Topic: End-of-life gel cables: characterization, basic research and recycling potential

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The article shows that current methods of recycling gel-containing copper cables are not compatible with the principles of sustainability and a closed-loop economy. This is important because these methods generate secondary waste in the form of wastewater. The analysis presented in this article highlights the problem of inadequate management of gel-filled copper cable waste, resulting in increased water pollution. It shows a wrong approach to industrial wastewater and waste management, and describes the technologies currently used to treat this type of waste. The article also shows the need for full recovery of raw materials from gel-filled cables, which is in line with sustainability and the circular economy. The basic research included thermogravimetric differential thermal analysis and viscosity testing. Thermogravimetric Differential Thermal Analysis (TG/DTA) of the cable was performed to determine phase transitions and material degradation with temperature. TG/DTA curves were recorded at 10°C/min from room temperature to 650°C under a protective argon atmosphere.

1. Introduction

Recycling gel cables is a challenge faced by recycling companies. Gel cables are filled with hydrophobic gel, which provides moisture protection for the cable's copper core. This type of cable is used, among other things, as telecommunications cables laid in areas exposed to moisture. The hydrophobic gel used is a serious problem in the cable and wire recycling process because it contaminates the end products [1].

The rest of the article describes the morphology of gel cables and the methods currently used to process them. Also presented are differential thermogravimetric thermal analysis and viscosity tests.

The issues discussed in the article are essential knowledge in the development of appropriate technology for the recovery of all raw materials included in these cables.

2. Tested material

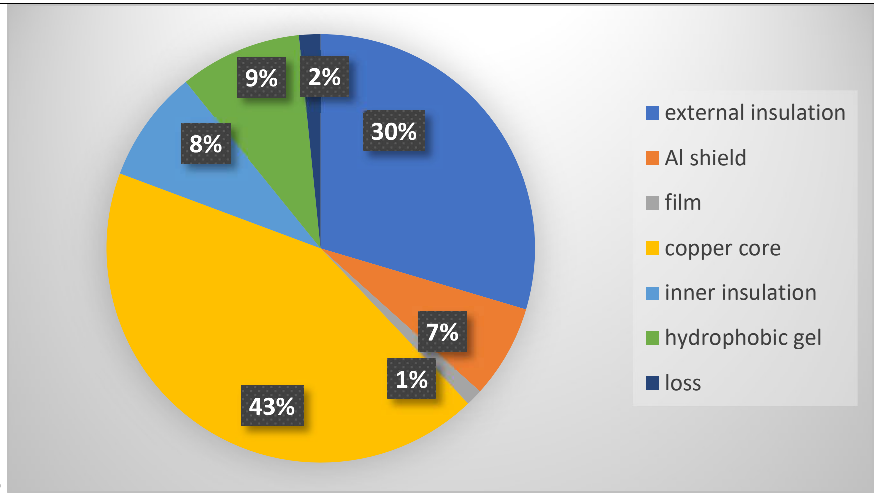
Telecommunications cable XzTKMXpw 7x2x0.5 manufactured by Bitner was used as the test material.
Explanation of designations:

T – telecommunications,
K – cable,
M – local,
Xp – bundled with foam polyethylene insulation with a layer of solid polyethylene,
Xz – polyethylene sheath with moisture barrier,
w – filled with gel

Cable construction according to data sheets [2]:
1. Conductors: single stranded copper,
2. Insulation: foam polyethylene with an outer layer of solid polyethylene,
3. Filling: hydrophobic gel,
4. Moisture barrier: aluminum tape covered on both sides with a layer of ethylene copolymer,
5. Coating: coated polyethylene

The morphological tests performed are described in the article [3] and the grouped results are shown in Figureure 1.

Morphology		
Name	Mass [g]	Share [%]
external insulation	1,64	29,60
Al shield	0,39	7,04
film	0,07	1,26
copper core	2,37	42,78
inner insulation	0,47	8,48
hydrophobic gel	0,51	9,21
total	5,45	98,38
loss	0,09	1,62



b)

c)

d)

Figure.1 Gel cable XzTKMXpw 7x2x0.5, a) morphology b) morphology diagram c) cross-section d) materials [3].

3. Methods currently in use

The article "State of the art of recycling gel-containing copper cables in the context of sustainability and circular economy" presents an overview of patented methods for recycling gel-containing cables [4]. The patents discussed are grouped in Table 1.

