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iSilver Materials

Research and development of low temperature pastes for silicon heterojunction solar cells

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苏州晶银新材料科技有限公司
Suzhou iSilver Materials Co., Ltd.

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Part 1

Company profile

Company Profile

晶银新材
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- Suzhou isilver Materials was founded in 2011.
- A high-tech enterprise engaged in the field of new energy and semiconductor.
- Purchased and listed by Suzhou Good-ark (SZ002079) in 2020.

Focus on photovoltaic and semiconductor electronic materials
Core technology system of independent innovation

> 27 acres	> 1000 tons	> 200 tons	> 160 people	> 10 million yuan
Area	Plant capacity	Capacity of LTP	Employee	Per capita output value

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Part 2

The direction of low temperature pastes

Application status and limitations of the paste for heterojunction cells

Three difficulties:

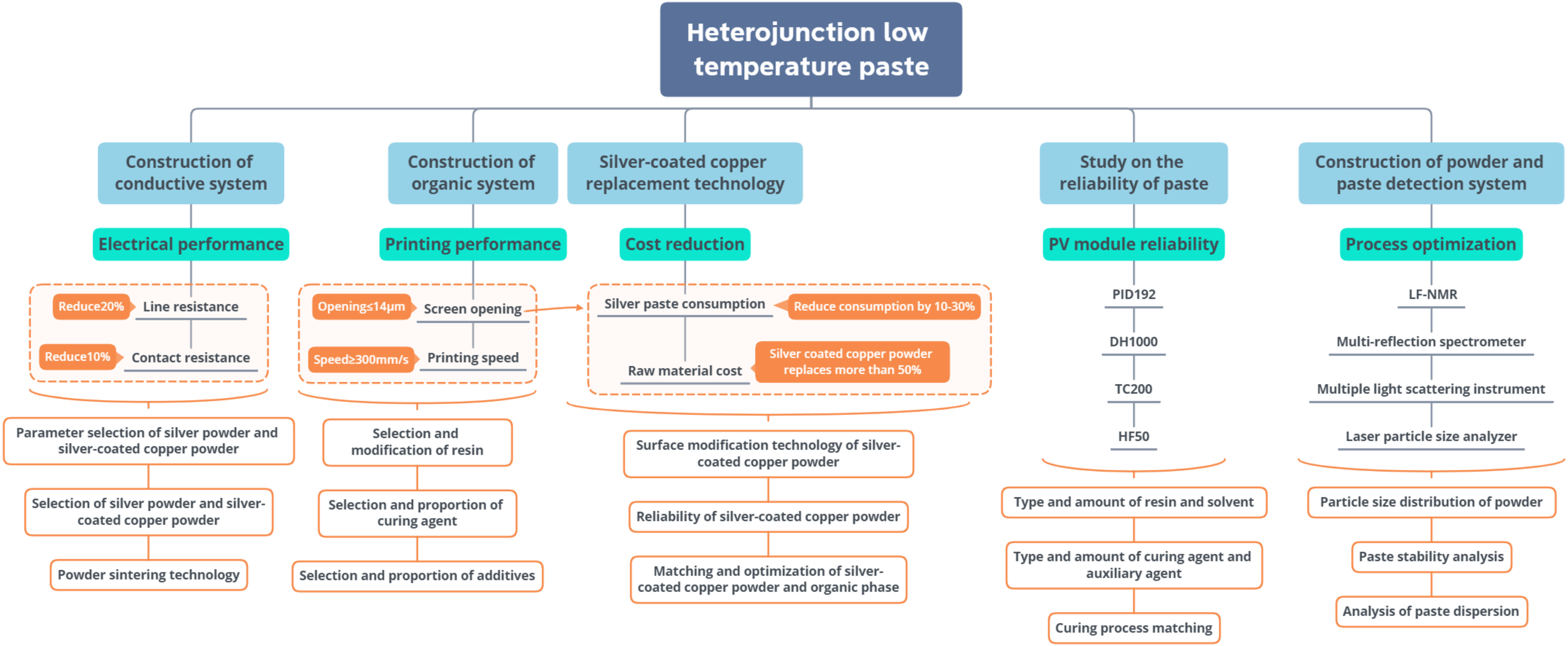
- **High consumption——1.5-2 times higher than that of the high temperature paste**

18-22mg/W on regular production line of heterojunction cells， compared with PERC cells (10-12mg/w)

- **Low printing speed——Low productivity**
  - the printing speed of 300-350mm/s on production line，compared with PERC cell (450-500mm/s)

- **Wider grid —— Heavy use of paste,Low efficiency**
  - About 35-40μm in width on production line，compared with PERC cell (20-25μm)

R&D roadmap of low temperature paste



Heterojunction low temperature paste

- **Construction of conductive system**
  - **Electrical performance**
    - Reduce20% → Line resistance
    - Reduce10% → Contact resistance
  - Parameter selection of silver powder and silver-coated copper powder
  - Selection of silver powder and silver-coated copper powder
  - Powder sintering technology
- **Construction of organic system**
  - **Printing performance**
    - Opening≤14μm → Screen opening
    - Speed≥300mm/s → Printing speed
  - Selection and modification of resin
  - Selection and proportion of curing agent
  - Selection and proportion of additives
- **Silver-coated copper replacement technology**
  - **Cost reduction**
    - Silver paste consumption ← Reduce consumption by 10-30%
    - Raw material cost ← Silver coated copper powder replaces more than 50%
  - Surface modification technology of silver-coated copper powder
  - Reliability of silver-coated copper powder
  - Matching and optimization of silver-coated copper powder and organic phase
- **Study on the reliability of paste**
  - **PV module reliability**
    - PID192
    - DH1000
    - TC200
    - HF50
  - Type and amount of resin and solvent
  - Type and amount of curing agent and auxiliary agent
  - Curing process matching
- **Construction of powder and paste detection system**
  - **Process optimization**
    - LF-NMR
    - Multi-reflection spectrometer
    - Multiple light scattering instrument
    - Laser particle size analyzer
  - Particle size distribution of powder
  - Paste stability analysis
  - Analysis of paste dispersion

R&D direction of low temperature paste

Direction of low temperature paste

- **Develop paste with high conductivity**
  - Select suitable particle size range and thickness ratio of sheet powder and spherical powder to optimize the ratio
  - Select suitable resin curing system, control shrinkage rate and optimize interface contact
  - Selecting suitable additives and solvents, optimizing the formulation of carrier, and further increasing the content of conductive powder
  - Compactness of past and interface contact
- **Develop ultrafine printing technology**
  - Design metal powder system, improve the ability of ultra-fine printing , reduce wet weight
  - Select suitable high dispersion organic system to improve powder dispersion, avoid screen blocking, grid break
  - Optimize the formula, help the paste pass through and back
  - Printability
- **Develop paste with high welding tension**
  - Reduce the internal stress concentration: Reduce the defects after curing resin, add flexibilizers
  - Improve weldability: Control solid content and add welding aid
  - To improve the adhesion of TCO layer: Select appropriate resin, add coupling agent and other additives
  - Adhesive force and weldability
- **Develop low-cost technology**
  - Choose base metal powders instead, such as silver clad copper, silver clad alloy powder
  - Select suitable surface coating system and develop matching organic system to improve dispersion and conductivity , reduce the loss of efficiency caused by base metal substitution
  - Develop novel processes, optimize formulations, improve the reliability of base metal replacement technologies
  - Production cost of paste

