Stabilization / Solidification of First Generation End-of-Life Photovoltaic Panel Waste in Cement Mortar

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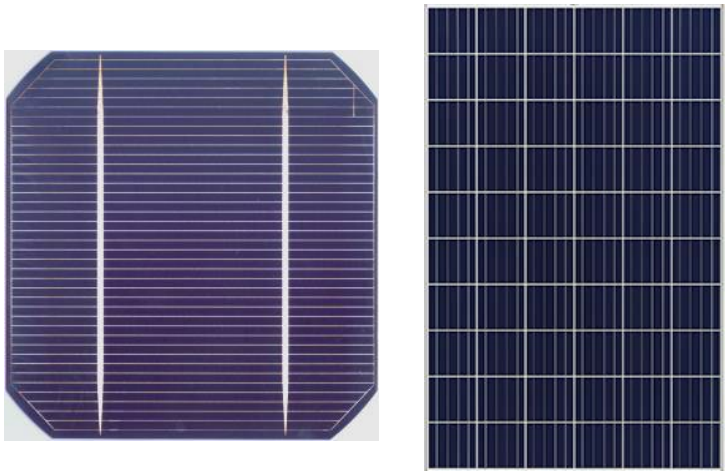
Introduction

- End of life 1st generation photovoltaic panels (PVPs)

- Safe disposal plan:
  I. Recover valuable materials
  II. Prevent metal leaching to the environment

- Metals: Ag, Pb, Cu, Zn, Al, Sn



Monocrystalline PVP (left) – Polycrystalline PVP (right)