Table 1. A list od patents for the recycling of gel cables.

Country	Publication date	Publication number	Title	Kind of method
USA	06.11.1979	US4173493A	Reclamation of conductive wire[5]	Wet, continuous application
USA	14.12.1982	US4363449A	Process for reclaiming jelly-filled[6]	Wet, continuous application
Australia	18.11.1999	WO9959167A1	Process and apparatus for recycling jelly filled cable[7]	Dry, cyclic application
Australia	29.11.1999	AU3322899A	Process and apparatus for recycling jelly filled cable[8]	Dry, cyclic application
USA	04.08.2005	US2005166944A1	Cascade extracting and solvent refreshing method for recycling jelly cables[9]	Wet, cyclic application
South Korea	17.02.2010	KR100943060B1	Recycling device for jelly filling cable and Recycling method for the same[10]	Dry, continuous application
South Korea	24.05.2012	KR101147919B1	Recycling device for communication cable and method using the same[11]	Dry, cyclic application
South Korea	21.02.2013	KR101235798B1	A copper wire of jelly cable recycling device and recycling method using thereof[12]	Dry, cyclic application
South Korea	14.05.2014	KR101395385B1	Re-fabricating device of un useful copper	Dry, cyclic application

			cable and method of said it[13]	
South Korea	04.09.2014	KR20140106790A	Apparatus for recovering jelly from jelly filling cable[14]	Hybrid, cyclic application
South Korea	23.09.2014	KR20140112133A	Method for recovering jelly from jelly filling cable[15]	Hybrid, cyclic application
South Korea	09.03.2015	KR20150024591A	Apparatus for recycling a jelly filling cable and method therefor[16]	Hybrid, continuous application
South Korea	16.03.2015	KR20150028394A	Method for insulation jelly collection of jelly charging communication cable[17]	Dry, continuous application
South Korea	16.03.2015	KR20150028393A	Insulation jelly collection device of jelly charging communication cable[18]	Dry, continuous application
South Korea	30.07.2015	WO2015111780A1	Device and method for recycling composite material cable[19]	Wet, continuous application
South Korea	24.08.2016	KR101650321B1	Method for recycling of waste cable[20]	Wet, continuous application
Korea Południowa	12.02.2016	KR101593132B1	Waste wire recycling apparatus[21]	Wet, cyclic application
South Korea	28.12.2016	KR101690827B1	Recycling apparatus of jelly filled waste cable to recover copper in high purity and the recycling method using the same[22]	Wet, cyclic application
South Korea	24.05.2017	KR101739567B1	Apparatus for recycling a jelly filling cable[23]	Dry, continuous application
South Korea	30.10.2017	KR20170119912A	Apparatus for recycling a jelly cable[24]	Wet, continuous application

The technologies listed in Table 1 emphasize cleaning metals and plastics from hydrophobic gel. These technologies can be divided into 3 categories: wet, dry or a hybrid combination thereof. Their application requires the construction of additional process lines, which can be used in cyclic or continuous operation mode. The technologies in question generate secondary waste in the form of wastewater, which is not in accordance with the Closed Circuit Economy. From the presented analysis of the state of the art of recycling copper cables containing gel, there is a need to develop a technology that ensures the recovery of all raw materials from waste gel cables[4].

4. Basic research

Badania podstawowe obejmowały badania lepkości oraz analizę DTA/TG badanego materiału

4.1 Viscosity

Rheological behavior of the petrogel was analyzed by using a rheometer Lamy Rheology RM 200 with MS DIN 11S measuring system with sample volume 27 ml and EVA MS DIN PLUS temperature control. The rheological tests were conducted within a temperature range of 80-100°C and a shear rate varied from 0.1 to 500 s−1.