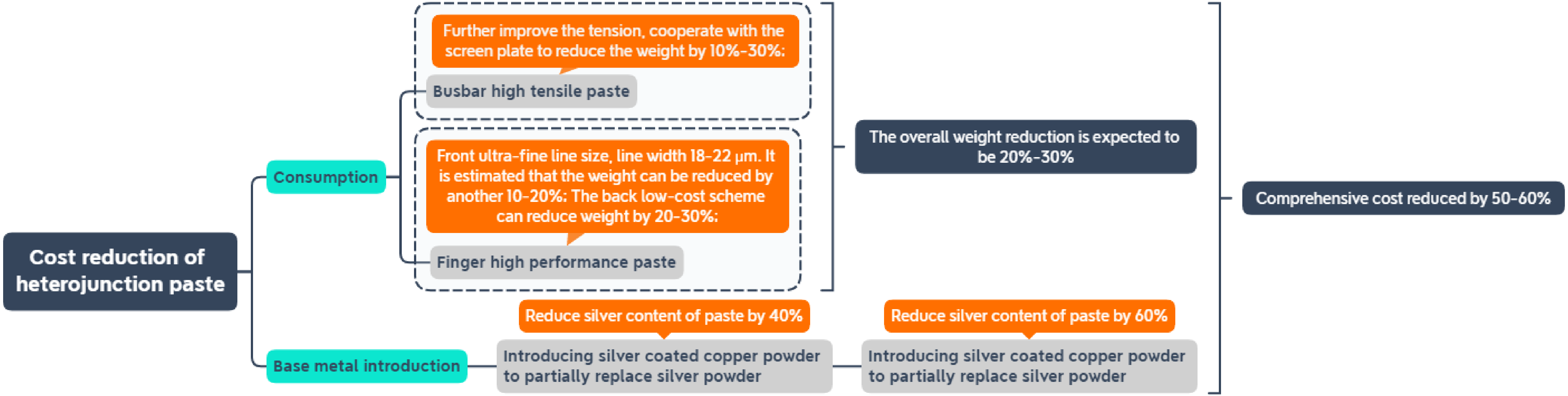
Comprehensive properties

Third generation paste

Fourth generation paste

	Dual printing Busbar	Dual printing Finger	Dual printing Finger	Dual printing Alloyed Busbar	Dual printing Finger with low-cost model	Dual printing Finger with silver-coated copper	Dual printing Finger with silver-coated copper
Category	**HC639-ZX**	**HC649-H**	**HC689-H**	**HSC639-Z**	**HD689-G**	**HAC639-T**	**HAC689-T**
Silver content（%）	92-93	92-93	92-93	60-70	89-91	43-50	30-40
Volume resistivity (μΩ.cm)	6.0-7.0	5.0-6.0	5.5-6.5	8.0-9.5	5.0-6.0	7.0-8.5	7.5-9.0
Viscosity（Pa•s)	250-300	250-300	≥350	≥350	≥350	≥350	≥350
Printing speed （mm/s)	—	≥21	≥12	—	≥18	≥18	≥16
Pulling strength (N/mm)	≥2.0	—	—	≥2.0	—	—	—

Cost reduction roadmap of low temperature paste



Cost reduction of heterojunction paste

- Consumption
  - Busbar high tensile paste
    - Further improve the tension, cooperate with the screen plate to reduce the weight by 10%-30%;
  - Finger high performance paste
    - Front ultra-fine line size, line width 18-22 μm. It is estimated that the weight can be reduced by another 10-20%; The back low-cost scheme can reduce weight by 20-30%;
  - The overall weight reduction is expected to be 20%-30%
- Base metal introduction
  - Introducing silver coated copper powder to partially replace silver powder
    - Reduce silver content of paste by 40%
  - Introducing silver coated copper powder to partially replace silver powder
    - Reduce silver content of paste by 60%

