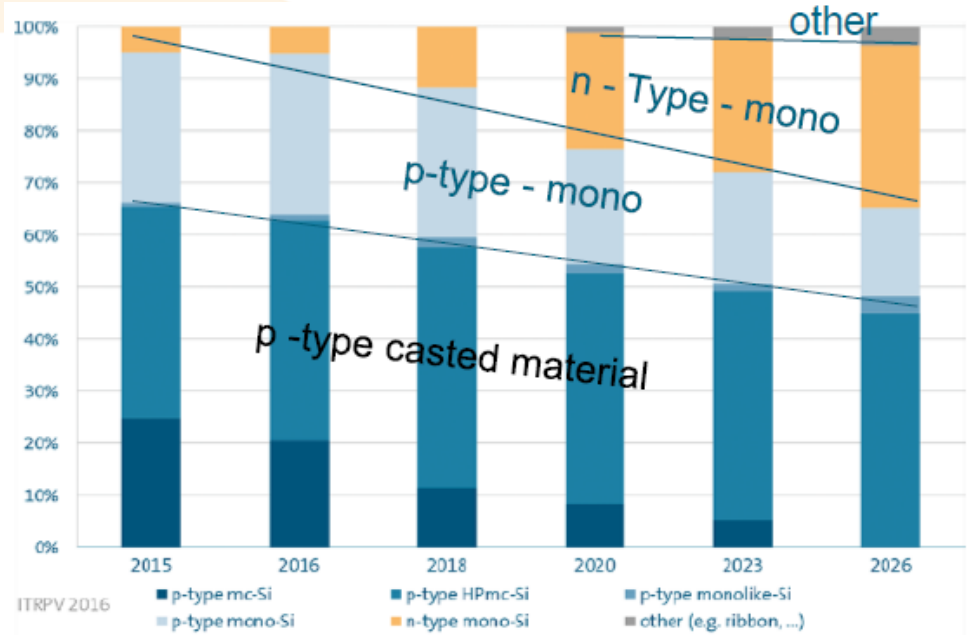
Source: HIS, PV Suppliers Tracker 2015Q3

Outline

- Motivation
- Experimental Setup
- Results & Discussion
- Conclusion

Cell Efficiency; Market Share





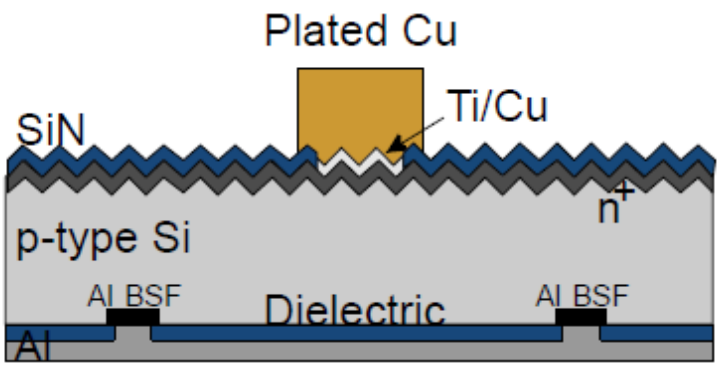
- N-type cells provide higher efficiency
- Projected growth of market share for N-type cells
- Cost needs to be controlled