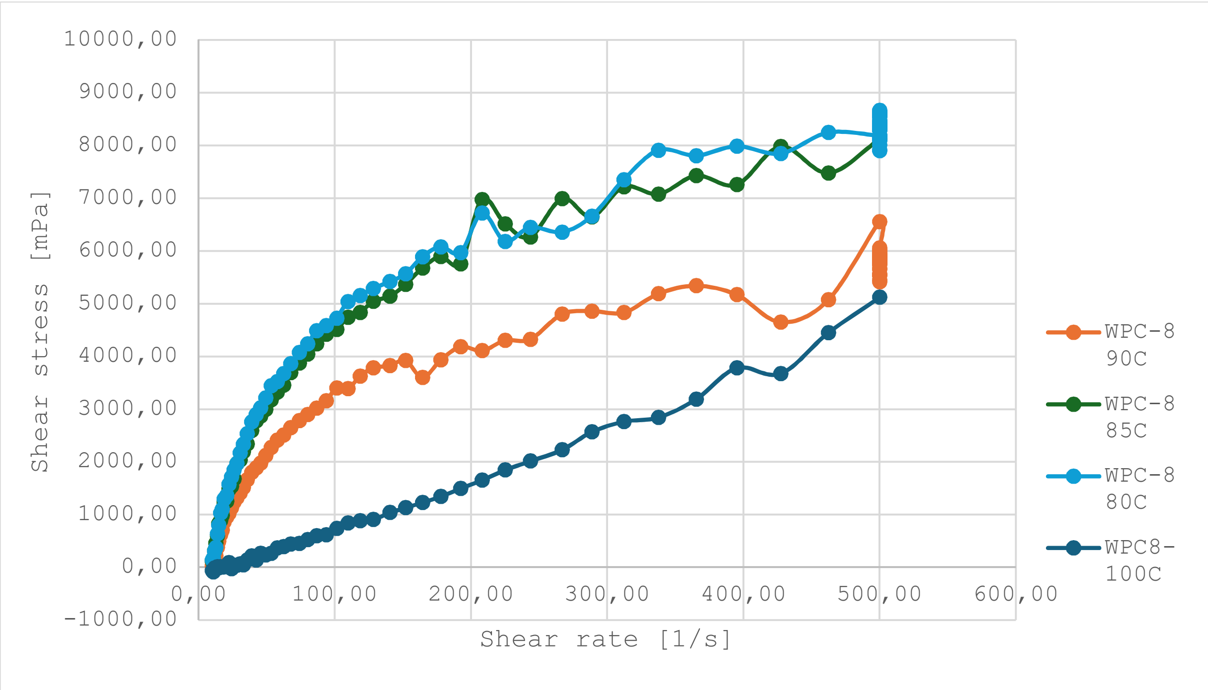


Figure.2 Petrogel flow curve in the temperature range of 80-100°C.

