High-Efficiency Silver-Free Silicon Heterojunction (SHJ) Solar Cells

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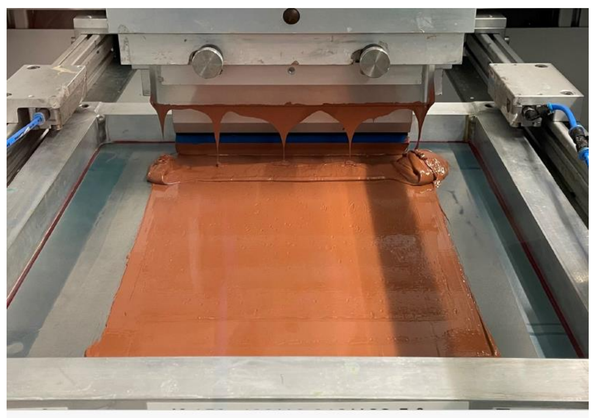
Context and Motivation

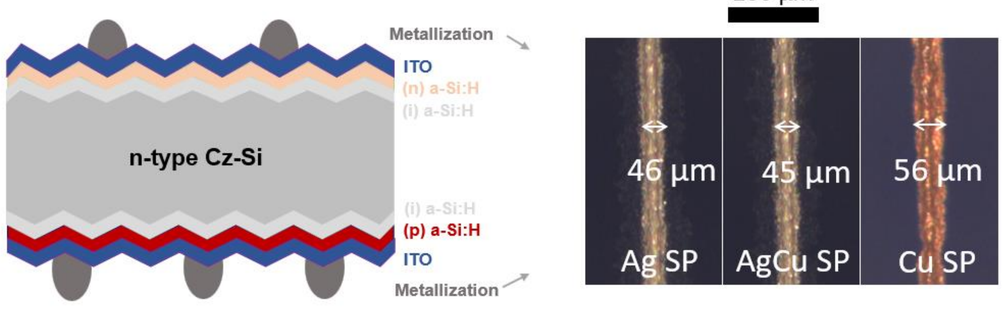
- **The high silver (Ag) cost and scarcity** could limit the growth of PV industry.
- **Copper (Cu) offers a low-cost, abundant alternative** with similar conductivity as Ag.
- **Reducing power losses** due to Cu-metallization in SHJ solar cells
- **Advancing Cu metallization** supports sustainable, terawatt-scale photovoltaic manufacturing..

Sample Preparation

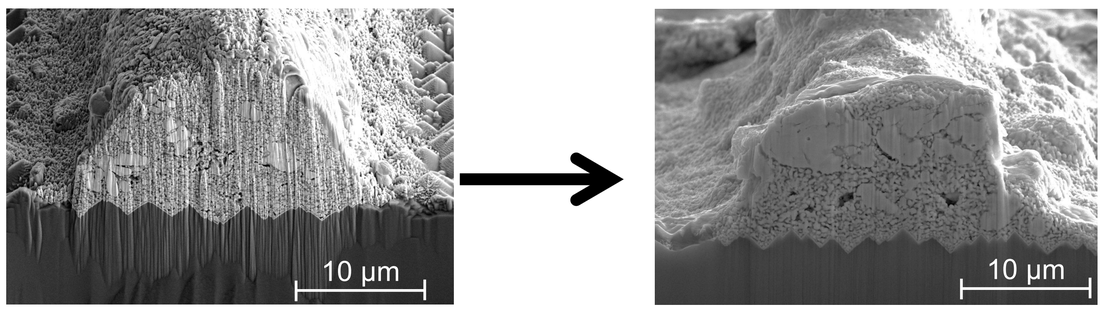


- Ag, AgCu, and Cu pastes were screen-printed (SP) on M2 metallization-free SHJ solar cells.
- The printing and curing conditions were optimized according to each paste's properties
- Cu is cured at 300°C for 5s while AgCu and Ag are cured at 170°C for 40 min

Finger Geometry and SEM-Images



Using AgCu-paste, a finger width comparable to the used reference Ag-paste was achieved, while using Cu-paste resulted in slightly wider fingers.

