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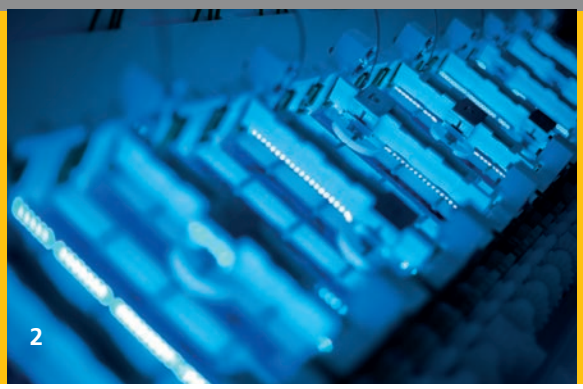

1 *Solar cell with plated nickel and copper on top of screen printed seed layer.*
2 *Industrial inline copper plating tool at Fraunhofer ISE.*

COPPER METALLIZATION FOR SILICON SOLAR CELLS

Substitute for Silver on Solar Cells

Despite recently achieved reductions in consumption, screen printed silver used in solar cell front side metallization is still an important cost driver in solar cell production. Furthermore, the conductivity of printed and fired metallization is limited due to glass compounds and porous structure.

A metallization scheme based on copper plating has the potential to lower these costs at similar or even improved efficiency. Plating allows the formation of very compact and highly conductive contacts. Copper is just as conductive as silver, but occurs far more frequently. Thus, its price is about 100 times lower, making it less costly for solar cell production and less susceptible to price fluctuations.

Research and Development

Different approaches to enable a copper based metallization have been continuously researched at Fraunhofer ISE for several years, including plating on fine line screen printed seed layers and direct plating on silicon.

Long-term stability and contact adhesion have been the most challenging issues to tackle. Especially with respect to contact adhesion, breakthroughs have been realized very recently in cooperation with partners.

With these achievements, such cost-saving metallization processes can be adapted by a multitude of manufacturers with very little efforts. Based on our experience Fraunhofer ISE can offer support with these processes, together with its partners.

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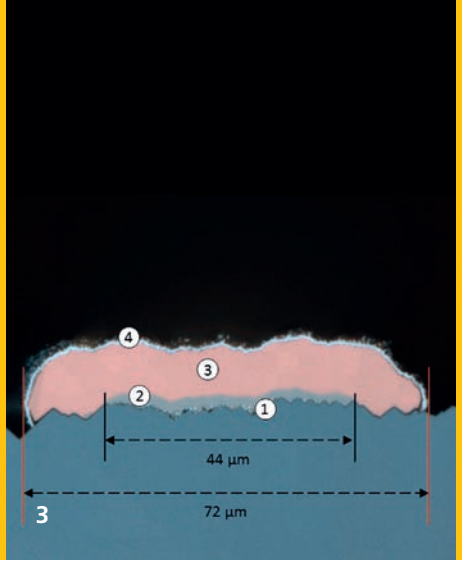
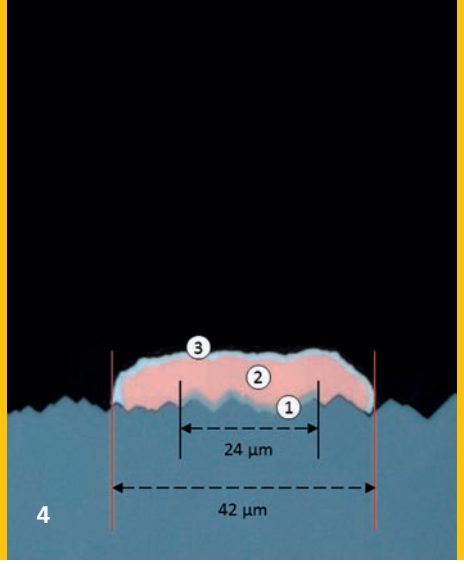
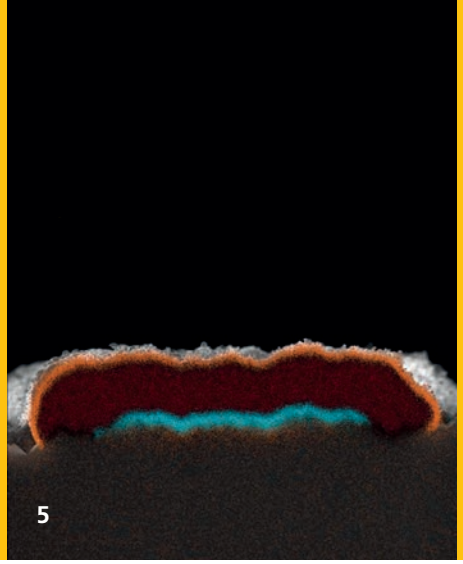