Reference: ITRPV 2016

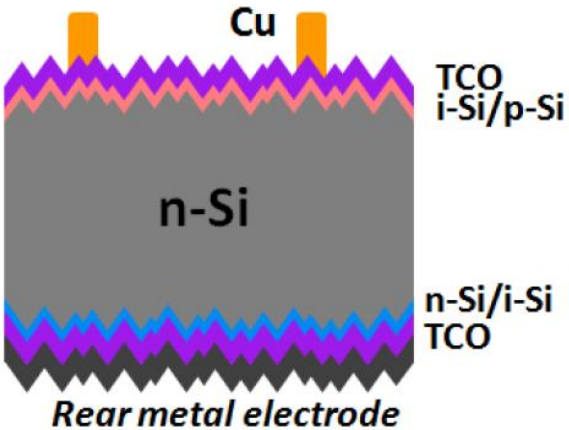
Plating Application on Solar Cells

- Cu plating applicable to all types Si solar cells; more beneficial for n-type

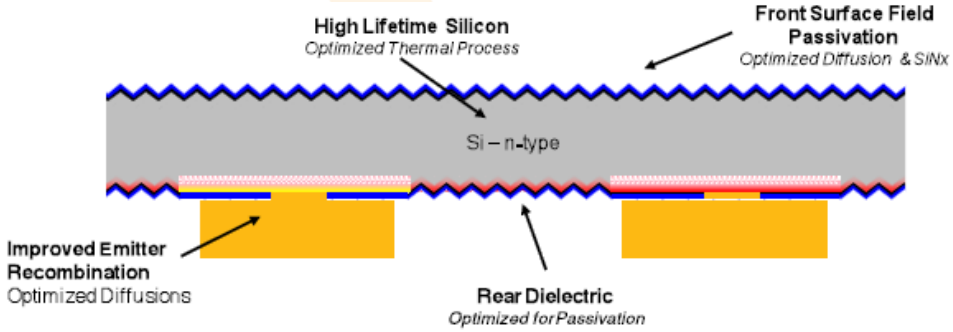
p-PERC



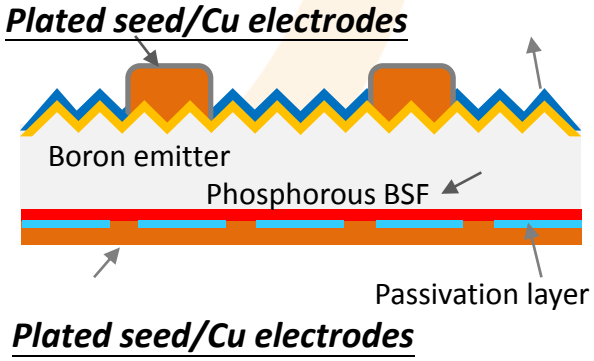
HJT



IBC



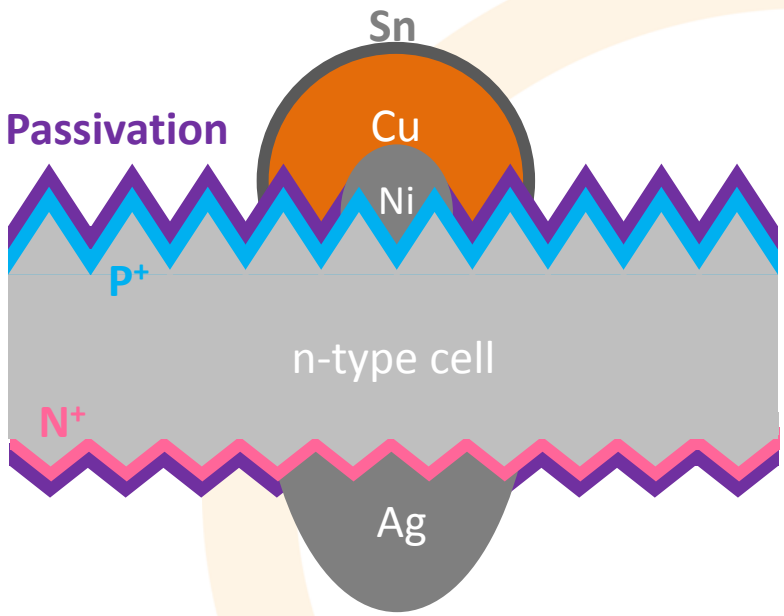
n-PERT



Outline

- Motivation
- **Experimental Setup**
- Results & Discussion
- Conclusion

Cell Structure and Process Flow

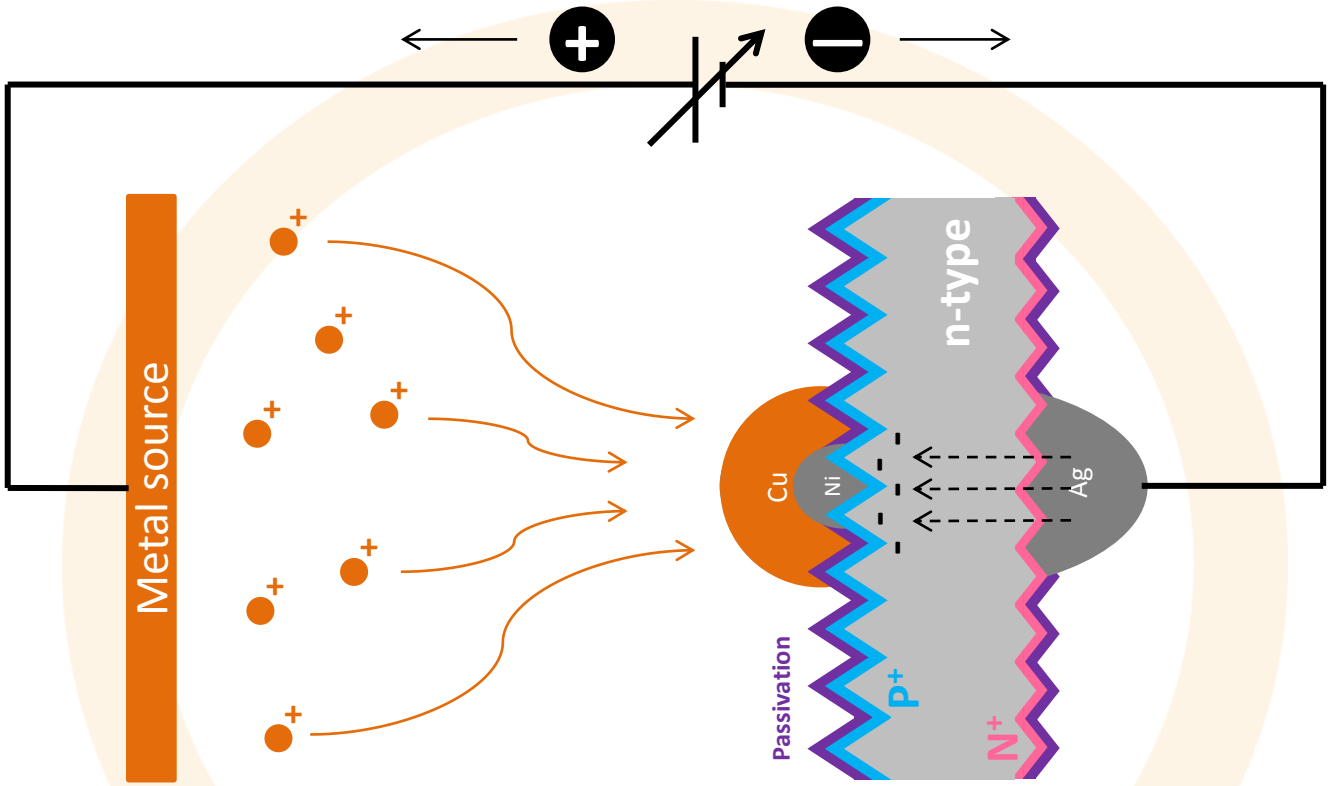


Schematic cross-section of the solar cell

- Texture
- Boron doping (emitter)
- Phosphorus doping (BSF)
- Front and rear passivation/ capping
- Rear-side Ag printing and sintering
- **Front side laser opening**
- **Plating Ni/Cu/Sn**