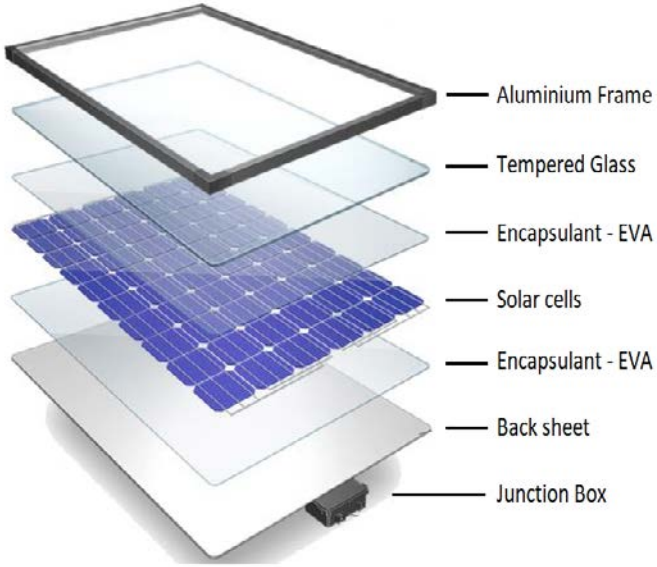
<u>Scope:</u>

- Stabilization / Solidification in cement mortars

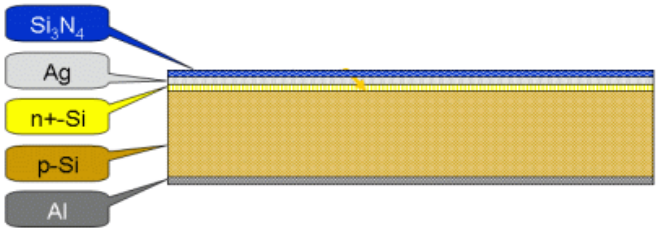
- Stability assessment

- Potential utilization in constructions

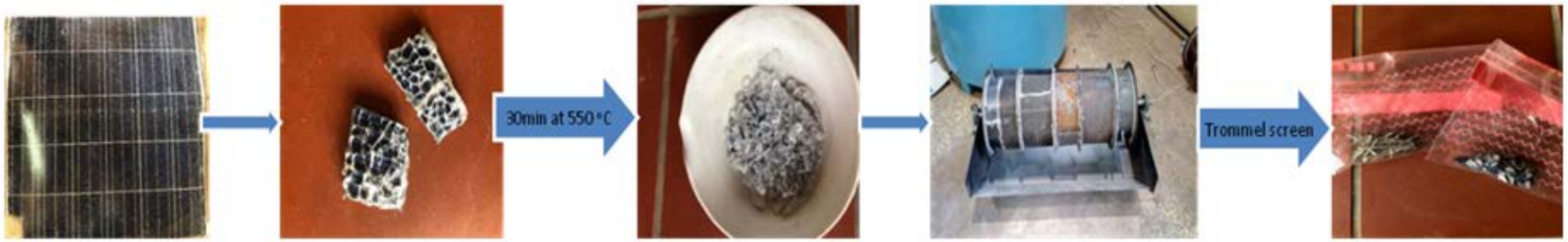
Pre-treatment



1st generation PVP structure



1st generation solar cell structure



Material recovery process from 1st generation PVP

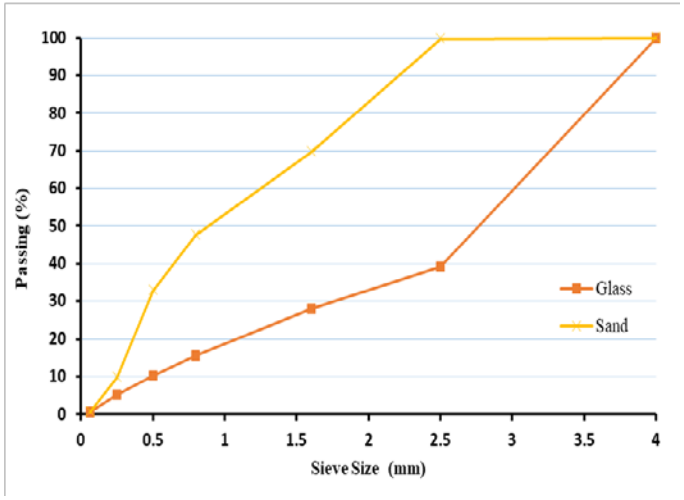
Sample preparation

❖ Experiments were carried out with 3 materials:

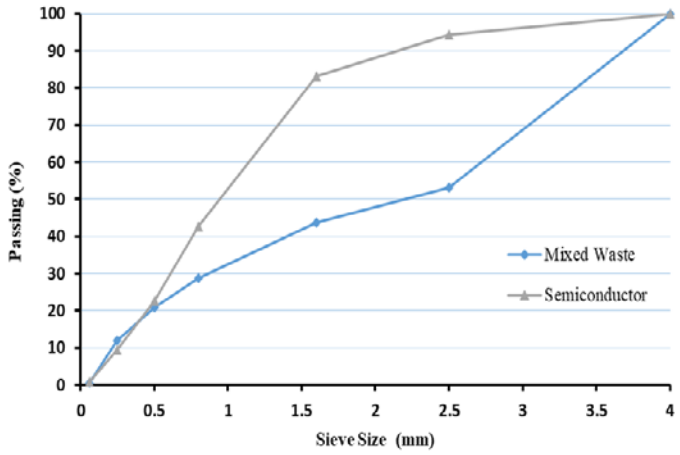
1. Recovered semiconductor (silicon)
2. Recovered glass
3. Mixed waste (glass, silicon and ash as retrieved after electrode removal)

Samples were ground and their grading was measured.

- 99.5% w/w is passing a 4mm sieve



- Glass and mixed waste are the coarsest aggregates



Grading of aggregates used in the cement mortar

Mortar preparation

- Prismatic mortar samples: prepared according to EN 196-1
  - 40x40x160 mm
  - Water to cement ratio (w/c): 0.55
  - Sand to cement ratio(s/c): 3.0.
  - CEM II 32.5R Portland cement
  - Calcareous sand

Prismatic mortars in the mold

- Prepared samples consisted of sand replacement by:
  1. Reference (R)
  2. Glass in 10, 20% w/w (G10, G20)
  3. Mixed waste in 1, 2.5, 5, 10, 20% w/w (M1, M2.5, M5, M10, M20)
  4. Semiconductor 5% w/w (SC)

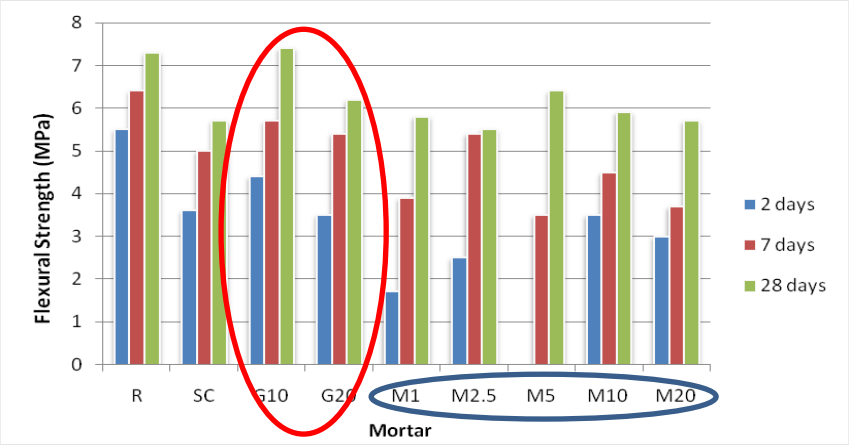
Mechanical strength

- Samples containing only glass from PVP:
  Develop their strength similarly to the reference

- Samples containing semiconductor (SC and M_x):

