



TG Companies LLC

Tucson, AZ, USA

Recovering Ag from Si Cells and Intact Cells from Si Modules

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Acknowledgment

- ▶ Funding:
 - ▶ US Nation Science Foundation grant# 1720800 and 1831148





A Looming Problem

- ▶ Solar modules that we deploy will eventually come back to us as waste
 - ▶ End-of-life, prematurely failed, damaged (during shipping, installation & operation), thrown out early, disqualified (during production)
 - ▶ Estimated 6 million tonnes/year by 2050 (IRENA, 2016)
- ▶ **How do we handle this waste?**





Current Technologies

- ▶ Current technologies for module recycling are unprofitable (low revenue and high cost)
 - ▶ ~\$3/module revenue by recycling
 - ▶ \$20–25/module for recyclers to take in modules in US





Our Approach

- ▶ Reuse of extracted Si cells for new modules
 - ▶ Si cells retain good efficiency longer than modules
 - ▶ This means recovering cells intact from modules
- ▶ If cell reuse is impossible, we recover raw materials
 - ▶ Raw materials in cells include Si, Pb, Cu, Sn
 - ▶ ~0.1 g of Ag per cell makes it the most valuable material in Si cell





Reuse of Si Cells from Modules

Cell	Recovery %	\$/module
AI BSF*	100%	\$8.28
Poly PERC*	100%	\$12.15
Mono PERC*	100%	\$15.52

Values as of 7/7/2020

*50% of the price for newly produced cells

- Value from recovered Si cells (60 cell modules)
 - AI BSF cells
 - Poly PERC cells
 - Mono PERC cells
- Our approach generates higher revenues





Furnace for Cell Extraction from Modules

- ▶ Si cells extracted from modules by pyrolysis
- ▶ Special considerations in furnace design to avoid cell breakage and contamination



Cell Extraction Furnace

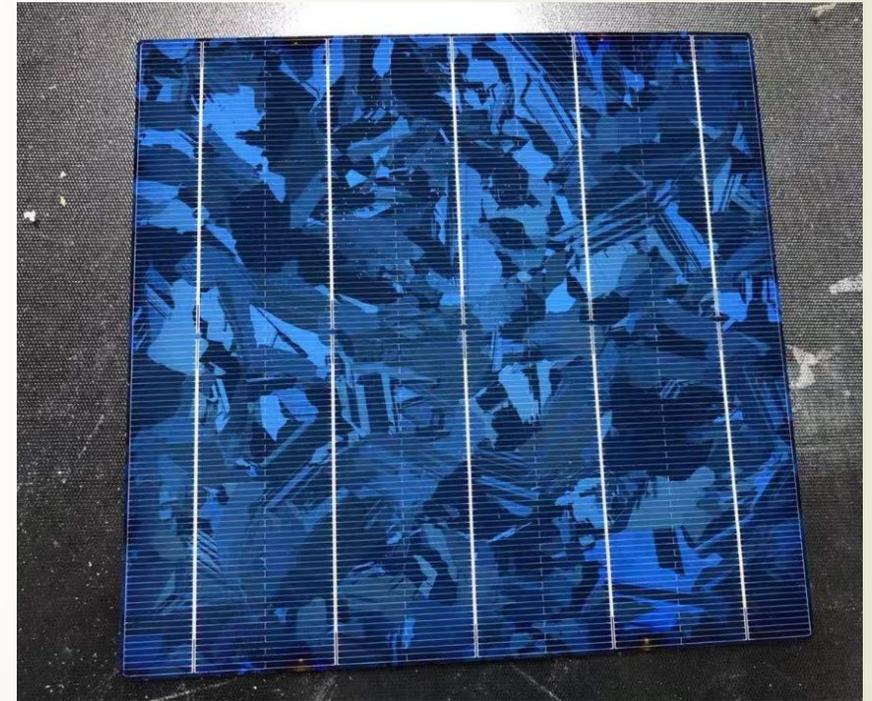




Cells Successfully Extracted



Extracted PERC cell



Extracted Al BSF cell





We Provide Cell Extraction Service

- ▶ For your quality assurance and reliability studies
- ▶ We extract cells from your modules
- ▶ You can send us your whole module or module cutouts





Addressing Broken Cells

- Unlikely that all cells can be recovered intact
- Even successfully recovered cells may not qualify for reuse
- These cells go through recovery of raw materials





Value in Recovered Materials

Material	% Recovery per Module	Value
Glass	100	\$1.35
Al	100	\$1.74
Polymers	0	0
Si*	90	\$1.57
Ag	100	\$4.19
Cu	100	\$0.55
Pb	100	\$0.02
Sn	100	\$0.13
Total		\$9.55

Values as of 7/7/2020,
60-cell Al BSF module

* Second-grade Si recovery

- The key materials recovered here are Si, Ag, Al, and glass
- Lower revenue than reuse
- Ag is the highest value and easiest to recover





Process to Recover Metals & Si

- First, extract solar cells from modules by pyrolysis
- Dissolving metals in a leach solution then electrowinning them out one by one
- The front and back sides of Si wafer are heavily doped, and need to be etched off to recover solar-grade Si





A Current Problem

- ▶ Not every Si wafer we process will end up in solar modules
 - ▶ Typically 1–2% of wafers become scraps during production (broken, low efficiency, discoloration, etc.)
 - ▶ Almost 4 thousand tonnes of scraps in 2019





Value in Recovered Materials

Material	Recovery %	\$/60 cells
Si*	90	\$1.57
Ag	100	\$4.19
Al	0	
Total		\$5.76

Values as of 7/7/2020, 60-cell module

*Si is sold as second-grade solar Si

- ▶ The materials to recover from scraps are Si and Ag
- ▶ Recovered Si assumed to be solar-grade Si
- ▶ Ag has a much higher value
 - ▶ Also much easier to recover





Our Ag Recovery Technology

- ▶ Current technology recovers only ~70% Ag from cells
- ▶ We recover 100% Ag from cells
- ▶ Ag purity at least 99%
- ▶ Leach solution reusable
- ▶ US patent pending

Chemistry	Initial Ag	Recovered Ag	Recovery%
New	1.270 g	1.188 g	93%
New	1.144 g	1.107 g	97%
HNO ₃	4.066 g	2.728 g	67%
HNO ₃	4.032 g	2.781 g	69%





We Sell Tool for Ag Recovery from Cells

- ▶ Tool in the photo recovers both Ag & solar-grade Si
- ▶ We also sell a Ag recovery tool
 - ▶ It provides a better return on investment
- ▶ In 2019, there is an estimated 37.5 tonnes of Ag in scrap wafers
 - ▶ This is \$25–63M worth of Ag to be recovered



Ag & Si Recovery Tool





Questions

- ▶ Since I can't answer your questions today, feel free to email me:

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