Technical feasibility of recycling PV panel glass to ceramics and tiles

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Abstract

A large amount of PV panels has been installed, which shortly come to the end of their lives and which have to be recycled to avoid a large amount of waste disposal. Around 70% of the total mass of PV panels are flat glass. Recycling of flat glass recovered from waste PV panels is a foreseen issue. Possible recycling schemes from waste flat glass are ceramics and tiles which have a relatively higher tolerance for impurities. In this study, we demonstrate the recycling of waste flat glass recovered from waste PV panels as ceramics and tiles with different separation techniques.

Keywords:

glass recycling, ceramic materials and glass, glass cullet, waste PV panels

1 INTRODUCTION

Recently, a large amount of PV panels has been installed not only in Japan but also in the world. Shortly, those panels come to the end of their lives and have to be recycled to avoid a large amount of waste disposal. Around 70% of the total mass of PV panels are flat glass. Recycling of flat glass has a very low tolerance for impurities [1, 2]. Therefore, waste glass is hardly recovered and recycled, except for recycling for road bed [3]. The recycling of flat glass recovered from waste PV panels is the foreseen issue. Other possible recycling schemes from waste flat glass are ceramics and tiles which have a relatively higher tolerance for impurities [1, 4-6]. In this study, we demonstrate the recycling of waste flat glass recovered from waste PV panels as ceramics and tiles with different separation techniques.

Table 1: Collected disused PV panels

Collection Period		FY 2018 total	Apr. - Dec. 2018	Jan. - Mar. 2019
Number of pallets [units]		80	38	42
Number of PV Panels [units]		3,335	1,026	2,309
Total weight of PV Panels [t]		(e)51.3	15.8*1	(e)35.5*2
Semiconductor materials	mono-Si [units]	107	56	51
	multi-Si [units]	1,139	796	343
	Thin film and Compounds [units]	9	0	9
	Unidentified [units]	2,080	174	1,906

*1 The total weight was not observed when they are collected. The weight was observed when they are shredded.

*2 The average weight of a PV panel for the panels collected in year 2018 was used for the estimation, because

2 PREPARATION OF WASTE PV PANELS FOR TESTING

We collected 3,335 waste PV panels which count for around 51 tonnes, as shown in Table 1. Those waste panels are a mixture of various semiconductor materials, various manufacturers, and various manufacturing years. Among various types of semiconductor materials, most of them are multicrystalline silicon, which almost reflects the market share in the past. For the wast PV panels collected in the last quarter of the Japanese fiscal year 2018, semiconductor materials, manufacturers, and manufacturing years could not be identified due to a time restriction. With regard to the transportation of waste PV panels, we found that various sizes of panels cause inefficient loading ratio. In addition, when the frame of panels is removed before transportation, those wase panels could be transported in a higher loading ratio.

Process flow diagram for waste PV recycling in this study was shown in Fig. 1. Firstly, several existing processes, such as shredding, sieving, magnetic separation, and eddy current separation, are used for primary disassembly. One of the recovered materials mainly consists of glass and EVA (ethylene vinyl acetate) which is used as encapsulation material. For that mixture of materials, we applied further separation techniques which consist of two steps, i.e., disassembly and separation. For the disassembly, two techniques are demonstrated; electrical pulse and intensive mixers. Two separation techniques are conducted, sieve classification and wet separation table. For every four combinations of those techniques, conditions for higher separation rate and lower separation rate are employed. Eventually, eight different glass cullet is available as a raw material for ceramics and tiles. Just for a reference, a specimen without any disassembly and separation was also prepared. Table 2 indicates every type of specimens used for tests below.

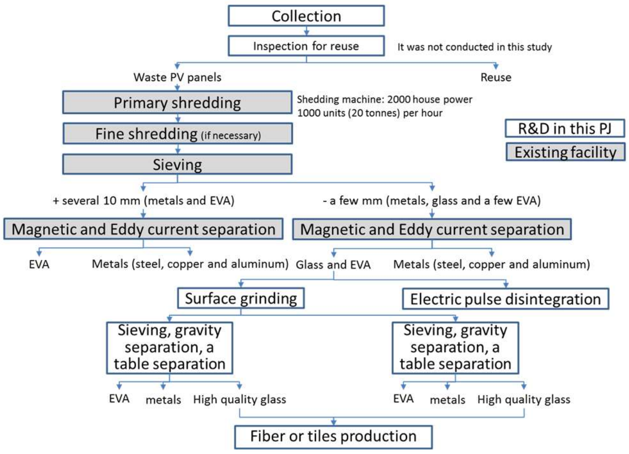

Fig. 1: Process flow diagram for waste PV recycling in this study

Table 2: Nine different types of test specimens prepared by different conditions

#	Disintegration	Separation	Separation rate
0	-	-	-
1	Electrical pulse	Sieve classific.	Higher
2	Electrical pulse	Sieve classific.	Lower
3	Electrical pulse	Wet table separ.	Higher
4	Electrical pulse	Wet table separ.	Lower
5	Intensive mixer	Sieve classific.	Higher
6	Intensive mixer	Sieve classific.	Lower
7	Intensive mixer	Wet table separ.	Higher
8	Intensive mixer	Wet table separ.	Lower

3 CERAMIC RAW MATERIAL TEST

One of possible recycling scheme of glass cullet with some impurities is ceramics. For making ceramics from the glass cullet, we conducted melting tests in several different temperatures and making samples from 50% cullet and 50% clay. From the melting tests, as shown in Fig. 2, recovered glass cullet does not melt below 600 degrees Celsius, it melts over 900 degrees Celsius, and it totally melts over 1000 degrees Celsius.

