Paste-based Silver Reduction for iTOPCon Rear Side Metallization

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Motivation and Aim

- Rapid increase in PV market share of iTOPCon solar cells
- Conventional iTOPCon metallization by Ag pastes on both sides
- Expected global Ag supply shortage within the next ten years + Ag expensive

➔ Goal of Ag reduction for iTOPCon solar cells

➔ This work: Reduction of rear side Ag via paste-based approaches

Conclusions

- "**Rear Cu**" approach: Ag reduction by 3/4 on rear side and by 1/2 in total
  → **Similar η** to conv. Ag grid → no detectable Cu oxidation or in-diffusion
  → Only two additional simple steps: screen printing + drying/curing of Cu
- "**Rear Al**" approach: no Ag on rear side, Ag reduction by 2/3 in total
  → **0.9%$_{abs}$ η gap** to conv. Ag grid in first attempt → future optimizations
  → No p^+ layer or SiO_2 penetration by Al paste, no poly-Si damage by LCO

Experimental

- Approach 1: "**Rear Cu**" [1]

➔ **Ag contact layer** with **reduced Ag** laydown + **Cu conduction layer** for bulk compensation and connection of isolated Ag "islands" (see microscopy image)

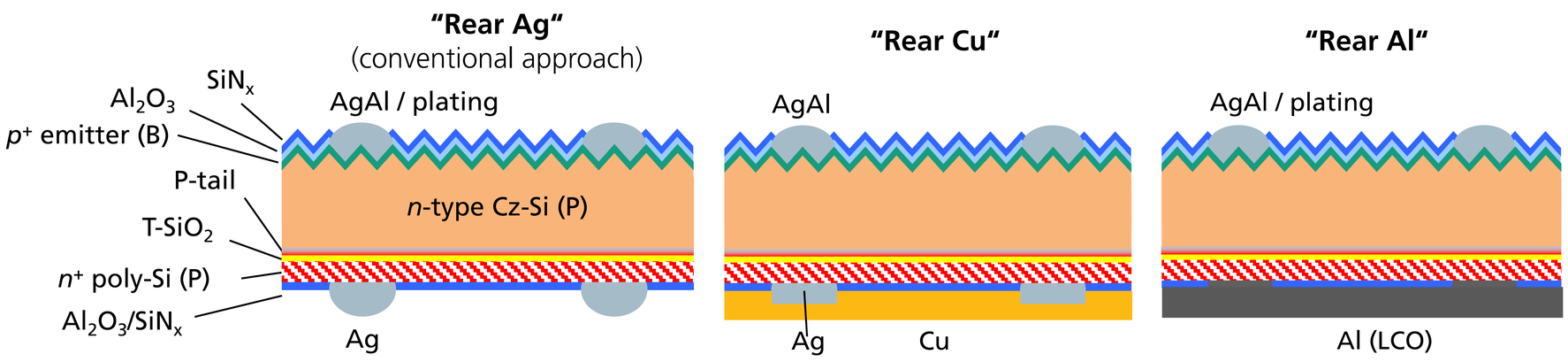
- Approach 2: "**Rear Al**" [2]

➔ **LCO + Al** instead of Ag

- Challenge: simultaneous prevention of poly-Si consumption (damage, $\downarrow V_{OC}$, $\uparrow \rho_c$) by Al (see SEM images) and achievement of paste conductivity ($\downarrow r_S$)

➔ Firing profile variation

➔ Prevention of front side thermal influence by plating



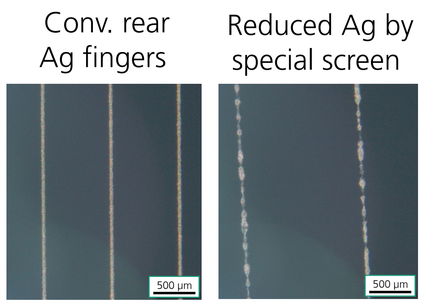
iTOPCon precursor	M2, 80 nm poly-Si, type A/B	M2, 80 nm poly-Si, type A	M2, 80 nm poly-Si, type B
Rear side LCO			**LCO** size/coverage variation
Rear side screen printing	Conventional **Ag** fingers with **75 mg** laydown	**Ag** (interrupted) fingers with reduced laydown (→ **20 mg**) by **special screen**	Special **„TTC-22A" series Al paste by Toyo** for contacting n^+-poly-Si layer; full area
Front side printing	Conventional AgAl fingers with 40 mg laydown		
Contact firing	Conventional firing profile		Firing profile variation
Rear side printing		**Low-*T* Cu paste**; full area	
Drying/Curing		**150 °C, 5 min; conv. furnace**	

iTOPCon cross-sections and corresponding rough process flows

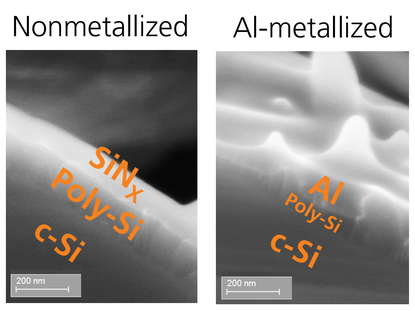
Results

I-V results: comparison of „Rear Cu" and „Real Al" to „Rear Ag"

Best Solar Cell	η (%)	V_{OC} (mV)	j_{SC} (mA/cm²)	*FF* (%)	r_S (Ωcm²)
"**Rear Cu**" (front AgAl), prec. A	22.95	701	40.8	80.2	0.61
"**Rear Ag**" (front AgAl), prec. A	22.95	699	40.7	80.7	0.52
"**Rear Al**" (front AgAl), prec. B	21.71	693	40.5	77.4	1.02
"**Rear Ag**" (front AgAl), prec. B	22.64	703	40.6	79.3	0.61
"**Rear Al**" (front plating), prec. B	21.82	685	40.2	79.2	0.72
"**Rear Ag**" (front plating), prec. B	22.75	694	40.4	81.1	0.39



Microscopy images of iTOPCon rear side



SEM images of iTOPCon rear side

➔ Conventional firing
  ➔ Al conductivity but poly-Si damage

➔ Adapted burnout, peak and time
  ➔ No improvement achieved yet

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1 Chen et al., "Thermal Stable High-Efficiency Copper Screen Printed Back Contact Solar Cells", Solar RRL, 2022
2 Suzuki et al., "Screen-printed aluminum contacts on n⁺-doped silicon", EUPVSEC, 2020

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Toyal Toyo Aluminium K.K.