

SEMICON SHANGHAI 2012

PV Ribbon:

Overview of Product Specifications and Comparison of Production Processes

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Agenda

- PV Ribbon and Industry Dynamics
- PV Ribbon Specifications and Requirements
- Critical Quality Parameters for PV Ribbon
- PV Ribbon Production:

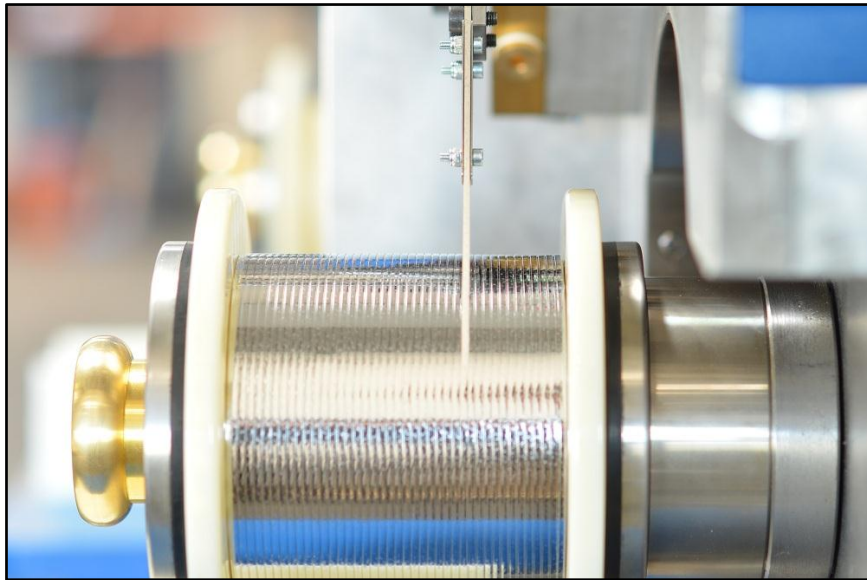
PlasmaPREPLATE Tinning vs. Traditional Tinning



What is PV Ribbon?

PV ribbon is a hot dip tinned copper conductor used in photovoltaic panels.

- **Interconnect/Tabbing Ribbon** – for solar cell interconnection
- **PV Bus Bar** – connects interconnect ribbons to the junction box

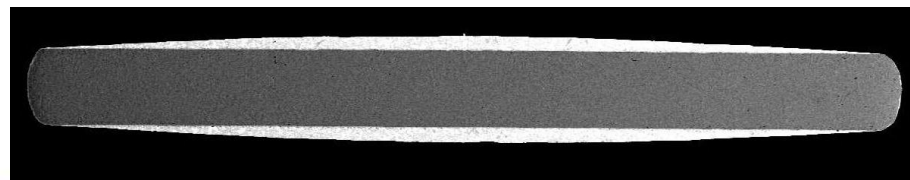


PV Ribbon Market Dynamics

- Many different types of panels & cells => **many different types of PV ribbons**
- Innovation & new cell & panel design => **changing PV ribbon specifications**
- Constant price pressure on solar panel => **pressure on PV ribbon pricing**
- PV ribbon is a key component to ensure panel **efficiency and durability**
- Quality PV ribbon reduces **stringer downtime and scrap rate on stringer**
- Ever more demanding PV ribbon specifications:
 - **Ever thinner cells => ever softer wire, particularly Yield Strength**
 - **3/4/5/6 ribbons per cell instead of 2 => smaller ribbons & larger output required**
 - **More automated panel production & soldering => ever smaller PV ribbon tolerances**

PV Ribbon Product Range

- **Conductor size range:**
 - PV Bus Bar: width [3mm – 6mm] x thickness [0.2mm – 0.5mm]
 - Interconnect Ribbon: width [0.8mm – 2mm] x thickness [0.15mm – 0.25mm]
- **Conductor material:** ETP, DIP Form, or OFC (CD-110, CD-101, CD-102)
- **Solder Types:** Sn; SnPb; SnAg; SnCuAg; SnPbAg; BiSn; BiSnAg
- **Solder coat thickness range:** 10 micron – 40 micron +/- 10%-30%
- **Typical solder coat thickness:** 20 micron +/- 4micron
- **Solder Thickness Measurement:** X-Ray, Micrometer, Laser (in-line)
- **Packing options:**
 - Typical spool types: Europe: DIN K125, K160, K200, K250 / Asia: P4, P10
 - Various discs/pancakes
 - Cut length ribbons