Comprehensive cost reduced by 50-60%

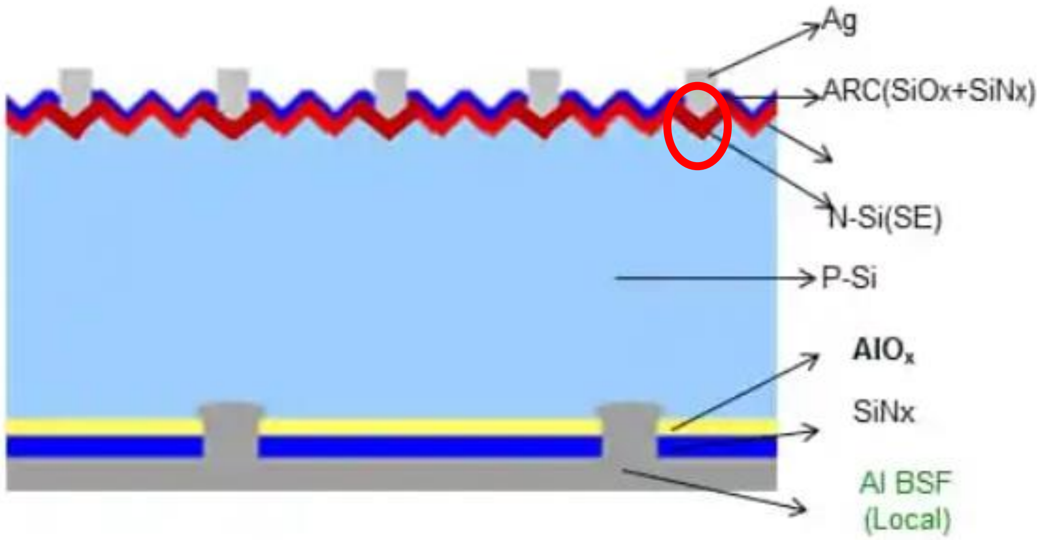
Part 3

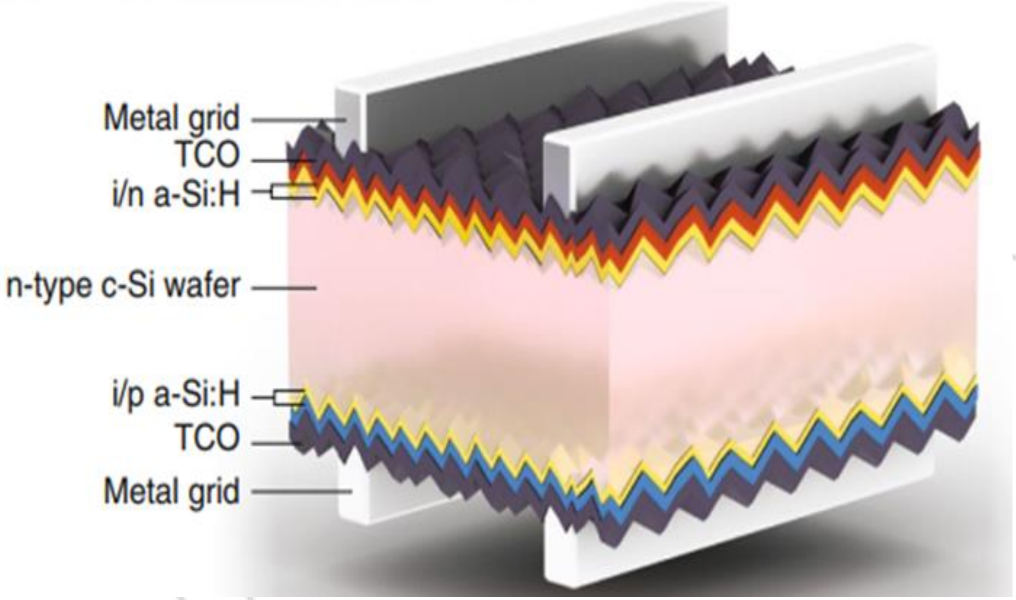
High conductivity technology of low temperature pastes

Difference between high and low temperature paste

Different point：

High temperature front silver paste	Difference	Heterojunction paste
700-800℃	Temperature	170-200℃
Contact with *p-n* junction, burn through anti - reflection layer	Contact theory	Not in direct contact with *p-n* junction, but contact with TCO
Spherical silver powder, flake glass powder, organic component	Composition	Flake, spherical silver powder, organic component
mainly plays a printing role	Organic component	Printing and adhesion
Start early, mature	Development situation	Start late, developing

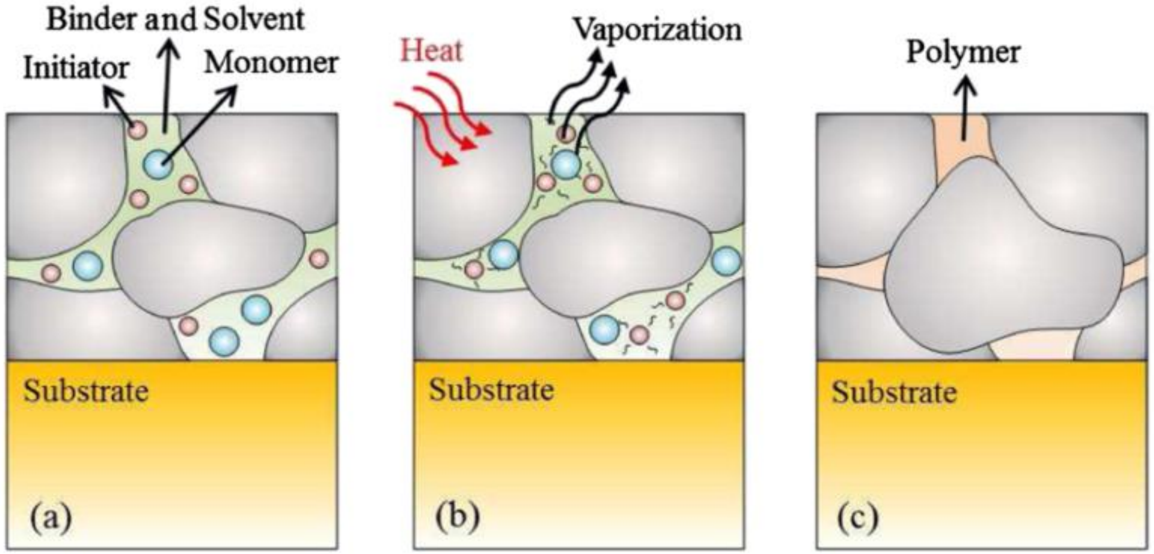




Study on the conductive theory of low temperature paste

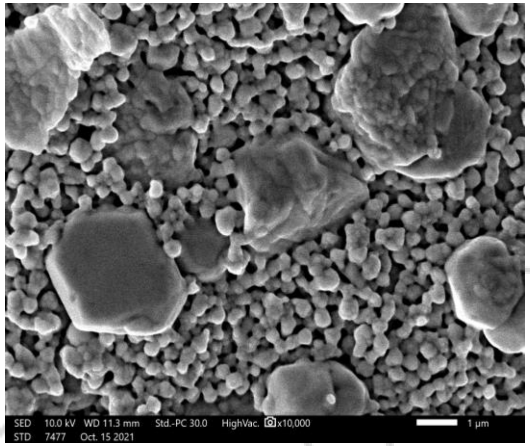
Conductive theory and Ohmic contact of low temperature paste：

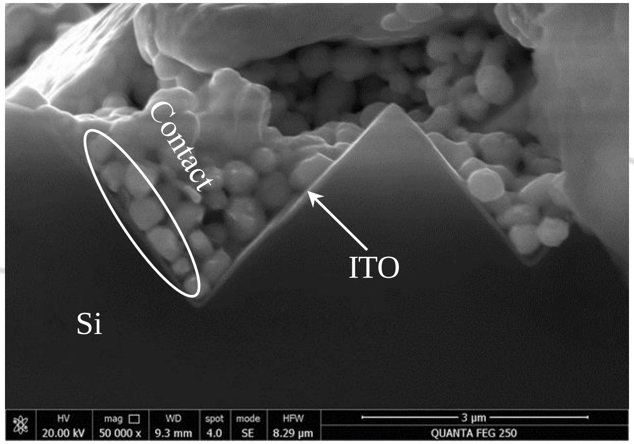
- ✓ After baking, the solvent in the paste evaporates, the resin is crosslinked and solidified, and there is resin on the surface of the conductive powder, which cannot directly transfer electrons.
- ✓ Conduction theory: electron transmission mainly through seepage effect and tunneling effect.



Research content

- Study on ohmic contact mechanism between low temperature paste and TCO layer.
- Optimize conductive phase and organic phase , improve the densification of the paste after curing, enhance the contact, and reduce the bulk resistance and contact resistance through the nano size effect.