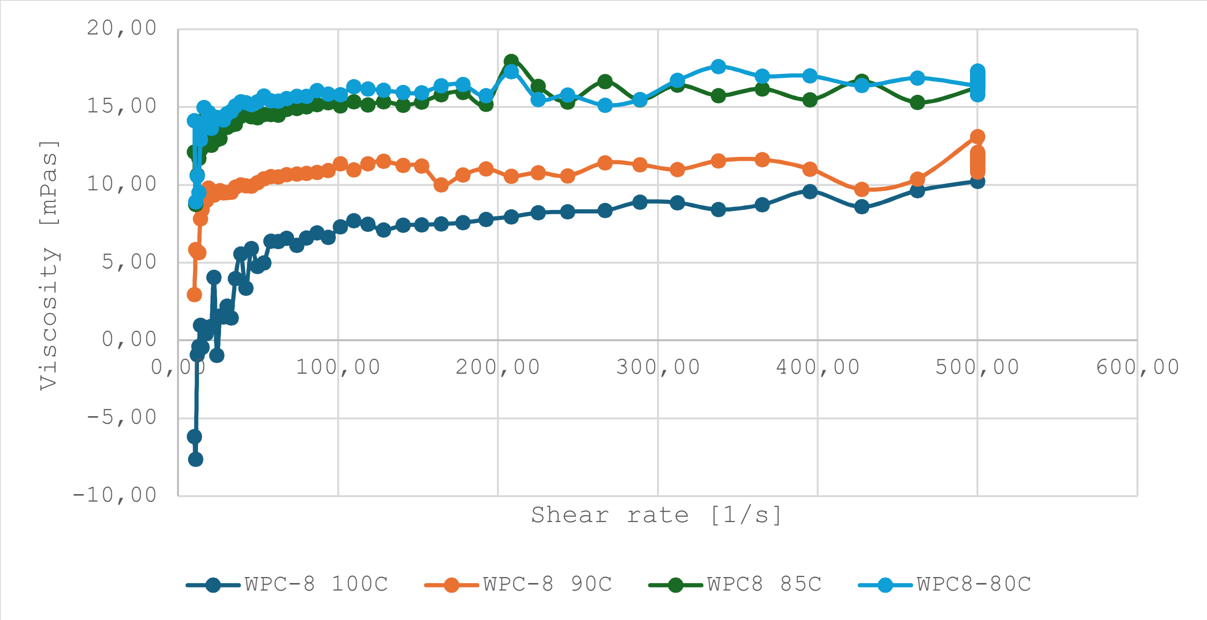


Figure 3. Viscosity curve in the temperature range of 80-100°C.

The rheological characteristic of petrogel WPC-8 is strongly dependent from temperature. The correlation between the shear stress and the shear rate is nonlinear in the temperature range 80-90C (figure 2.), the emulsion exhibits a non-Newtonian liquid characteristic with shear thickening behavior flow curve (Figure3).

Viscosity curve show exhibits a non-Newtonian liquid characteristic with shear thickenning behavior flow curve (Figure2). With temperature increase material showed an increasing tendency toward shear thinning effect and highest shear thinning effect is observed at 100°C.

In temperature 100C material showed almost Newtonian flow behaviour (R=0,976) in the range of shear rate 0-500 [1/s]. In temperature 100C model Bingham may be the best fit (R 0,992). For temperature range from 90-80 C the best fit obtain for Ostwald model with coefficient R= 0,99 for behaviour in 90C, R=0,997 in 85C and R=0,994 in 80C.

During the flow test with an increase in the shear rate changes in the sample temperature were observed due to mixing, , there was a gradual increase in the sample temperature during the measurement. For the measurement at a temperature of 100C, Δ Tmin-Tmax was 6.2°C, at a temperature of 90C Δ T was 6.9°C, at a temperature of 85C Δ T was 2.7C, and at a temperature of 80C Δ T was 5.5°C.

4.2 Analysis DTA/TG

Differential thermal analysis (DTA) with thermogravimetric analysis (TG) using STA Netzsch F3 Jupiter was carried out to determine the thermal stability and characteristic transformation temperatures of the materials studied. Measurements were performed in an argon atmosphere, in the temperature range from room temperature to 650°C at a heating rate of 10°C/min. $Al2O3$ crucibles were used for the measurements. The software bundled with the instrument was used to analyze characteristic temperatures. Figureure 4 shows the DTA/TG test stand.

Using DTA/TG studies, it was possible to determine the temperatures: the beginning of the mass loss (first onset) and, if possible, a significant decrease in mass (second onset); the end of the mass loss (end), as well as the maximum visible on the DTA signal corresponding to the phase transformation occurring in the polymer. In addition, the total mass loss was determined.

Figure 4: STA Netzsch F3 Jupiter

DTA/TG tests were performed on the entire cable (Figureure 5.), as well as on its individual polymer components: outer insulation (PE) (Figureure 6.), inner insulation (PE) (Figureure 7.), foil strips (PE) (Figureure 8.) and transparent film (PE) (Figureure 9.). In addition, tests were also carried out on pure WPC-8 petrogel.