CRITICAL PARAMETER: YIELD STRENGTH

WARPAGE is a result of cooling of solar cell after soldering/stringing

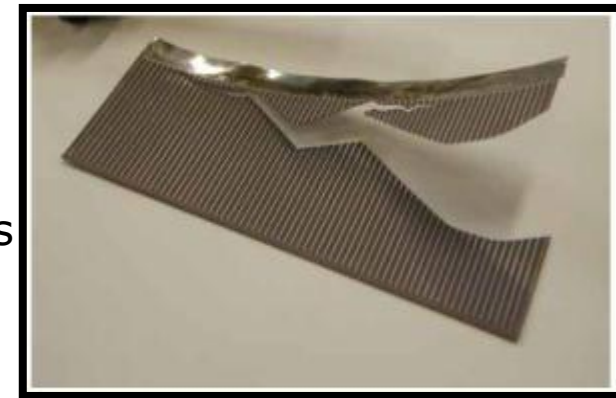
Ever thinner solar cells require ever lower YS (Rp0.2%)

- **5 year ago:** 300 μ m thick Si solar cell => YS < 130MPa*
- **Today:** 160 – 180 μ m thick Si solar cell => YS < 70MPa* / < 80MPa*
- **Tomorrow:** trend to thinner Si solar cell => YS < 50MPa*

* Rp0.2% measured using bare copper ribbon thickness (excl. solder coating)

Areas of Improvement:

- Ensure **input copper quality**
- Chose the right **annealing** and **rolling** techniques
- Optimize **transport systems** on the tinning line
- Optimize **payoff on the stringer**



CRITICAL PARAMETER: CAMBER

- Production of solar panels has become fully-automated with increasing stringing speeds
- High-output, fully-automated stringers require low camber interconnect ribbon to minimise down-time and scrap

Current Target Camber < 5mm in 1m

Areas of Improvement:

- Improve the **accuracy of layer winding on the spooler**, which requires precision mechanics and process control;
- Optimize **coating thickness tolerances**;
- Examine the **payoff system on stringer**

PlasmaPREPLATE Tinning Line for PV Ribbon Production

Payoff > PlasmaPREPLATE (annealing & surface preparation) > Tinning > Takeup



Flexible PV Ribbon Line Configuration



Alternative Production line configurations:

- **Stand-alone PV Ribbon Line** for annealing, tinning with takeup & payoff (for super-soft PV Ribbon @ max 210m/min)
- **Integrated PV Ribbon Line** integrated with a rolling mill so that rolling annealing, tinning is done inline and super-soft PV Ribbon is produced acid/flux-free @ max 210m/min
- **PlasmaANNEALER** is integrated with existing tinning lines & rolling mills whereby rolling, annealing, tinning can be done in-line to produce super-soft PV Ribbon @ max 210m/min
- **PlasmaANNEALER** for in-line operation with a high speed-rolling mill for annealing at up to 600m/min

Traditional Tinning vs. PlasmaPREPLATE Tinning

	Traditional Tinning	PlasmaPREPLATE
Process type	Multi-line tinning process with wet chemical surface preparation	Single line high-speed tinning, Dry surface treatment without fluxing
Production speed	30–100m/min , subject to ribbon softness	max 210m/min
Annealing type	furnace/resistive/induction (off-line)	Plasma (inline with tinning)
Surface preparation for tinning	Acid, rinsing, fluxing prior to tinning Expensive and harmful to operator	Dry, chemical-free plasma treatment Low cost and operator friendly
Production cost	High - Labor, chemicals, energy	Low
Production continuity	More frequent changeover – 5-50kg payoff and takeup spools	Less changing over – 500kg payoff spools 5-15kg takeup spools
Scrap rate	High - Wet processes difficult to control operator experience and skills are key	Low In-line PLC based quality control
Solder wastage	High - flux contamination in tin bath	Low - Flux-free production
Production control	Limited PLC with manual assistance – Complex multi-line production / line-to-line interference	Fully PLC controlled production – in-line PLC quality control & alarm system



PV Ribbon Product Quality

Benefits of PlasmaPREPLATE vs. Traditional Process

- Superior and consistent product quality:
 - Super soft wire with YS down to **50MPa on spool** & high level of elongation over 30%
 - Smooth consistent and shiny tin coat with **lower thickness tolerance**
 - Flux & chemical-free tinning allows **better process control** and finished product quality
- Rapid product development for new products with various specifications
- Computer enabled, **in-line product quality control**
- Computer assisted **Production Recipe Database**
- **In-line laser coating thickness measurement** system
- **Alarm and surface fault record database**



Cost of PV ribbon Production

Benefits of PlasmaPREPLATE vs. Traditional Process

- High production speed – **up to 210m/min**
- High production speed, production automation & process control = **less man power**
- Increased production **uptime** and less frequent spool **changeovers**
- **Dry surface preparation** (no rinsing, no drying, no waste disposal, no water treatment)
- Considerably **less tin waste** – no flux contamination of tin
- Low **operation costs** (lower power, cost of chemicals and their manipulation)
- Low **maintenance costs**
- Smaller compact **footprint**
- Computer enabled basic **maintenance alerts**
- **In-line quality control = improved product quality = less scrap and returns**