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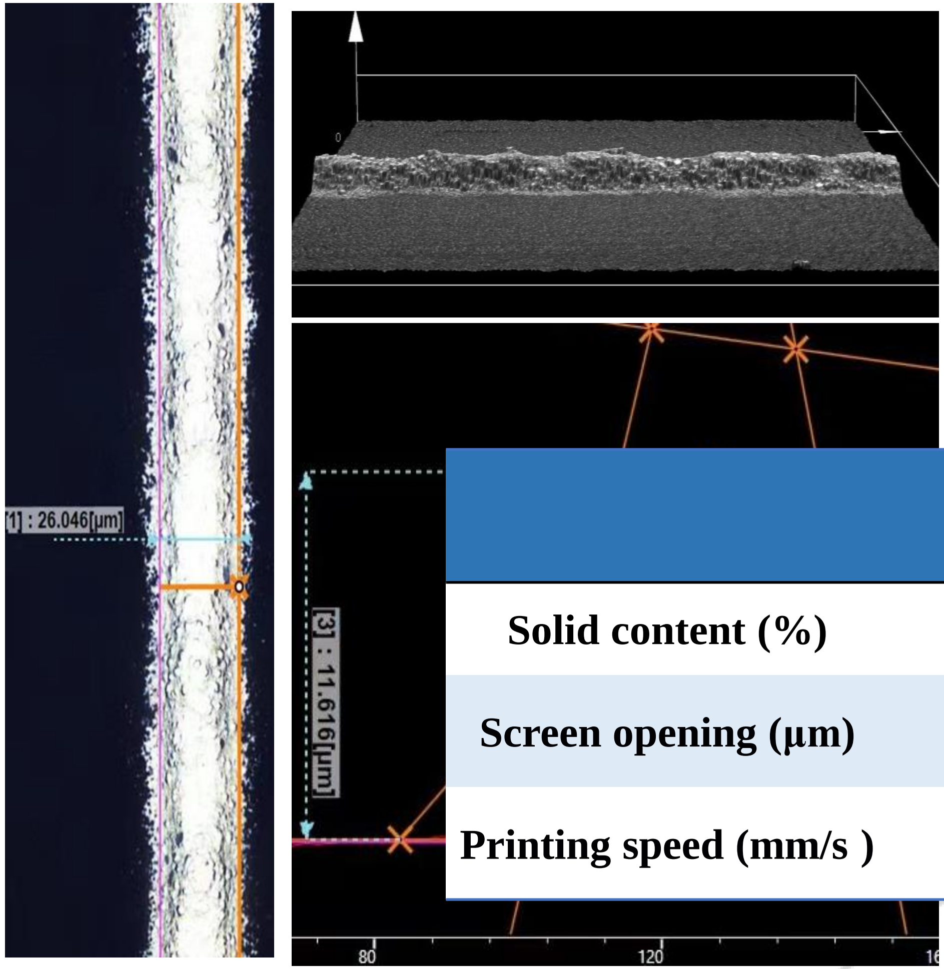
Part 4

Ultra-fine printing properties of low temperature paste

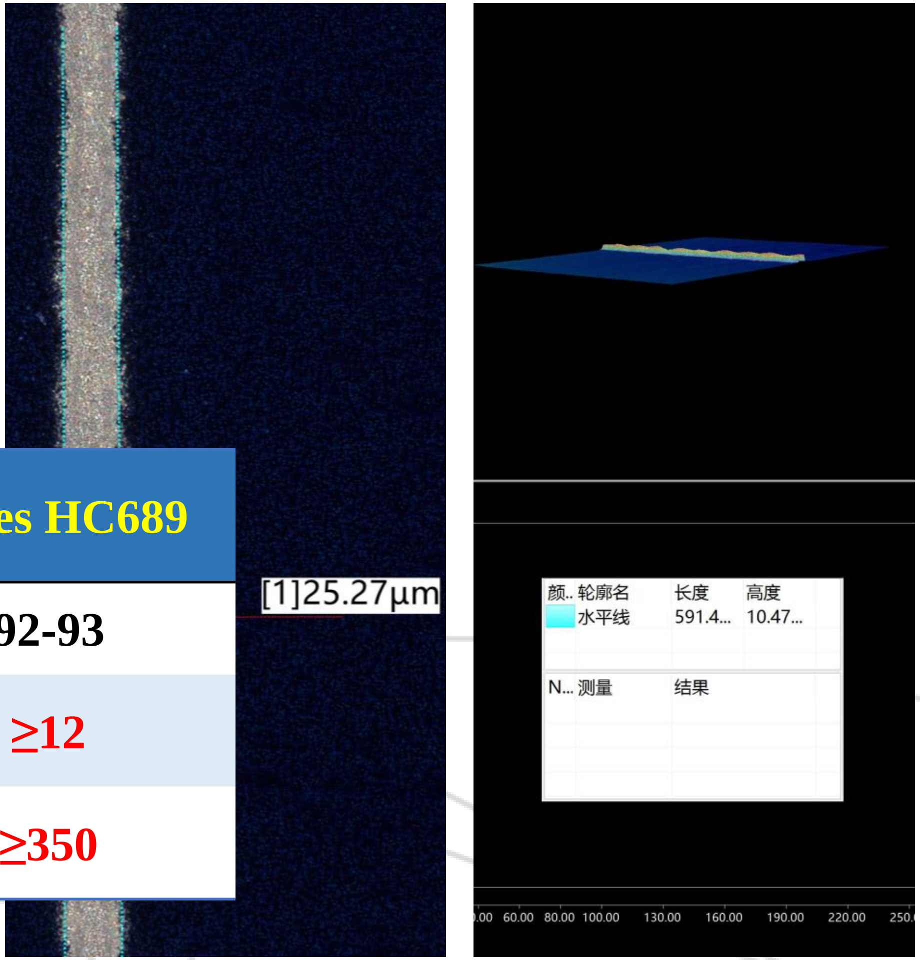
The new generation of front pure silver paste

480/11 PI knotless/opening 17μm



Second generation front fine grid
(in development)