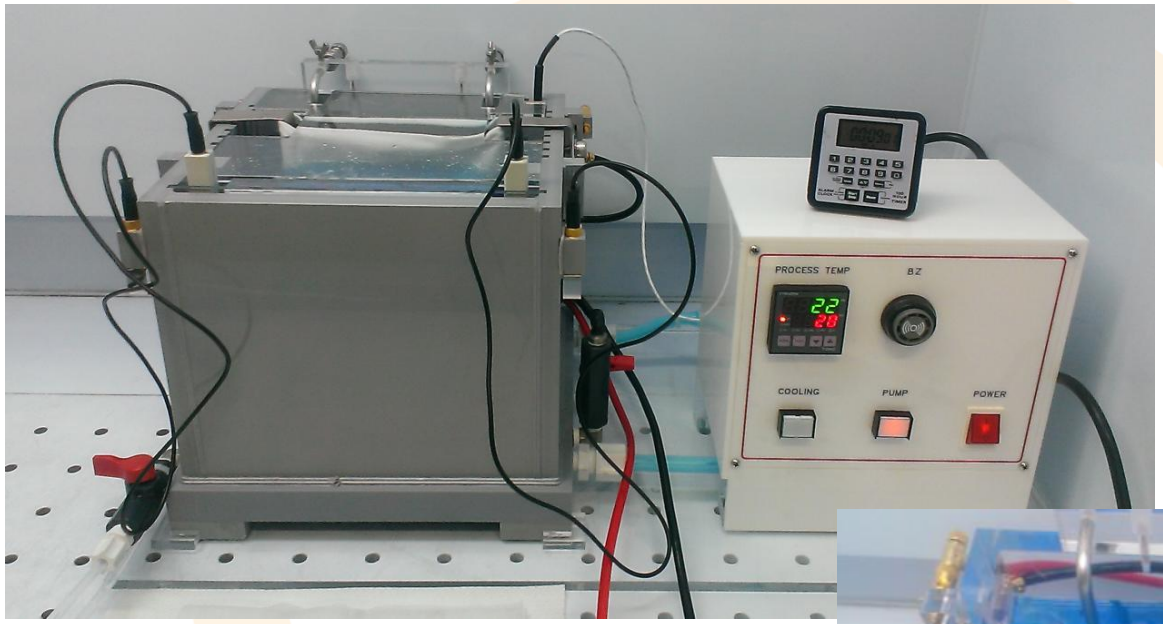
Cell process flow

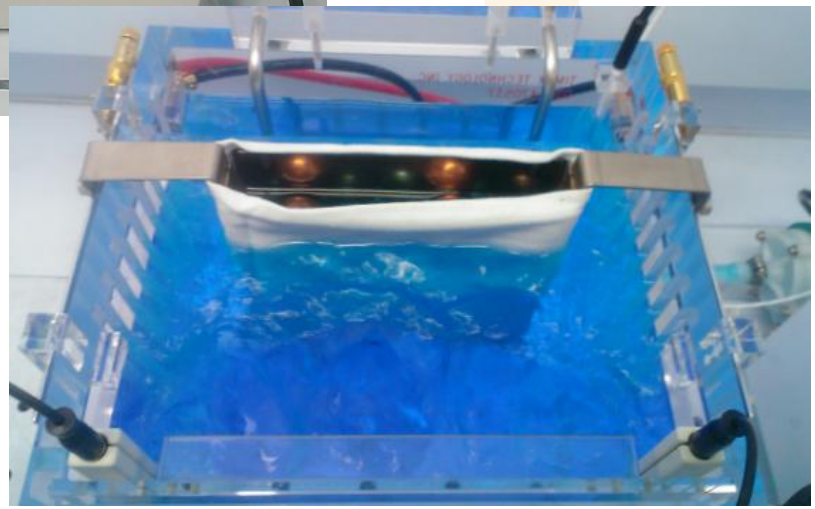
Forward Bias Plating (FBP)



- Applying a negative voltage to the rear contact of the cell, relative to the anode, making the cell in forward bias
- Both Ni and Cu deposited using FBP

Lab Plating Equipment





- Simple homemade equipment used for FBP and electroplating
- Separate tanks for Ni, Cu, Sn

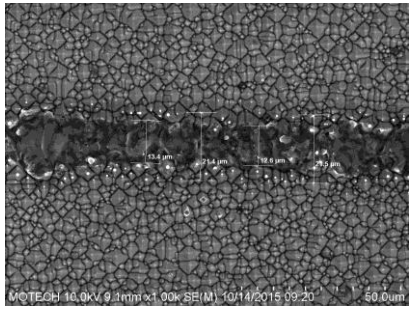
Outline

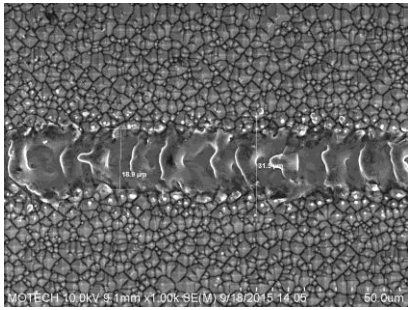
- Motivation
- Experimental Setup
- **Results & Discussion**
- Conclusion

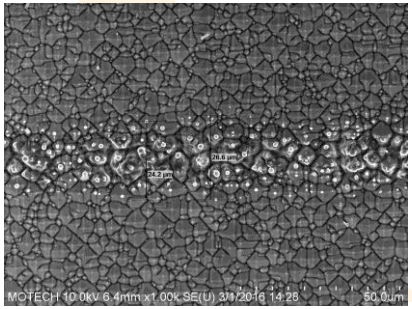
Tuning of Laser Process

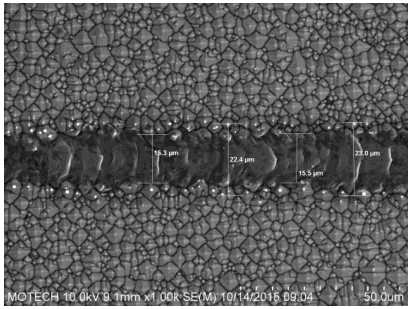
Tuning 532nm ns laser to achieve

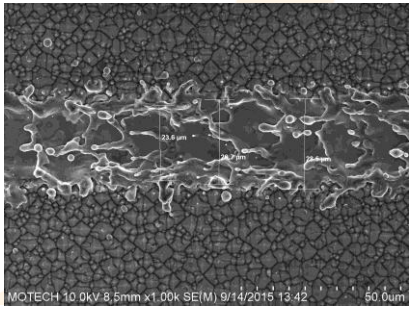
- Removal of SiNx
- Thin line; uniform width
- Usable emitter





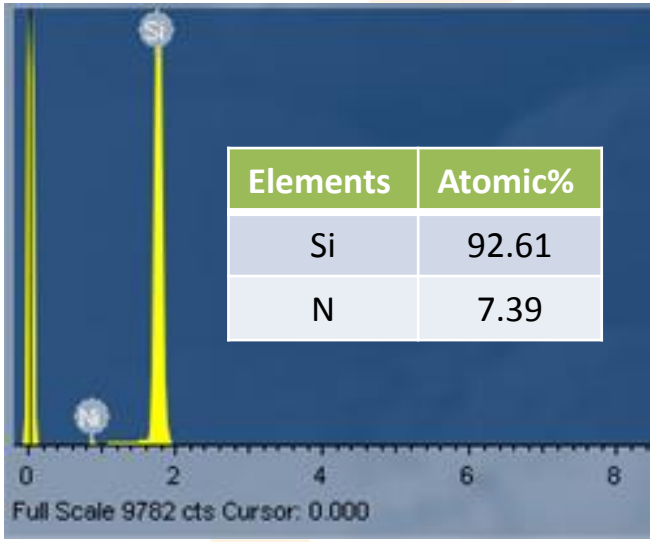




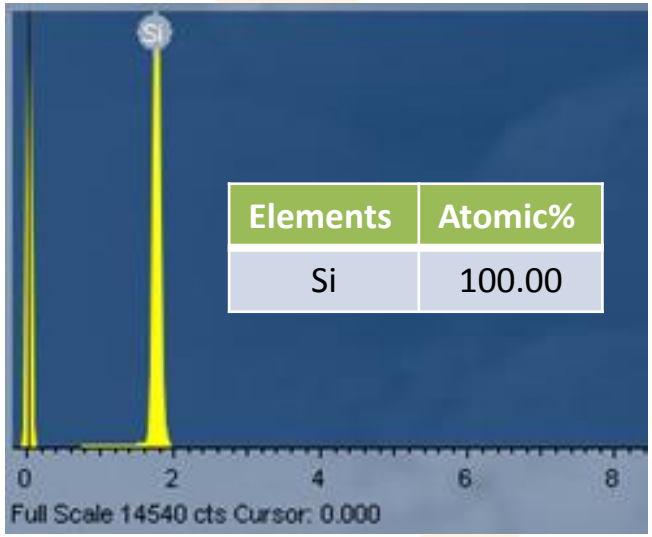


Ablation of SiNx

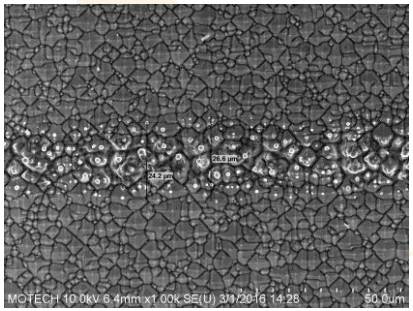
- EDS used to verify the removal of SiNx