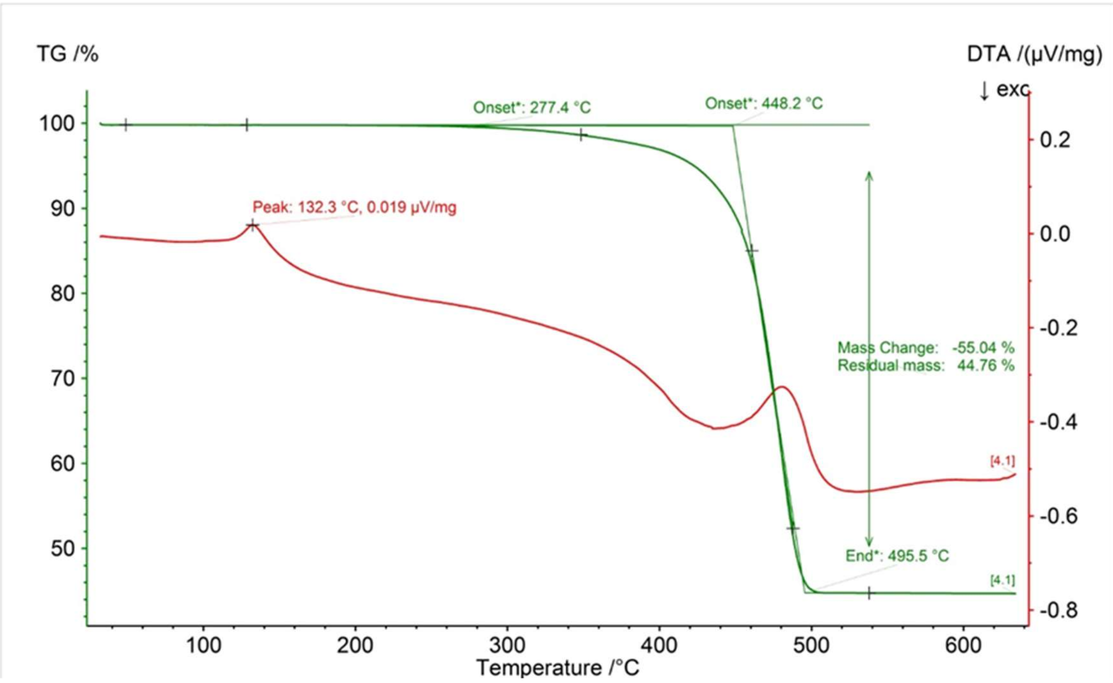


Figure 1. DTA/TG slice corresponding to the cross section of the entire gel cable.

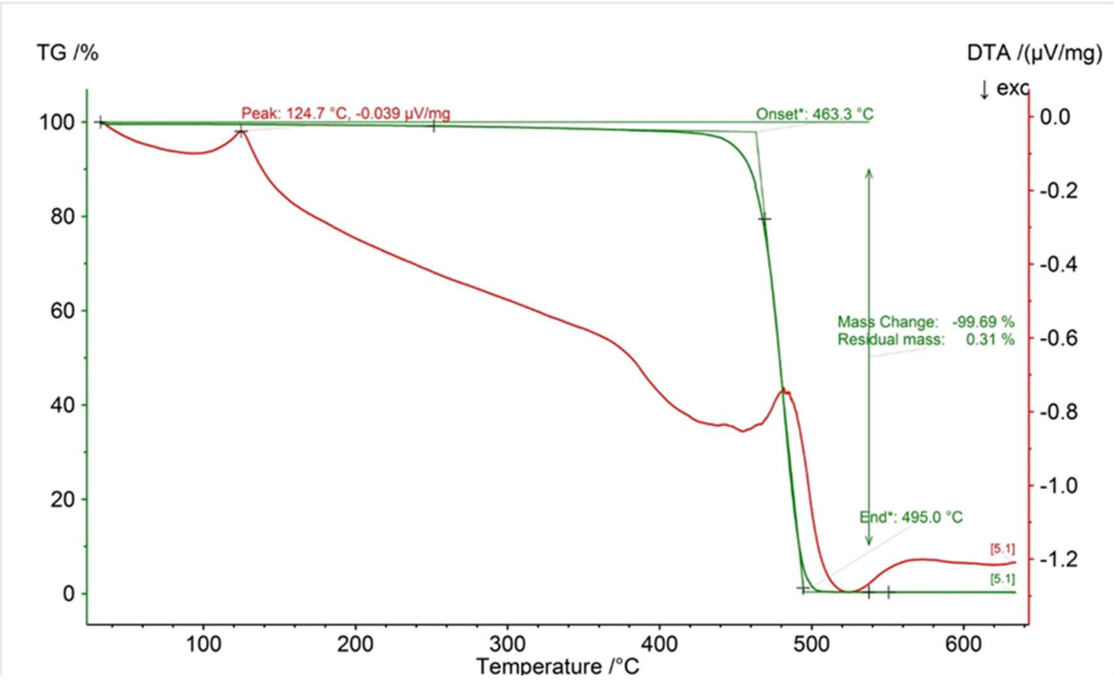


Figure 6. DTA/TG external insulation (PE).