I. Developed their mechanical strength at a slower rate

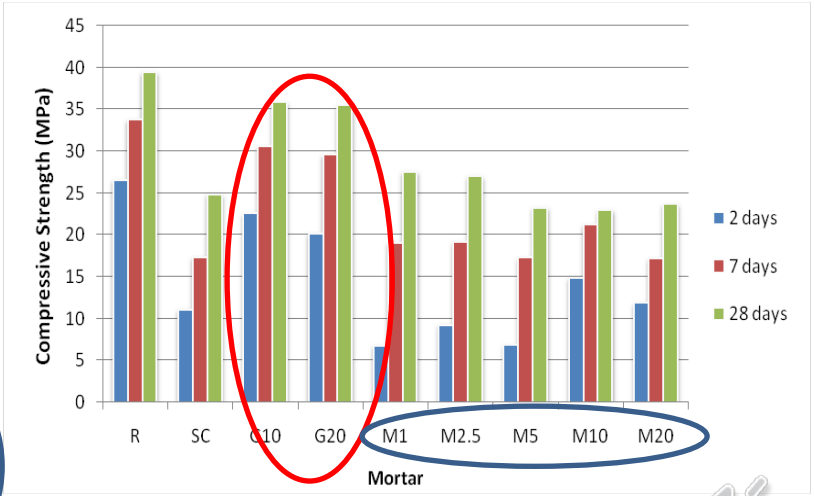
II. Final compressive strength was lower than reference (31.1 to 41.8%)



Flexural strength of the prepared mortar samples

Flexural and compressive strength values of the prepared mortar samples

Sample	Sand replacement (%)	Flexural Strength (MPa)			Compressive Strength (MPa)		
		2 days	7 days	28 days	2 days	7 days	28 days
R	none	5.5	6.4	7.3	26.6	33.8	39.5
G10	10% glass	4.4	5.7	7.4	22.6	30.6	35.9
G20	20%glass	3.5	5.4	6.2	20.2	29.6	35.5
M1	1% mixed waste	1.7	3.9	5.8	6.8	19.1	27.6
M2.5	2.5% mixed waste	2.5	5.4	5.5	9.3	19.2	27.0
M5	5& mixed waste	-	3.5	6.4	6.9	17.3	23.3
M10	10% mixed waste	3.5	4.5	5.9	14.9	21.3	23.0
M20	20% mixed waste	3.0	3.7	5.7	11.9	17.2	23.7
SC	5% semiconductor	3.6	5.0	5.7	11.1	17.4	24.9



Compressive strength of the prepared mortar samples

Sample expansion

Al on the backside of Si → H_2 gas formation → Gas entrapment → Expansion of mortars → Reduced mechanical properties

- Low mixed waste concentration (1, 2.5 % w/w): limited expansion
- Compressive strength: up to 20% higher than samples with over 5% mixed waste content

Reference sample without expansion (Left), semiconductor (SC) sample with air bubbles and expansion (Right)

Toxicity Characteristic Leaching Procedure

❖ US EPA 1311 - Toxicity Characteristic Leaching Procedure (TCLP)

Extraction fluid: acetic acid/NaOH pH of 4.9

Extraction fluid to solid ratio 20:1

Agitation in end-to-end shaker for 18h at 30RPM

Concentration measurement of metals found in PVPs by ICP-OES

➢ Concentration for Ag, Cu, Pb, Al, Zn: below quantification limit (50 µg/L)

➢ Negligible Sn concentration

➢ Successful stabilization of 1st generation PVP waste in cement mortars

Table 2: Metal concentration measurement obtained by ICP-OES for Ag, Cu, Pb, Al, Zn, Sn after TCLP.

	Metal concentration (µg/L)					
Sample	Ag	Cu	Pb	Zn	Al	Sn
R	<50	<50	<50	<50	<50	181
G10	<50	<50	<50	<50	<50	67
G20	<50	<50	<50	<50	<50	55
M1	<50	<50	<50	<50	<50	<50
M2.5	<50	<50	<50	<50	<50	<50
M5	<50	<50	<50	<50	<50	<50
M10	<50	<50	<50	<50	<50	58
M20	<50	<50	<50	<50	<50	<50
SC	<50	<50	<50	<50	<50	123

Conclusions

- Mortars containing glass separated from PVP waste:
  Mechanical strength similar to reference

- Samples containing semiconductor and mixed fractions:
  Slower and lower mechanical strength development due to expansion

- Samples with low mixed waste load:
  Insignificant expansion, compressive strength at 28 days (M1: 27.6 MPa, 31.1% lower than reference)

- TCLP measurements:
  Stabilization of 1st generation PVP waste in cement mortars was successful

  Cement mortar containing low aggregate substitution percentage of mixed waste from 1st generation PVP is effectively stabilized and can be potentially utilized in constructions [12] after further examination of its mechanical and physicochemical properties.

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Thank you for your attention!

Acknowledgements
First generation polycrystalline and monocrystalline Si end-of-life PVPs were provided by POLYECO S.A. This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code: T1EDK-04249).