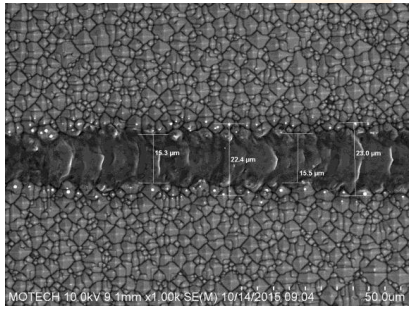


Elements	Atomic%
Si	92.61
N	7.39

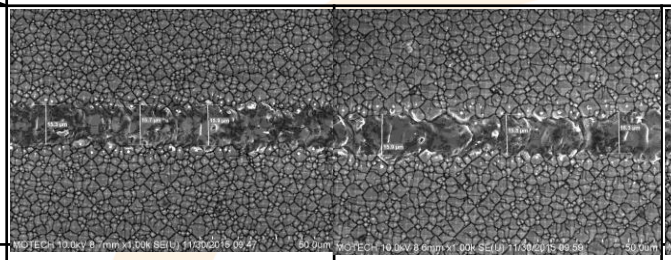
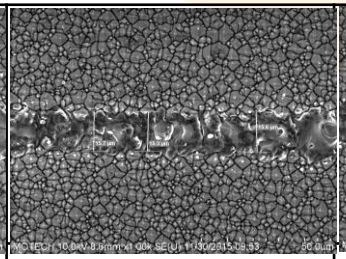
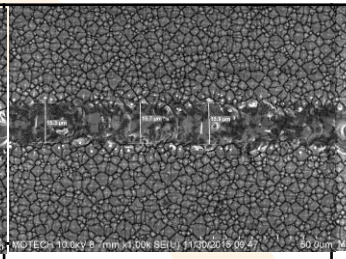
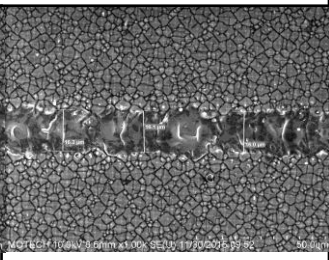


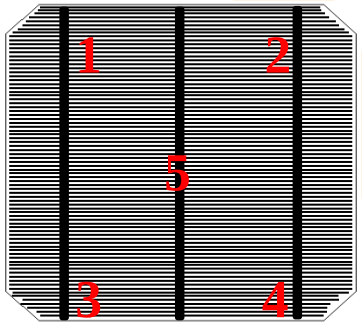
Elements	Atomic%
Si	100.00





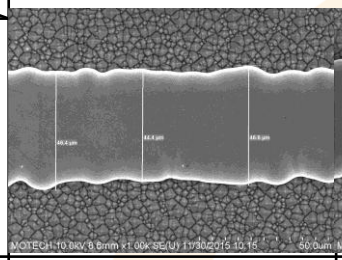
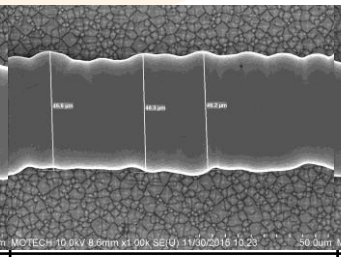
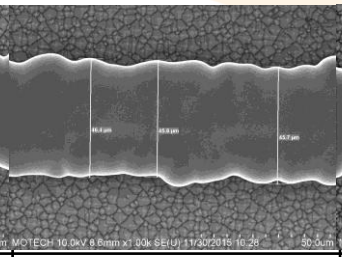
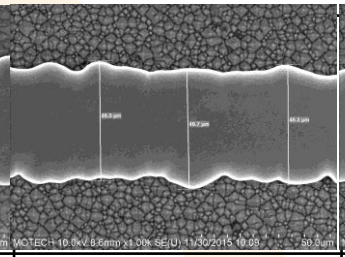
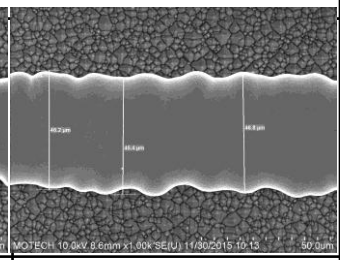
Contact Opening Width

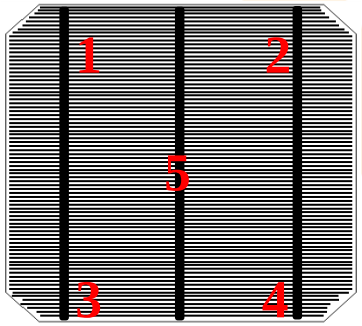
	Dielectric Layers Opening Width				
Finger 1-5					
Width (µm)	15.63	16.00	15.53	15.63	15.90
Ave. (µm)	15.74				
Std. (µm)	0.20				
Uniformity	1.49%				