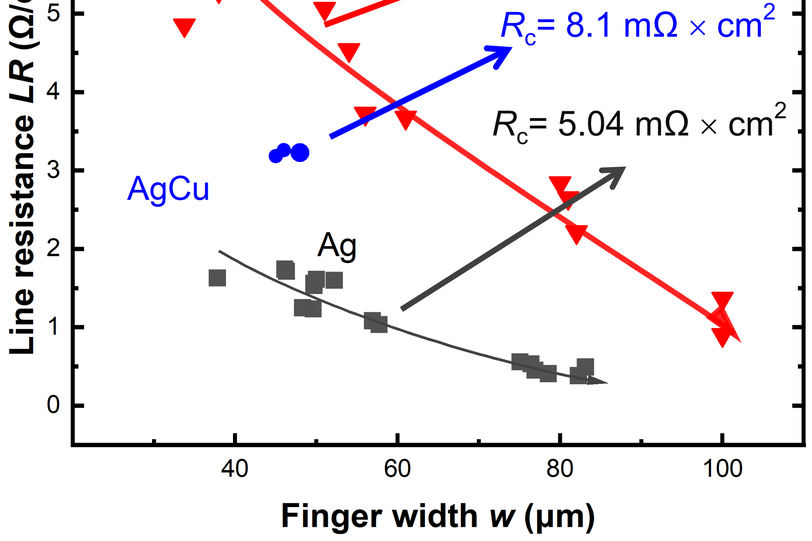


Non-annealed Cu finger

Annealed Cu finger

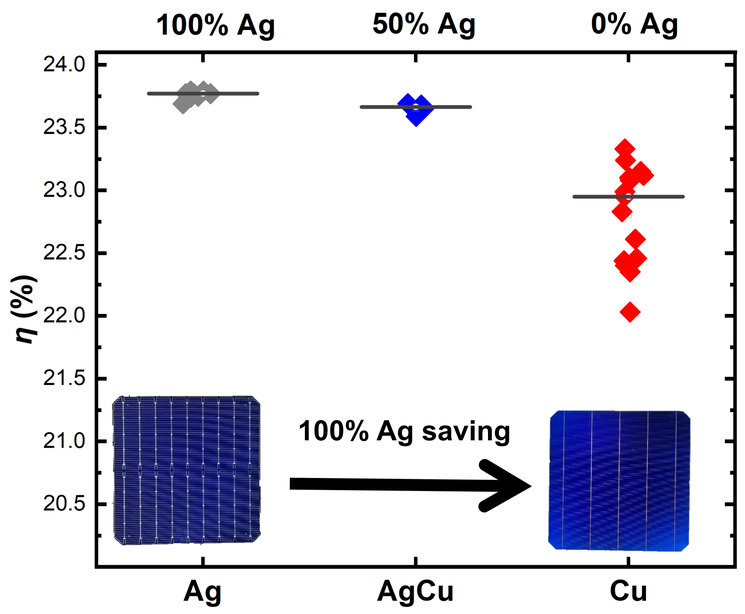
SEM images show enhanced particle connectivity after annealing, indicating the effectiveness of the Cu annealing process. (300°C; 5 sec)

Finger Resistivity

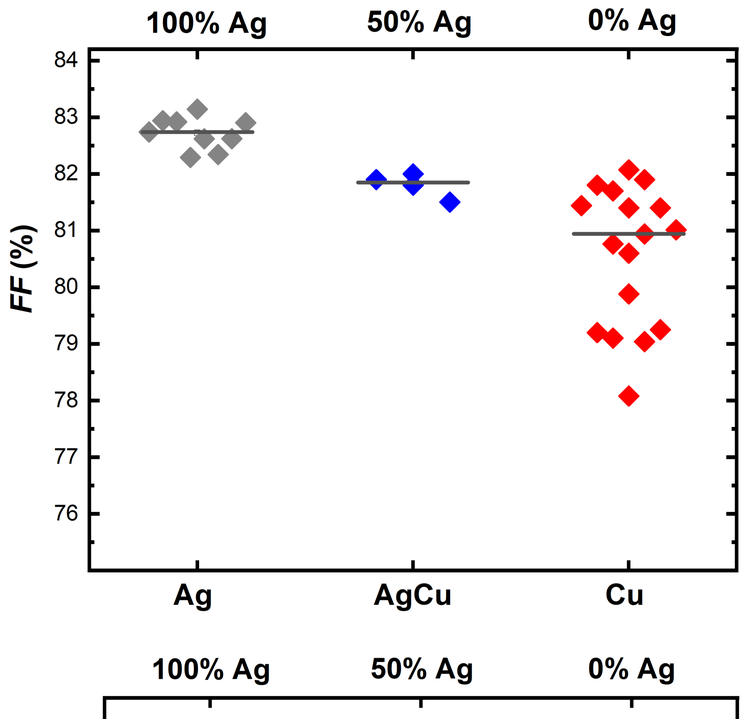


- The graph shows that **line resistance decreases** with **increasing finger width** for all three types of paste.
- For **a given finger width**, **Ag** has **the lowest line resistance**, **Cu has the highest**, and **AgCu is in between**.
- The **contact resistance (R_c)** of **Cu** was approximately **twice that of Ag**, while **AgCu** showed **intermediate values**.