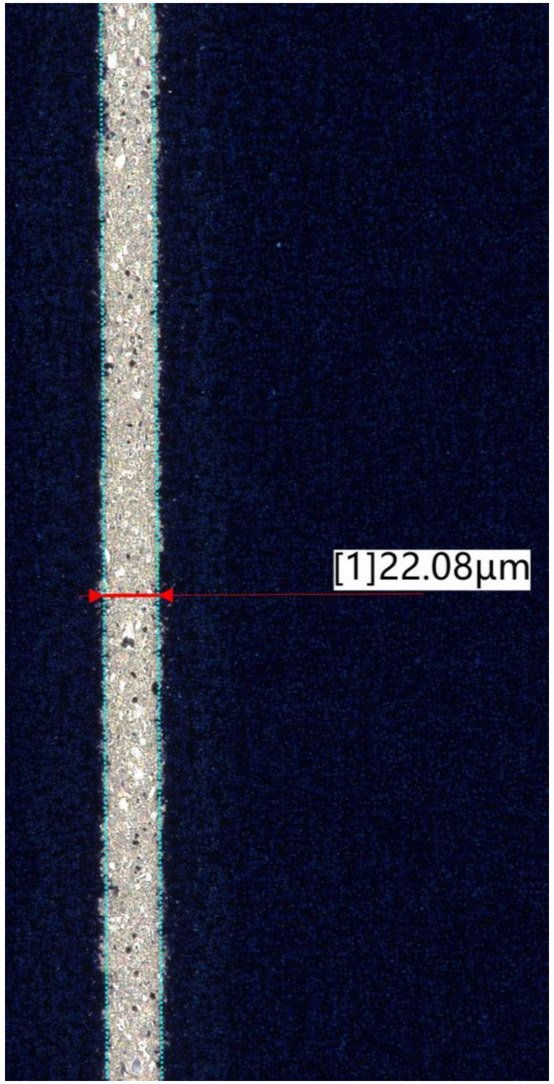
520/11 PI knotless/opening 12μm

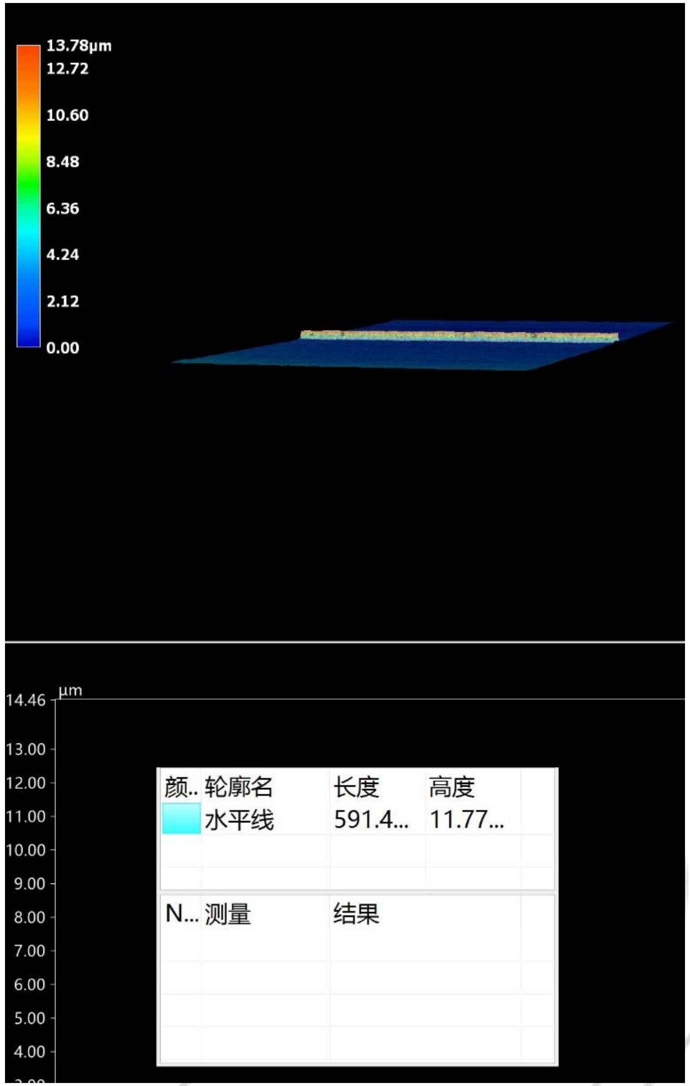


	Series HC649	Series HC689
Solid content (%)	92-93	92-93
Screen opening (μm)	≥22	≥12
Printing speed (mm/s)	230-280	≥350

Fine line scheme paste application

◆ HC series paste matching metal stencil printing:





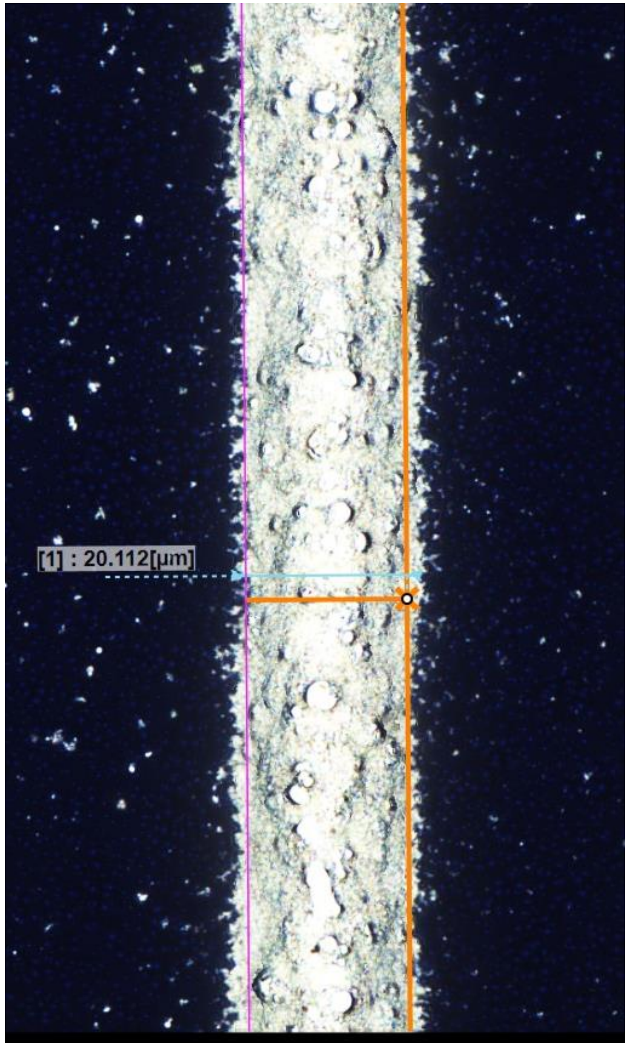
颜..	轮廓名	长度	高度
🟦	水平线	591.4...	11.77...

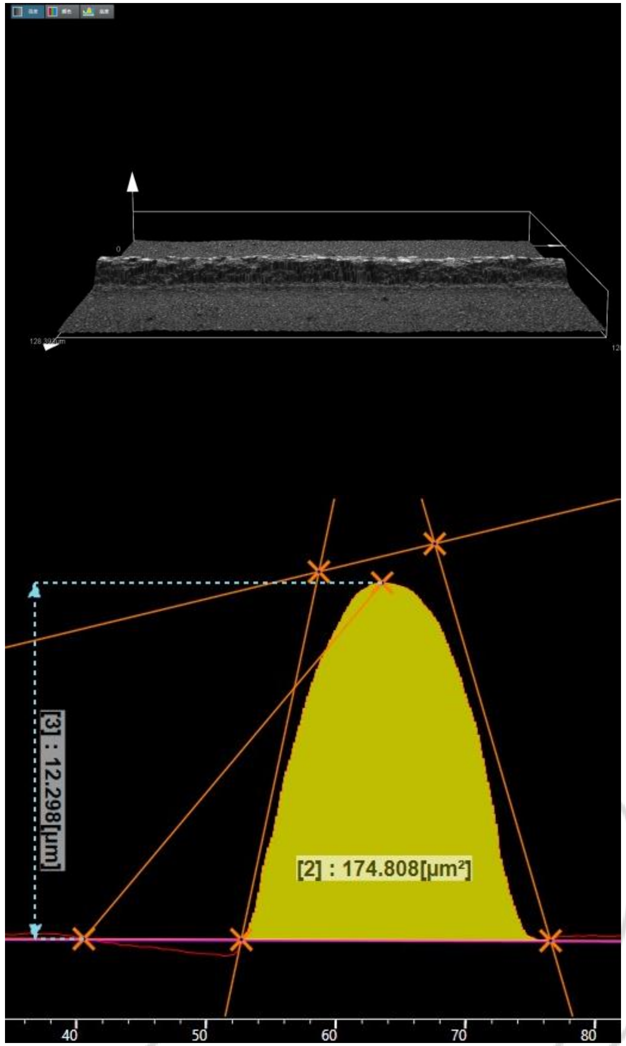
N...	测量	结果

- ➢ **Full-open stencil** is made of stainless steel with high strength, wear resistance and corrosion resistance as the main material.
- ➢ **Full-open stencil** adopts advanced laser technology for full open cutting of stainless steel sheet, and adopts special process to treat the steel plate, so that its opening is smoother and flat, and the line type is better.
- ➢ At present, the fine grid printing with the width of **22-25µm** can be achieved.