- Contact opening width can be as low as 15um by 532nm ns laser

FBP Metal Finger Width

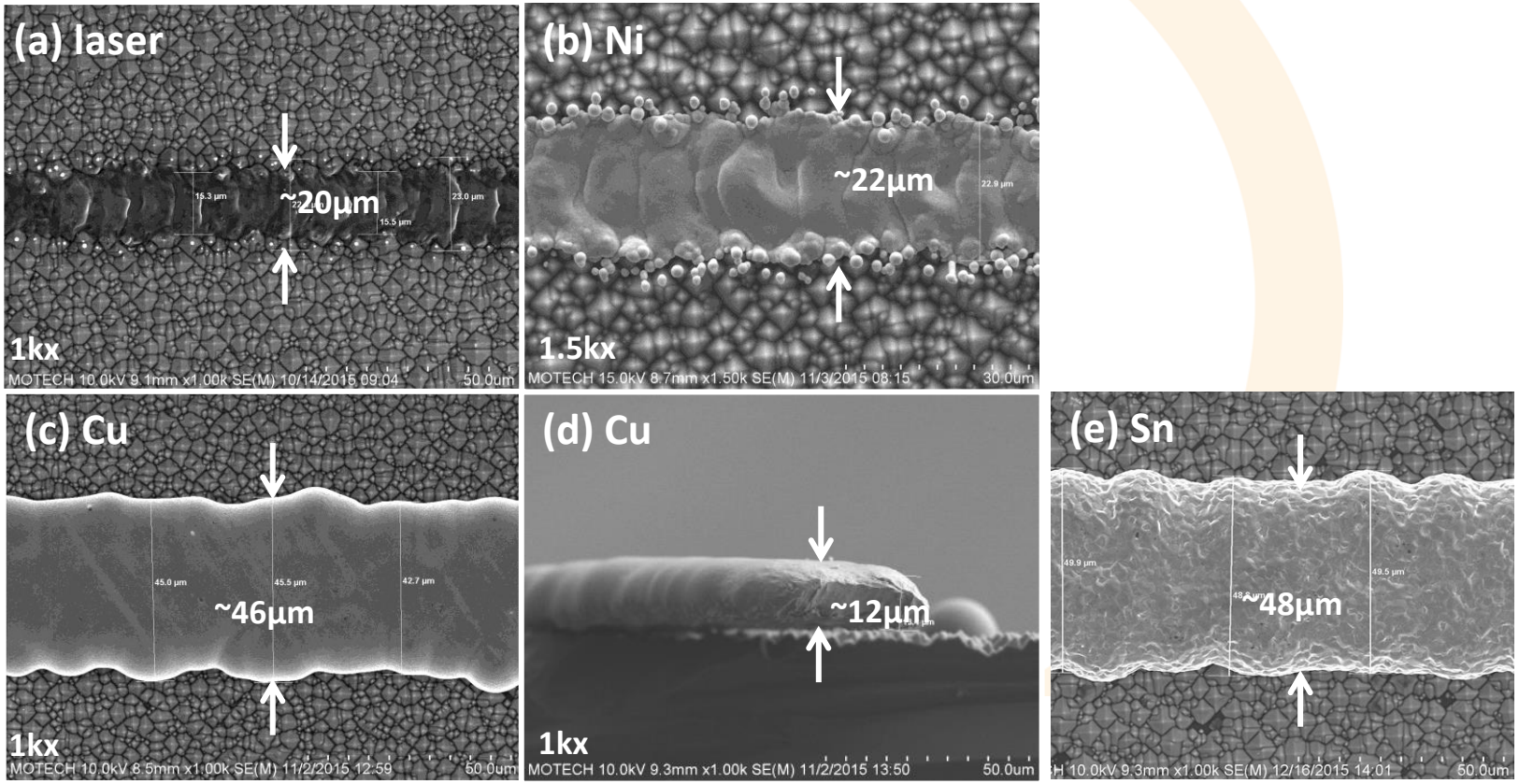
	Finger Width after Plating processes				
Finger 1-5					
Width (µm)	45.80	46.37	45.90	46.50	46.13
Ave. (µm)	46.14				
Std. (µm)	0.30				
Uniformity	0.76%				



- Achieved <50um finger width for plated electrodes

FBP Finger Shape

- Isotropic deposition
  - Overgrowth at the edges
  - Finger aspect ratio depends opening and thickness



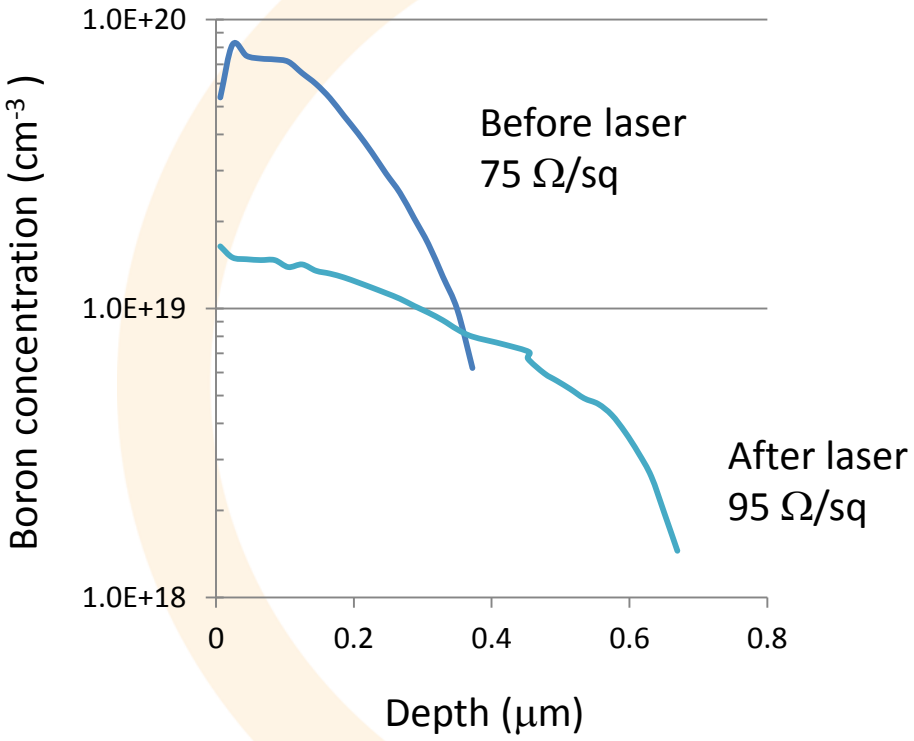
Highly Conductive Cu Fingers

- R-line measurement showed Cu fingers much more conductive

	R-line (Ω/cm)						ρ (μΩ.cm)
	Finger 1	Finger 2	Finger 3	Finger 4	Finger 5	**Avg.**	
Ag/Al paste	0.389	0.409	0.398	0.378	0.331	**0.381**	**~2.7**
Cu plating	0.253	0.255	0.259	0.258	0.223	**0.250**	**~1.9**