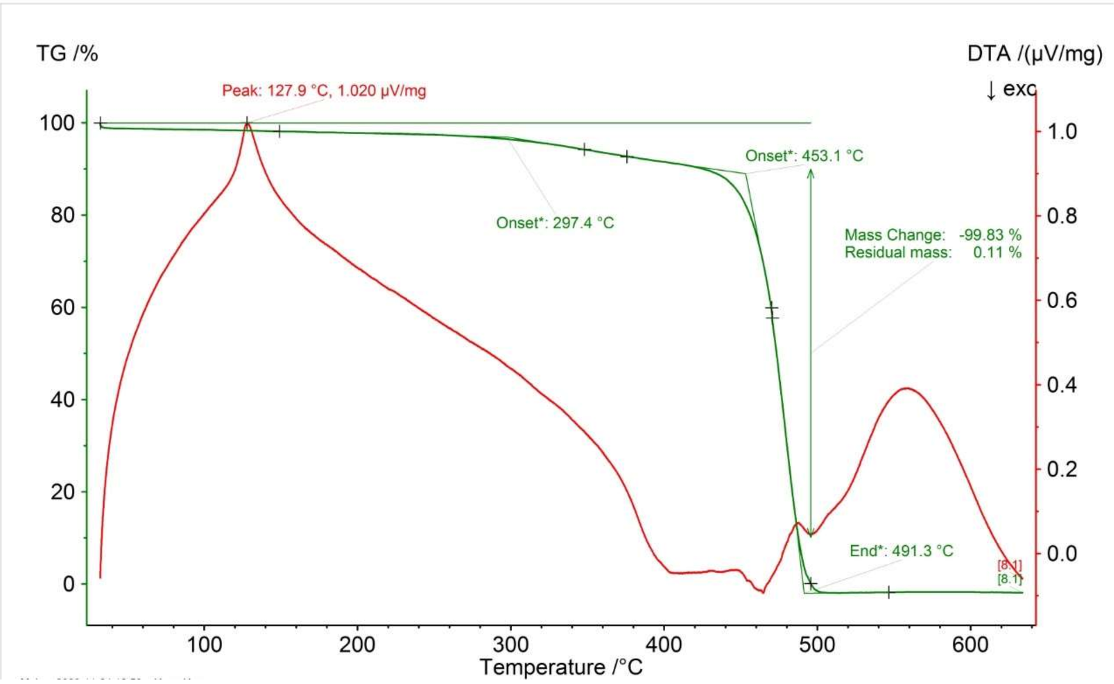


Figure 7. DTA/TG internal insulation (PE).