Fine line scheme paste application

◆ HJ series paste matching laser transfer：





- **Laser transfer equipment** uses a special scraper to press the heterojunction low-temperature paste into a special bearing film, and then uses a special laser head and its scanning transfer process, combined with a high-precision CCD system, to accurately transfer the paste from the bearing film to the silicon wafer.

- At present, extremely fine grid line printing with width as low as **20µm** has been achieved.

Part 5

Welding tensile properties of low temperature paste

Pull-out failure form of low temperature pastes

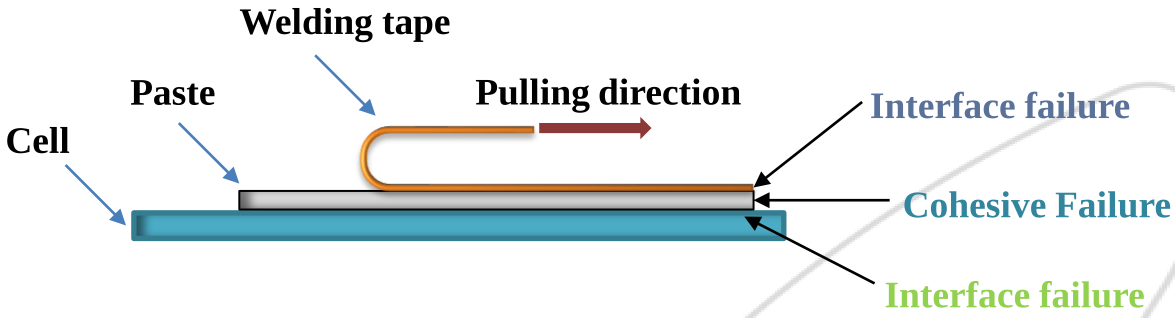
Failure Form

Interface failure between the welding tape and the paste

Interface failure between paste and TCO layer

Cohesive failure in paste

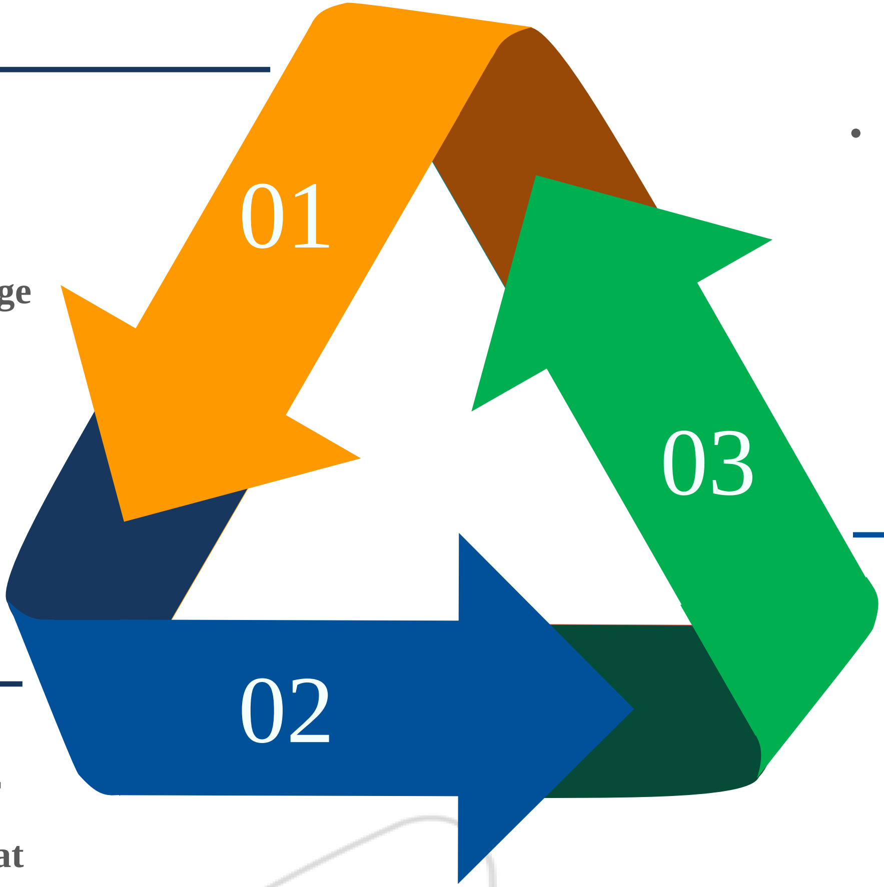
Mixed failure (interface and cohesive failure)



The failure of paste itself is the ideal failure form, that is, 100% cohesive failure, because this failure can obtain the maximum bonding strength when the material is bonded.

Bonding failure occurs at the weakest point and may not always occur at the interface. This indicates that the bonding strength is not only related to the force between the paste, the welding tape and the TCO layer, but also to the intermolecular force of the polymer resin. The chemical structure and aggregation state of polymer molecules will greatly affect the bonding strength.

The internal stress of low temperature paste



Shrinkage stress

- Shrinkage stress caused by volume shrinkage due to volatilization, cooling and chemical reaction during paste curing.

Internal stress caused by aging

- During the aging process of the paste after curing, the internal stress is easy to occur at the main fine grid joints due to temperature change or water vapor .

Thermal stress

- The CET of the paste is different from that of the TCO layer and the welding strip, so the change of temperature will cause thermal stress.

The internal stress of low temperature paste

relieving of internal stress

01

To copolymerize or increase the molecular weight of the polymer for lower concentration of functional groups in the system.

02

Adding toughening agent to reduce curing shrinkage stress.

03

Add inorganic additives to reduce internal stress.

04

The lower curing temperature is beneficial to reduce the thermal expansion stress, but may have an effect on the resistivity.

05

Adjust the CET of the paste, as close as possible to the TCO layer and welding tape.

06

In the selection of resin, use some better elastic resin to match the system.