According to the melting tests, ceramic samples are made in 950, 1000, and 1050 degrees Celsius. The appearance of these samples is shown in Fig. 3. It was proven that the appropriate temperature for making ceramics from the mixture with cullet is 1000 degrees Celsius. In the case of cullet obtained by electrical pulse and sieve classification, impurities content is larger than other separation techniques, which makes black colors in the samples. The

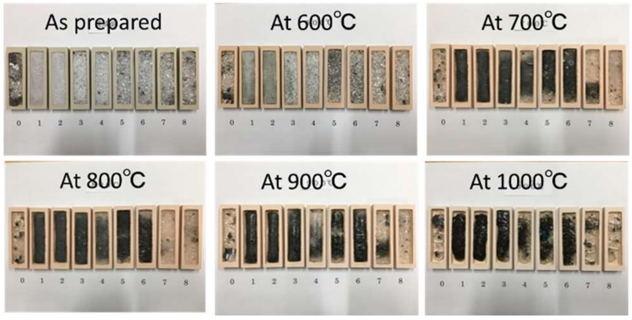

Fig. 2: Results of melting tests for nine types of recovered materials at different temperatures.

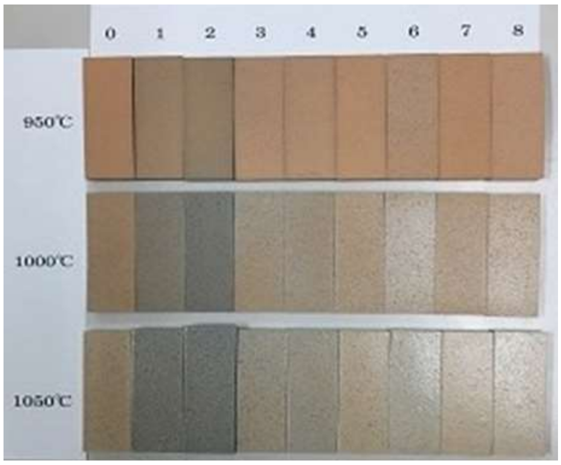

Fig. 3: Appearance of ceramic samples made in 950, 1000, and 1050 degrees Celsius

difference of cullet size did not affect any characteristics of samples.

4 TILE RAW MATERIAL TEST

Another possible recycled material from glass cullet with some impurities is a tile. For making tiles, it was found that we need to conduct pretreatment processes for recovered cullet; such as picking impurities and milling until under 1 mm. When the recovered materials are just melted, they appear colors caused by impurities as shown in Fig.4. By picking other materials than cullet, around 2% of metals and 2% of rubber and plastics are separated from the original cullet as shown in Table 3.

Using the pretreated cullet, we made porcelain tiles and water-permeable tiles with specific blending ratios with tile

Fig. 4: Pictures of materials as recovered (left) and these materials melted (right).

Table 3: Contents of recovered materials.

	Glass	Metals	Polymer & elastomer	Sheets	Total
Content [g]	482.0	8.0	8.3	1.0	499.3
[wt%]	96.4	1.6	1.7	0.2	99.9

powder, potsherd, and binder, as shown in Table 4. Those test pieces have sufficient performance as products. The appearance of those products is shown in Fig. 5. For porcelain tiles, 60% of raw materials is cullet, as shown in Table 4, which resulted in a lower temperature of firing, 1000 degrees Celsius. In regular operation, that is, without cullet, porcelain tiles are calcined in 1350 degrees Celsius, which means using cullet contributes to a large portion of CO_2 reduction. For permeable tiles, 13% of raw materials is cullet, as shown in Table 4. We could conclude that recovered cullet can be recycled as ceramics and tiles.

Table 4: Blending ratios for different tiles

Unit: %	Glass cullet	Tile powder	Pot-sherd	Binder
Ceramic tiles	60	20	—	20
Water-permeable tiles	13	—	74	13

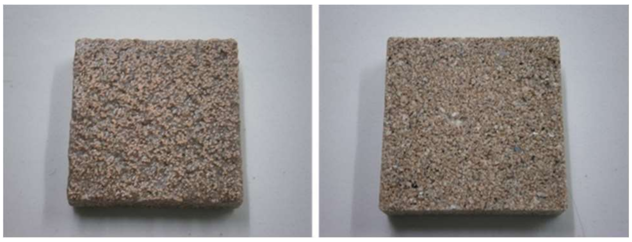

Fig. 5: Appearance of porcelain tiles (left) and water-permeable tiles (right) made from pretreated glass cullet

5 SUMMARY

We collected more than fifty tonnes of waste PV panels, which are shredded and separated by economically feasible existing facilities. Additional processes are conducted for a mixture of glass cullet and EVA to liberate glass cullet. For making ceramics, although some conditions fulfilled a quality, making conditions have to be investigated further. For making tiles, picking impurities and milling are required which shall not be economically feasible. Further technical development is required to conduct these recycling in economically feasible ways.

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