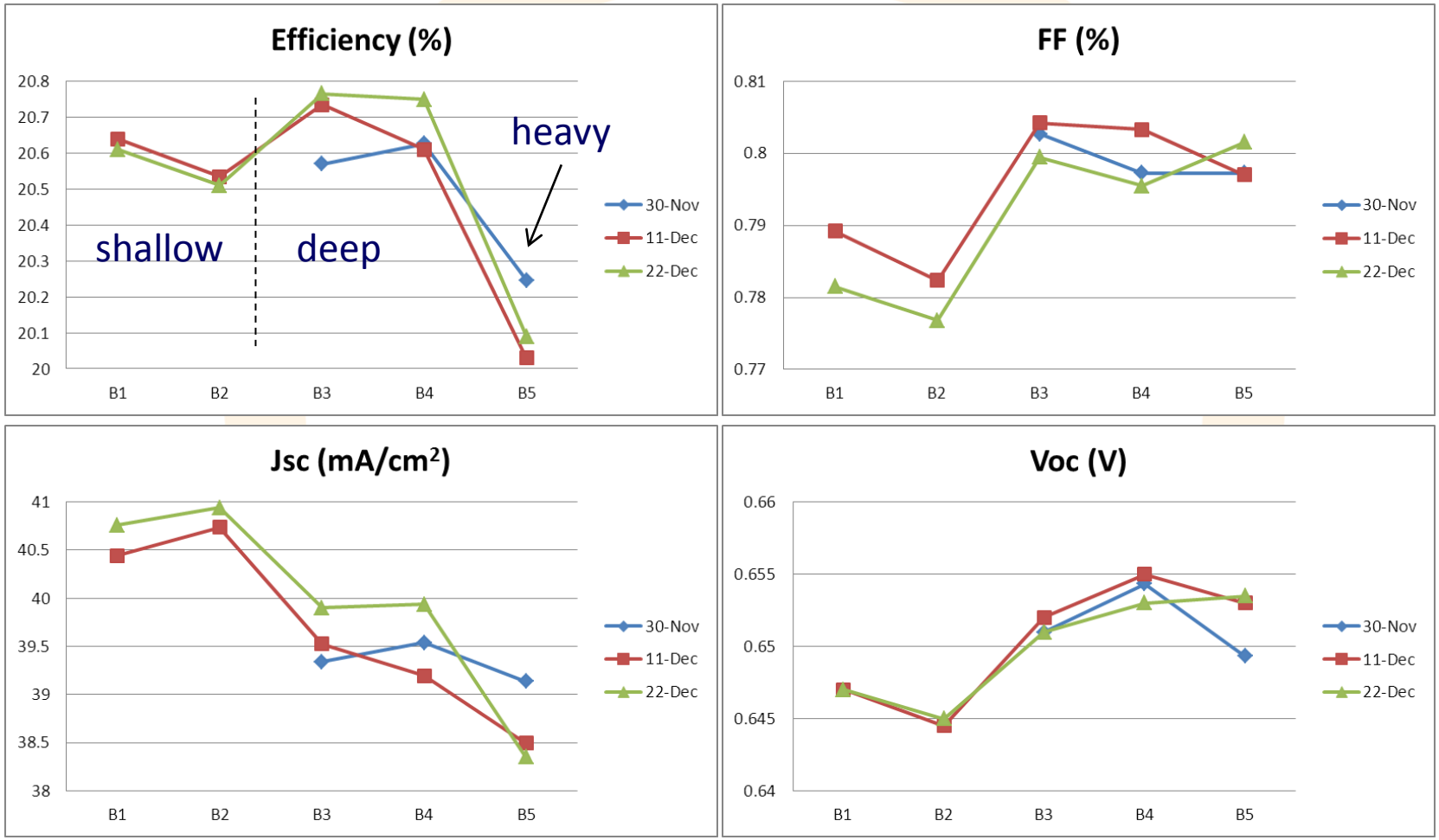
Emitter Modification by Laser

- Laser process significantly changed emitter profile

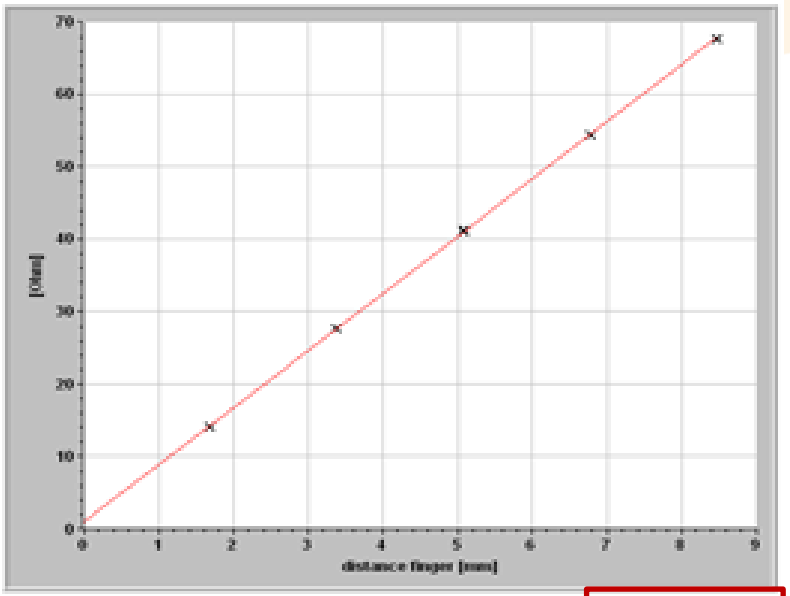


Emitter Experiments

- Various emitters tested for cell performance

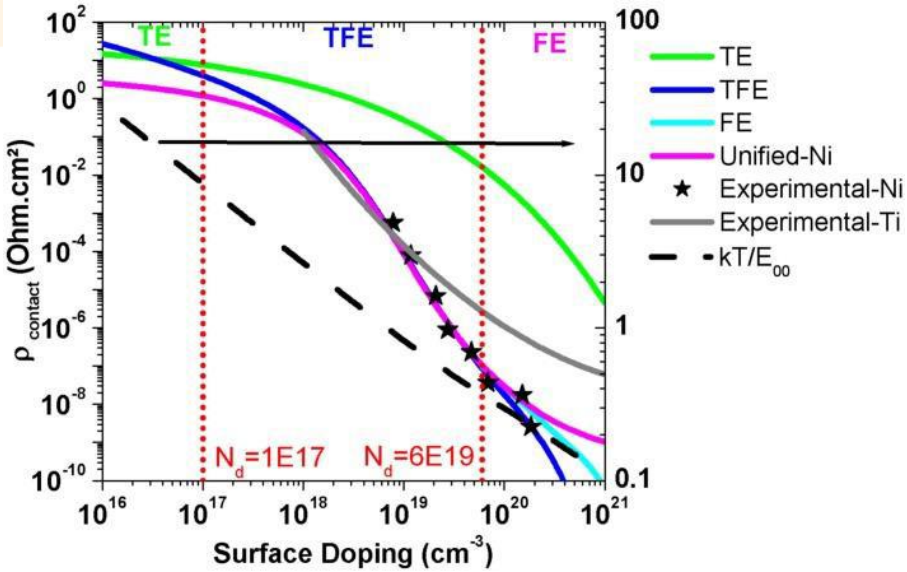


Contact Resistivity



Rc [Ohm]	Rsh [Ohm/sq]	LT [µm]	rhoC [mOhmcm²]
0.49 +/- 0.051	78.9	36.74	1.07 +/- 0.13