Low silver alloy busbar paste (in development)

	HC639-ZX	HSC639-Z
Silver content (%)	92-93	70-75
Volume resistivity (μΩ.cm)	5.5-6.0	8.0-9.5
Busbar tension (N/mm)	≥2.2	≥2.2

- **Preliminary test results: compared with the pure silver busbar paste, the efficiency is equel, and the tension of hand welding has no difference.**
- **Pilot and reliability tests are following.**
- **In this scheme without copper on busbar, the density of alloy powder is relatively low, and the wet weight decreases significantly.**

Part 6

Study on low temperature silver coated copper paste

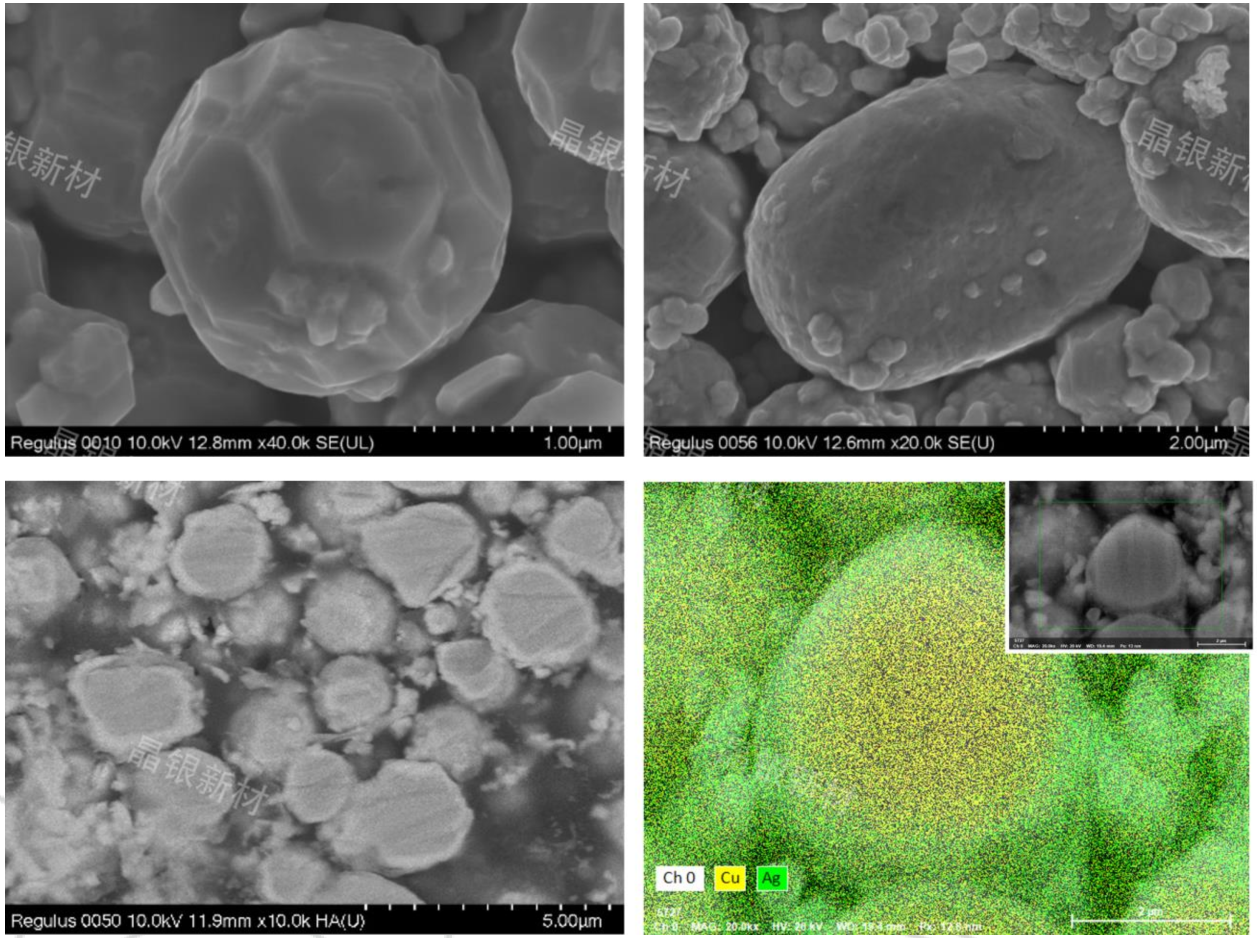
Core material - silver coated copper powder

Current situation：

- ✓ The main component of the plating solution is composed of silver nitrate solution. The electronegativity of copper is higher than that of silver, and a replacement reaction can occur. Free silver ions undergo a replacement and reduction reaction on the surface of copper powder to form silver coating.
- ✓ At present, most processes often use complexing agents to chelate free silver ions, increasing the complexing constant of silver ions and ensuring the stability of the plating solution during the metal coating process.

➢ Production process：

At present, electroless plating technology can ensure the uniformity, coating rate and stability of the coating.



Research status of silver coated copper paste

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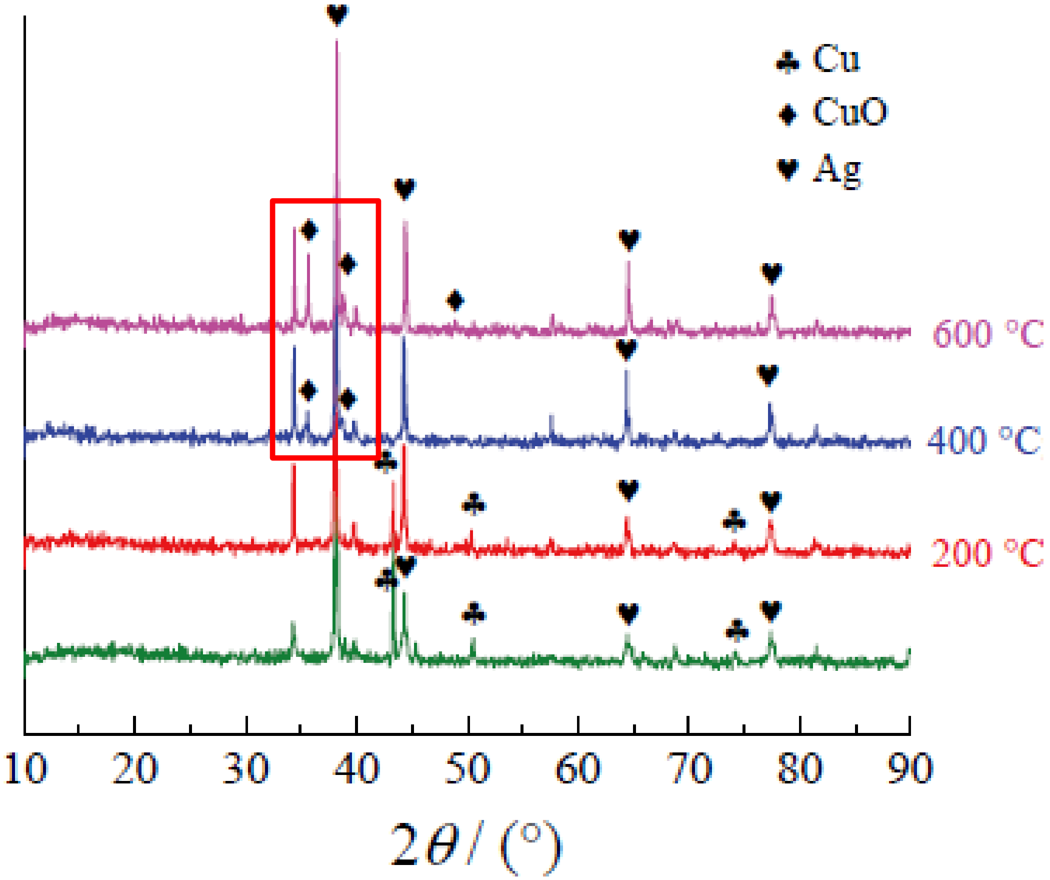
Oxidation resistance：

- ✓ After calcination at different temperatures, the characteristic peak of Cu weakens obviously or even disappears.
- ✓ There is no CuO characteristic peak in the silver-coated copper powder calcined at 200 ℃, indicating that the powder is not oxidized or the oxidation degree is very low.
- ✓ After calcination at 400 ℃ and 600 ℃, the (−111), (111) and (−202) crystal faces of CuO appear at 2θ of 35.5°, 38.7° and 48.7°, respectively.