3 *Microscope image showing a contact with fine screen printed seed layer (1), plated with nickel (2), copper (3) and silver (4).*

4 *Microscope image showing a directly plated contact featuring a nickel contacting layer (1), copper conducting layer (2) and tin capping layer (3).*

5 *SEM and EDX analysis corresponding to contact shown in figure 3 (left): orange: silver, cyan: nickel, red: copper.*

Fine Screen Printed Seed Layer

An extremely fine screen printed seed layer was applied to the solar cells. For each cell, only 20 mg of wet paste were used, corresponding to about 10 mg of silver. A standard 3-busbar front grid was used in this case. Adaptations in busbar geometry can result in even less paste consumption. The specific paste formulation used was fired in a standard fast firing process, optimizing the peak set temperature. The seed layers were then plated with a nickel diffusion barrier and a conducting layer of copper. A very thin silver capping layer (6 mg) was applied.

With our improved process, excellent adhesion, comparable to standard screen printed cells, was achieved. Test modules of such cells have been constructed in order to perform climate chamber stability tests. The process is very easy to implement into existing production lines which simply have to be equipped with a plating tool.

Direct Plating on Silicon

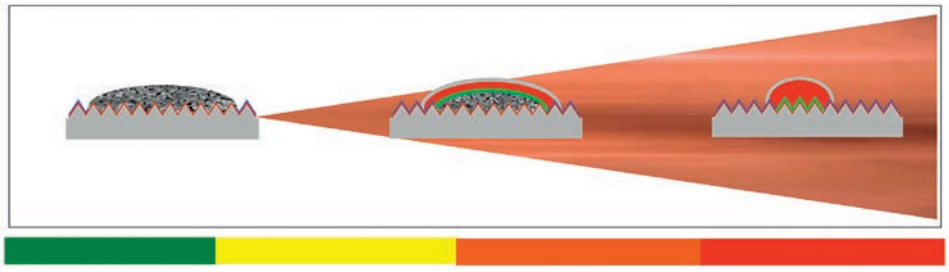
Contacts directly plated on silicon enable a completely silver-free and highly efficient metallization of solar cells. By studying the solid state reactions between nickel and silicon, Fraunhofer ISE has obtained a deep understanding of the process steps, enabling the development of a routine that leads to well-adhering contacts. With this routine, first modules were fabricated using standard soldering techniques.

Very narrow contact openings enable even higher cell efficiencies. This contact system has already proven to be competitive with an evaporated high-efficiency TiPdAg contact grid and is under investigation for use with our highly efficient n-type solar cell concepts. Our current research aim is to simplify the process to further increase the economic benefit.

Long-term Stability

The most important remaining challenge for a copper based metallization is to demonstrate its excellent long-term stability properties. Both preliminary results obtained in our labs with a simple accelerated aging method on cell level and field results (e. g. with BP solar's SATURN cells) indicate a performance at least equal to existing metallization systems.

The construction of modules now enables the comparison of such preliminary results with the widely accepted standardized IEC 61215 accelerated aging procedure. Climate chamber testing at TestLab PV Modules of Fraunhofer ISE has already been started.



6 *Roadmap for silver reductions in solar cell front contacts as followed in project „KuLi", based on the ITRPV roadmap.*