TLM data of Motech plated cell

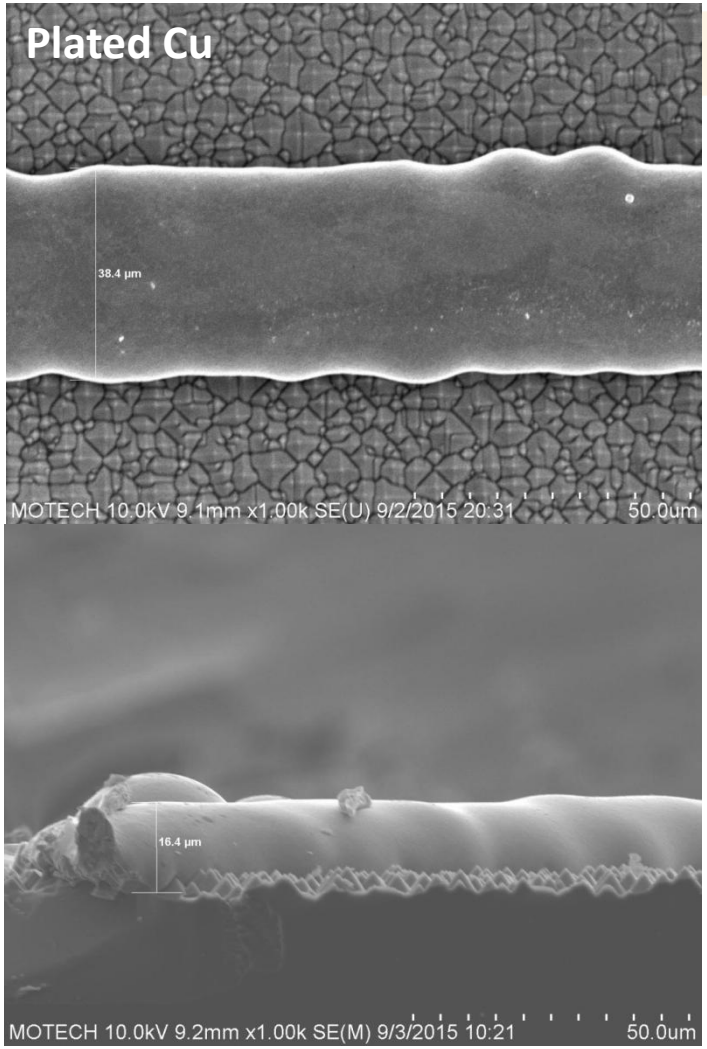


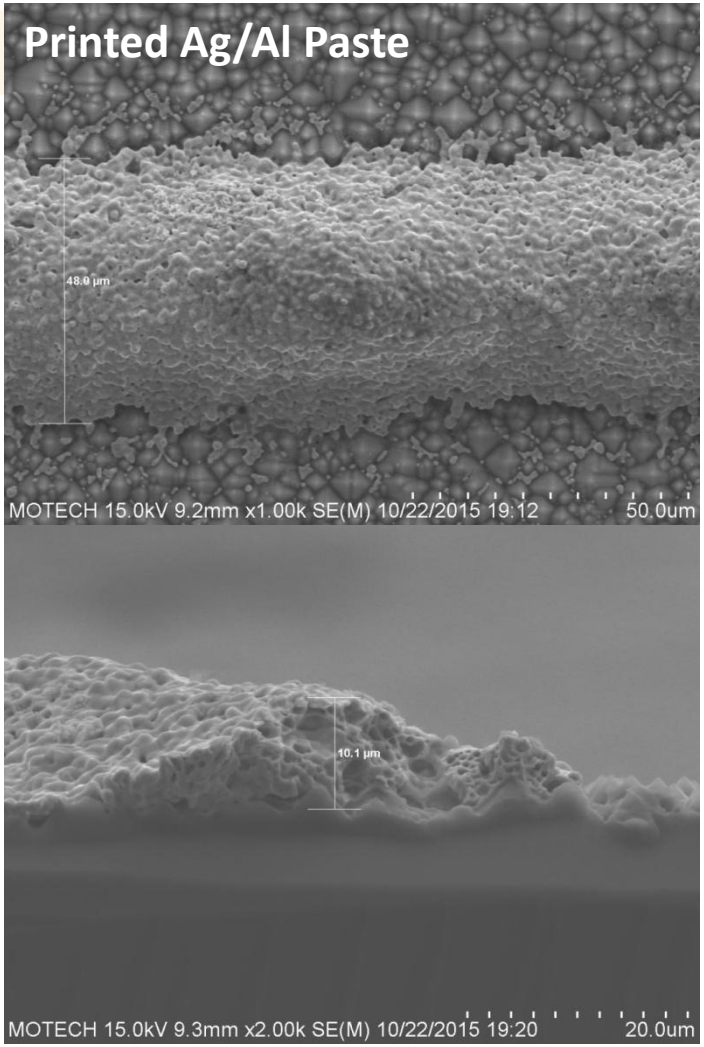
ρ_c of NiSi silicide contacts

Ref: Energy Procedia 38 (2013) 321 – 328

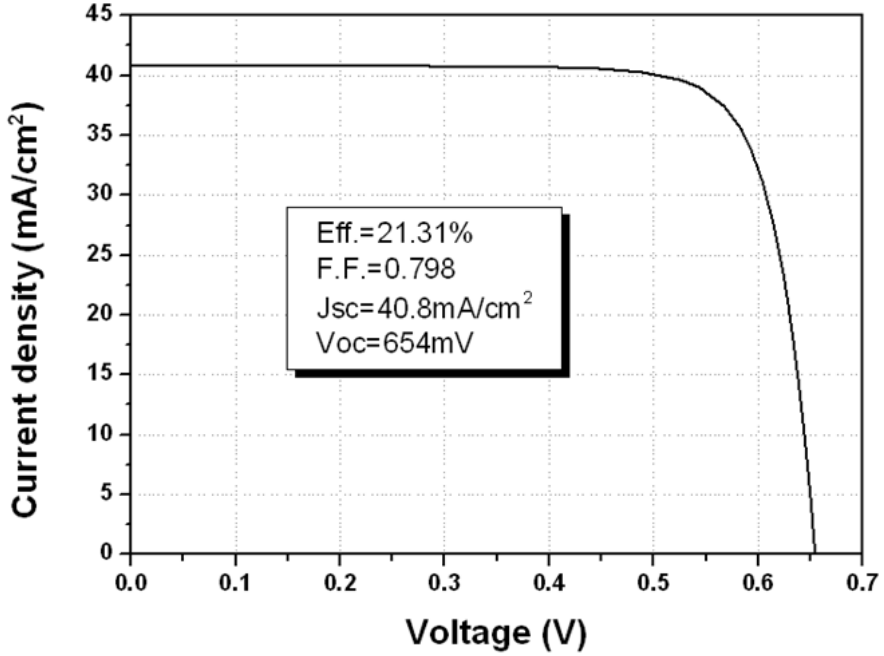
- ρ_c of printed Ag contact is generally 1~3 mΩ.cm^2.
- ρ_c of NiSi silicide contact can achieve 0.1~0.001 mΩ.cm^2 level with 1E19~5E19 cm^{-3} surface doping concentration