IV and EL Measurements

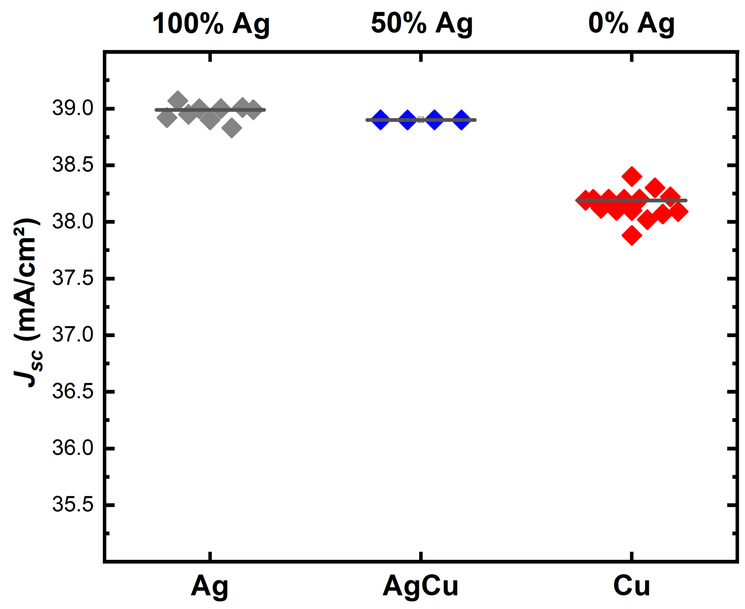


- **50% and 100% Ag reduction** maintained solar cells **performance close to Ag references**;
  → **50% Ag reduction** performed the closest.
- **Ag-free SHJ solar cells** achieved **over 23% efficiency** using **100% Cu paste**, with only **~0.4% loss** compared to Ag-reference solar cells..
- **50% Ag reduction** resulted in a **minimal efficiency drop of ~0.1%**, maintaining near-reference performance.

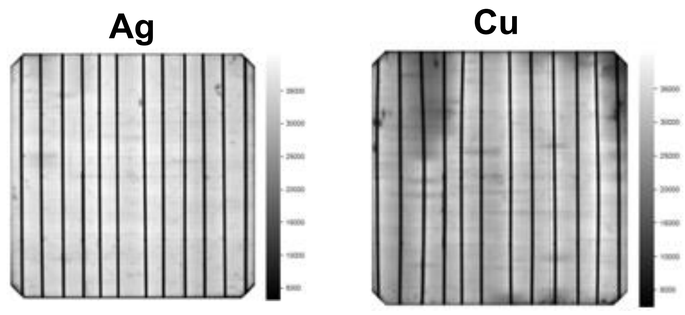


The efficiency drop observed in AgCu- and Cu-metallized solar cells due to:

- **Lower fill factor *(FF)*** mainly responsible for the decrease.
- **Higher resistance, particularly contact resistance** of Cu and AgCu contribute to the reduced *FF*.



- **AgCu-metallized solar cells** achieved **similar J_{sc}** to the reference, owing to **similar finger geometry**.
- **The slight efficiency drop** of Cu-metallized solar cells is also due to their **lower Jsc**, partly caused by **wider fingers**.



EL images of Cu SP solar cells show **dark regions indicating high resistance which can be** related to **poor sintering**, unlike Ag references metallized solar cells.

Summary and Outlook

- **AgCu and Cu screen printing showed strong performance and high potential as low-cost, sustainable alternatives for SHJ metallization, despite slightly higher resistance than Ag.**
- **High-efficiency SHJ solar cells** achieved with **significant Ag reduction**, including **silver-free solar cells (with 0% Ag usage)** nearing Ag-reference metallized solar cells performance.
- **Ongoing work** focuses on **finer finger lines** and **Stability studies** of Cu-metallized SHJ solar cells

Recent publications

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  Views expressed are those of the authors and not necessarily of the EU or granting authority.