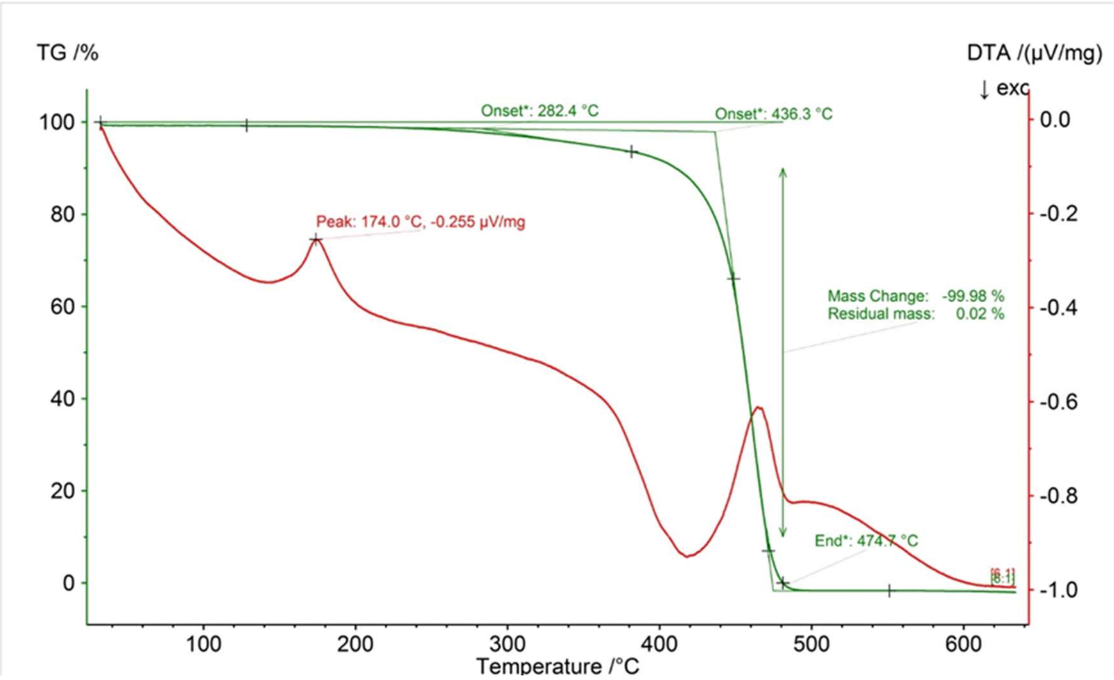


Figure 8. DTA/TG foil strips (PE).

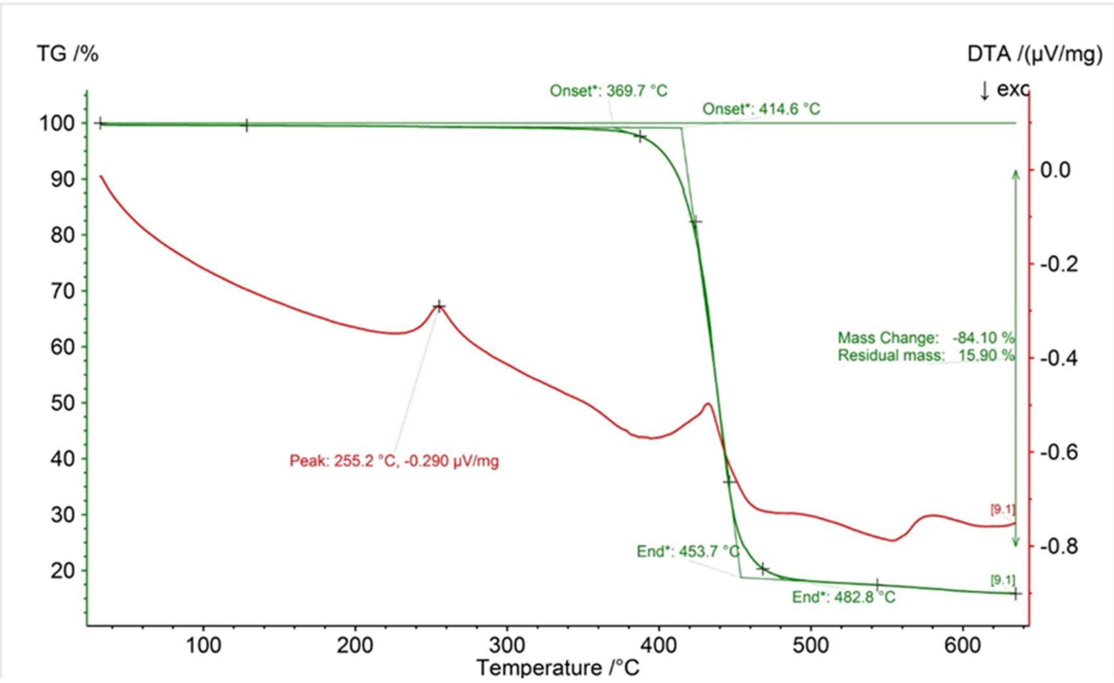


Figure 9. DTA/TG transparent film (PE).

From the tests for the entire cable, it can be observed that the overall mass proportion of polymers is about 55%. The cable itself consists of 3 different polymers, which is due to the different transformation temperatures observed on the DTA and degradation temperatures. In addition, the polymers from the black overall lagging and the colored copper lagging make up the bulk majority. The maximum temperature that the cable can be processed without changing the properties of the cable lagging polymers is about 105°C. For the petrogel itself, a transformation can be observed at 64.7°C, which is most likely related to the melting of the material.

5. Summary and discussion.

Morphological studies of the cable have shown that it contains economically and environmentally important raw materials that should be fully recovered. The presented analysis of the currently used processing methods for gel cables highlights their incompatibility with the principles of the Closed Circuit Economy. Basic research included differential thermogravimetric thermal analysis and viscosity tests. They show that the maximum temperature that can be processed on the cable is 105°C. Such a temperature acts behind the hydrophobic gel contained in the cables at the same time without changing the properties of the other raw materials.

Acknolwedgments

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