➢ Characteristic：

Only can only be used in low temperature paste, high temperature silver layer will melt resulting in exposed copper.

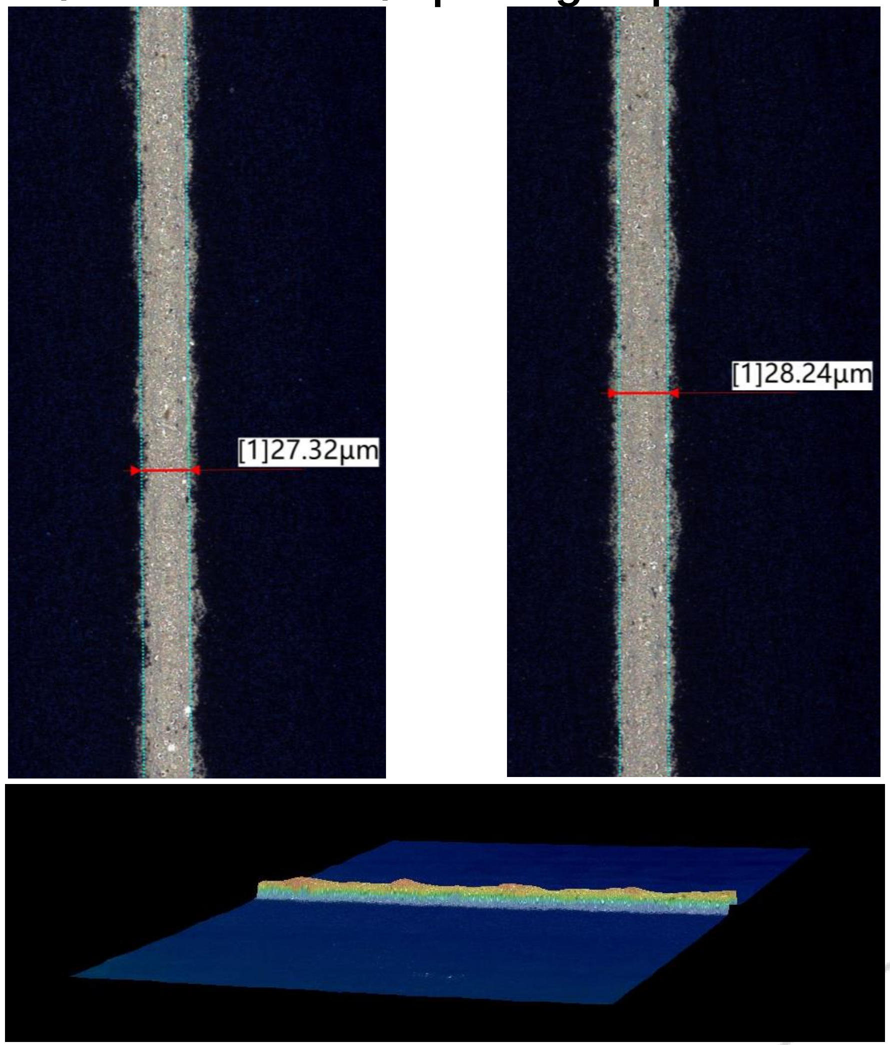


XRD pattern of silver-coated copper powder after calcination at different temperatures

LIN Jiali ZHANG Ying; CAO Mei ; GONG. Effect of calcination temperature on properties of electroless silver-plated copper particles Electroplating ＆ Finishing. 2020(19) :1348-1351

Silver coated copper finger paste

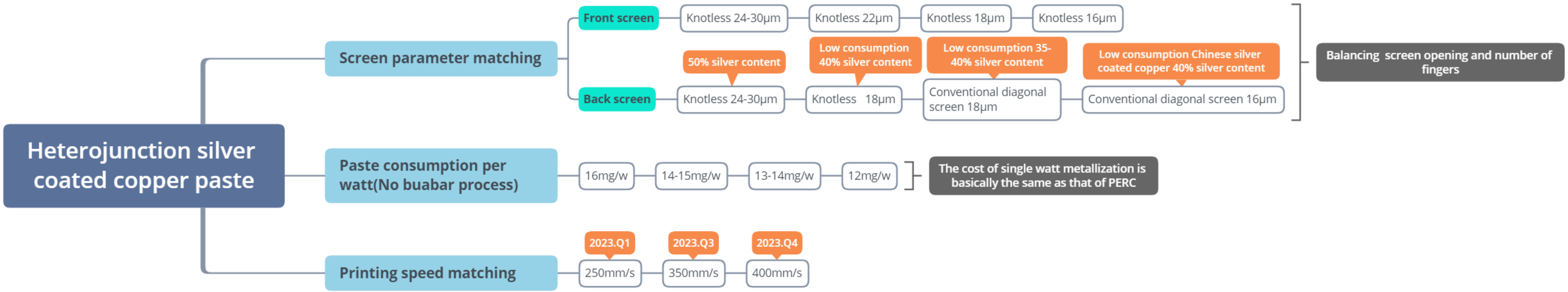
520/11 PI knotless/opening 18μm



	HAC639-T （Currently import）	HAC689-T （Next import）
Silver content（%）	43-50	30-40
Volume resistivity（μΩ.cm)	7.0-8.5	7.5-9.0
Printing speed (mm/s)	≥300	≥300

- The 50% silver coated copper fine grid paste has been used in several demonstration power stations with no abnormal power generation.
- 50% Ag silver coated copper fine grid paste has been mass produced.
- **Back 37% silver containing fine grid paste + Front 50% silver containing finger paste**， the efficiency is the same as that of sterling silver production line, and the metallization cost is greatly reduced.

Silver coated copper paste matching “No busbar" process



Heterojunction silver coated copper paste

- **Screen parameter matching**
  - **Front screen**: Knotless 24-30μm — Knotless 22μm — Knotless 18μm — Knotless 16μm
  - **Back screen**: Knotless 24-30μm (50% silver content) — Knotless 18μm (Low consumption 40% silver content) — Conventional diagonal screen 18μm (Low consumption 35-40% silver content) — Conventional diagonal screen 16μm (Low consumption Chinese silver coated copper 40% silver content)
  - Balancing screen opening and number of fingers
- **Paste consumption per watt(No buabar process)**
  - 16mg/w — 14-15mg/w — 13-14mg/w — 12mg/w
  - The cost of single watt metallization is basically the same as that of PERC
- **Printing speed matching**
  - 250mm/s (2023.Q1) — 350mm/s (2023.Q3) — 400mm/s (2023.Q4)

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Thanks for you attention!

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