Plated vs. Printed



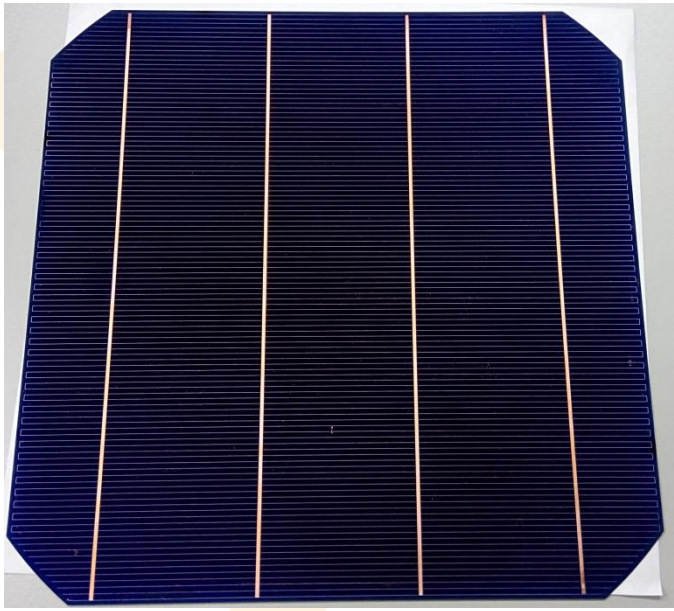


>21% Cell Efficiency



Data corrected

Cell Type:			nPERT
Serial Number:			0225479
Reference:			reference
Cell Area:		[cm²]	238.95
E	STC	[W/m²]	1000
Temp	STC	[°C]	25.00
E	meas.	[W/m²]	944
Temp	meas.	[°C]	26.66
Uoc		[V]	0.654
Isc		[A]	9.748
Ump		[V]	0.557
Imp		[A]	9.135
Pmax		[W]	5.092
FF		[%]	79.82
N		[%]	21.31
Rs		[mOhm]	2.07
Rsh		[Ohm]	119
Iap		[A] at 0.50V	9.577
Irev1		[A] at -10.00V	0.847
Irev2		[A] at -12.00V	1.407



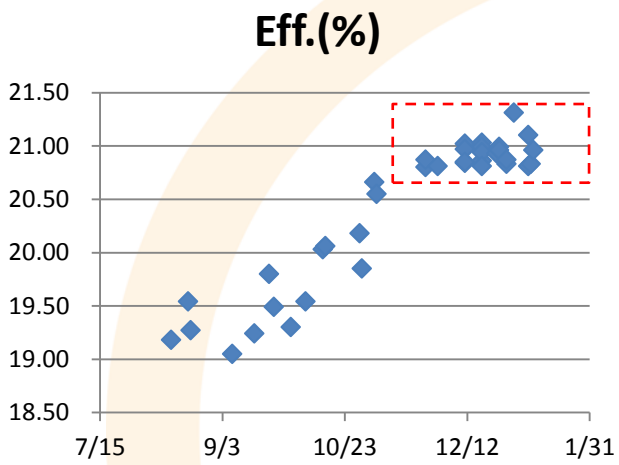
I-V curve of Motech plated n-PERT solar cell

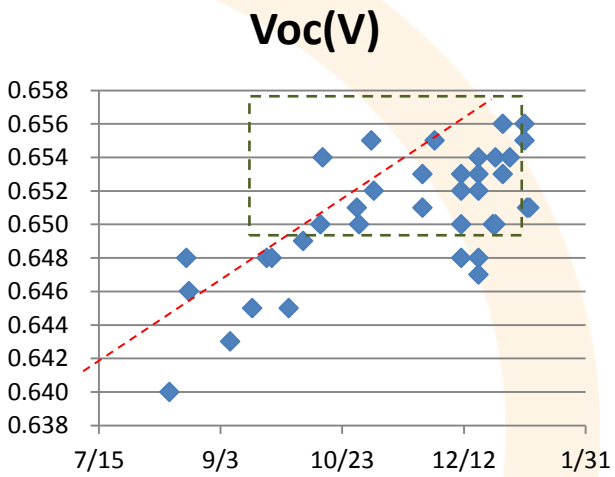
Best cell efficiency with different metallization

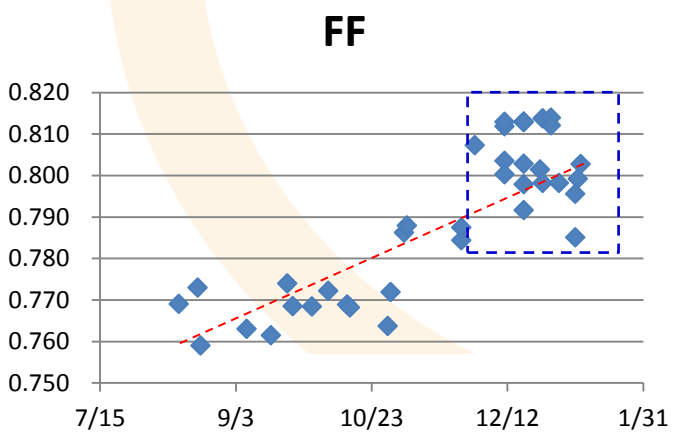
Conditions	Eff. (%)	FF	Voc (mV)	Jsc (mA/cm²)
Ag/Al paste	20.90	0.801	655	39.84
Ni/Cu/Sn	21.31	0.798	654	40.80

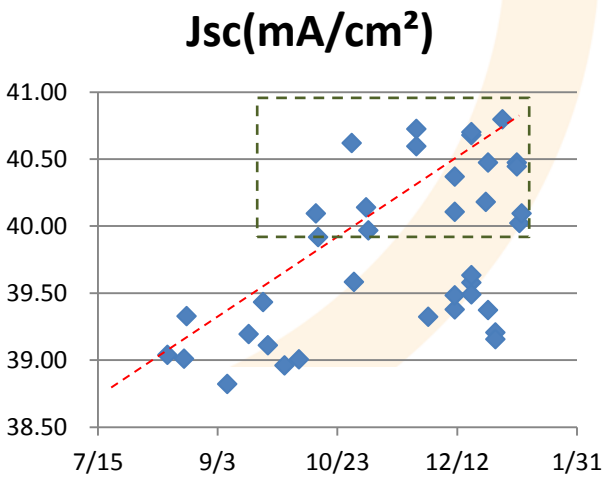
Trend Chart of Cell Performance

- Acknowledgement: one-year grant from Ministry of Economic Affairs









Outline

- Motivation
- Experimental Setup
- Results & Discussion
- **Conclusion**

Conclusion

- Demonstrated forward bias plating of Ni/Cu with 532nm ns-laser contact opening process
  - 6” plated n-PERT solar cell reached efficiency 21.31%
  - Fine line capability
  - Highly conductive fingers
- Continued development for
  - Contact performance
  - Adhesion
  - Reliability

Thank You
for Your Attention