THERMO-MECHANICAL PROPERTIES OF RECYCLED PLA

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BBI JU

Bio·based Industries
Consortium

Poly(lactide) - PLA

Poly(lactide) is the most examined biopolyester well known for it's good properties.

It is produced in a large scale with competitive price. It can be used for production of different plastic products.

It become promising change for fossil-based polymers especially for single-use products, primarily because of it's biodegradability.

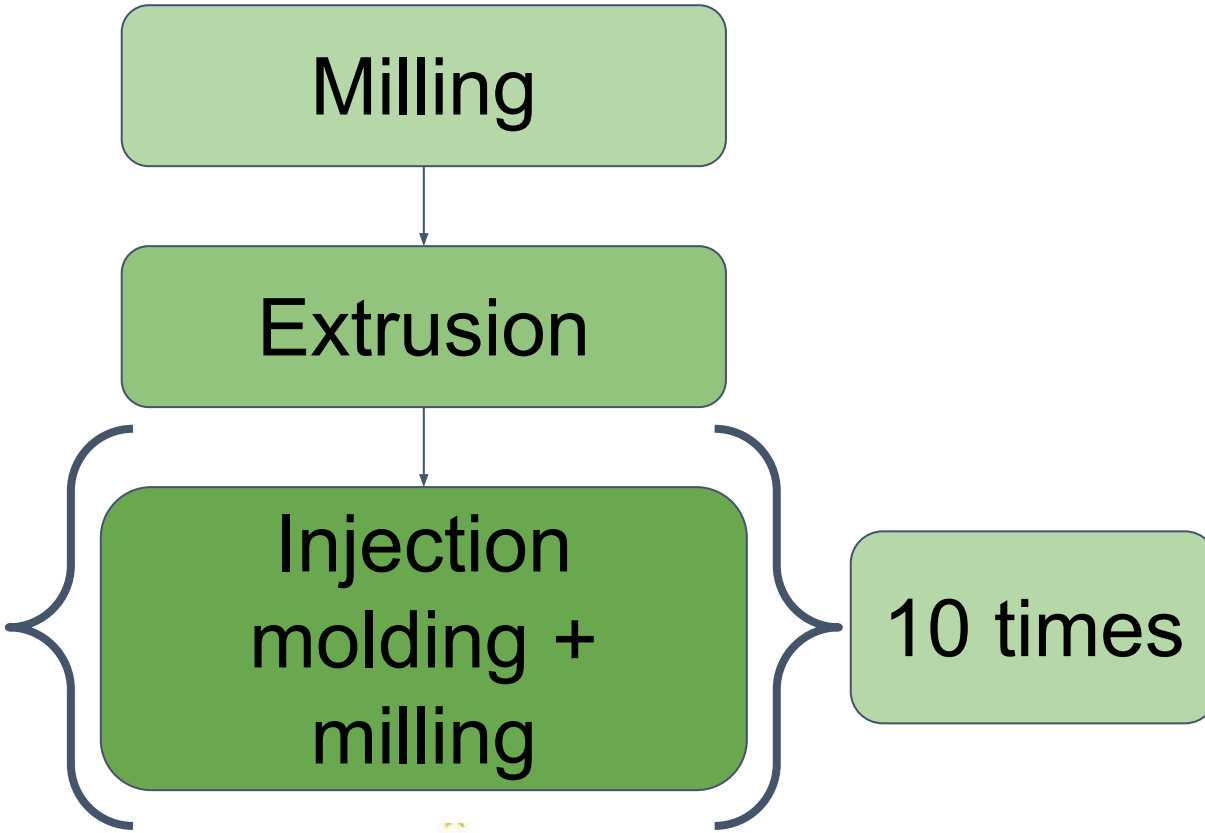
Poly(lactide) - PLA

Challenge - biodegradability in different environments - PLA does not degrade equally in soil, water and sea water and industrial composter under controlled conditions.

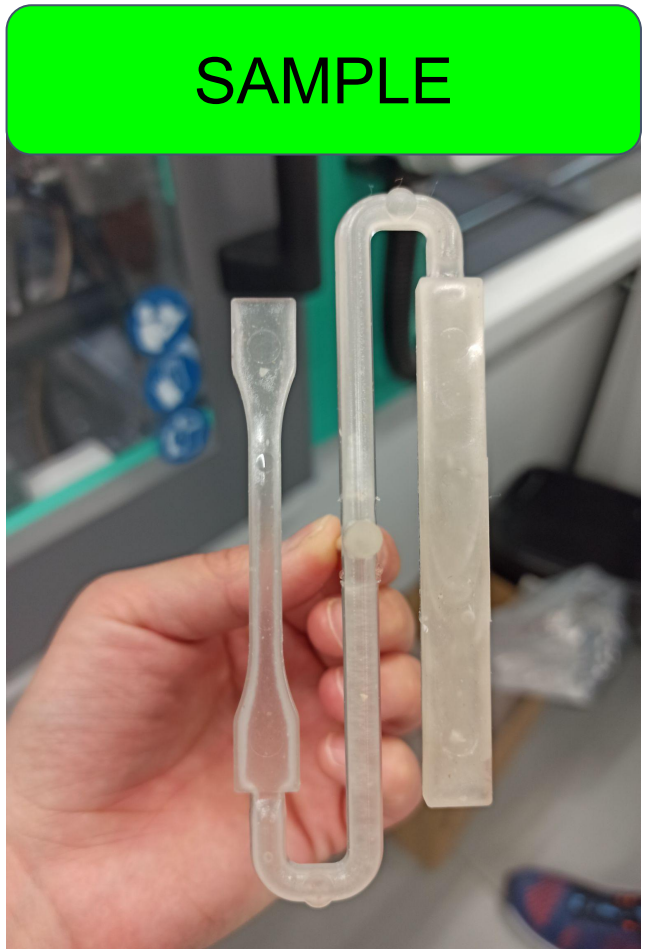
Is the biodegradation the best end-of-life?

Materials and methods

PLA bottles (industrial waste) were provided by Slovenian company Stramex PET.



Materials and methods

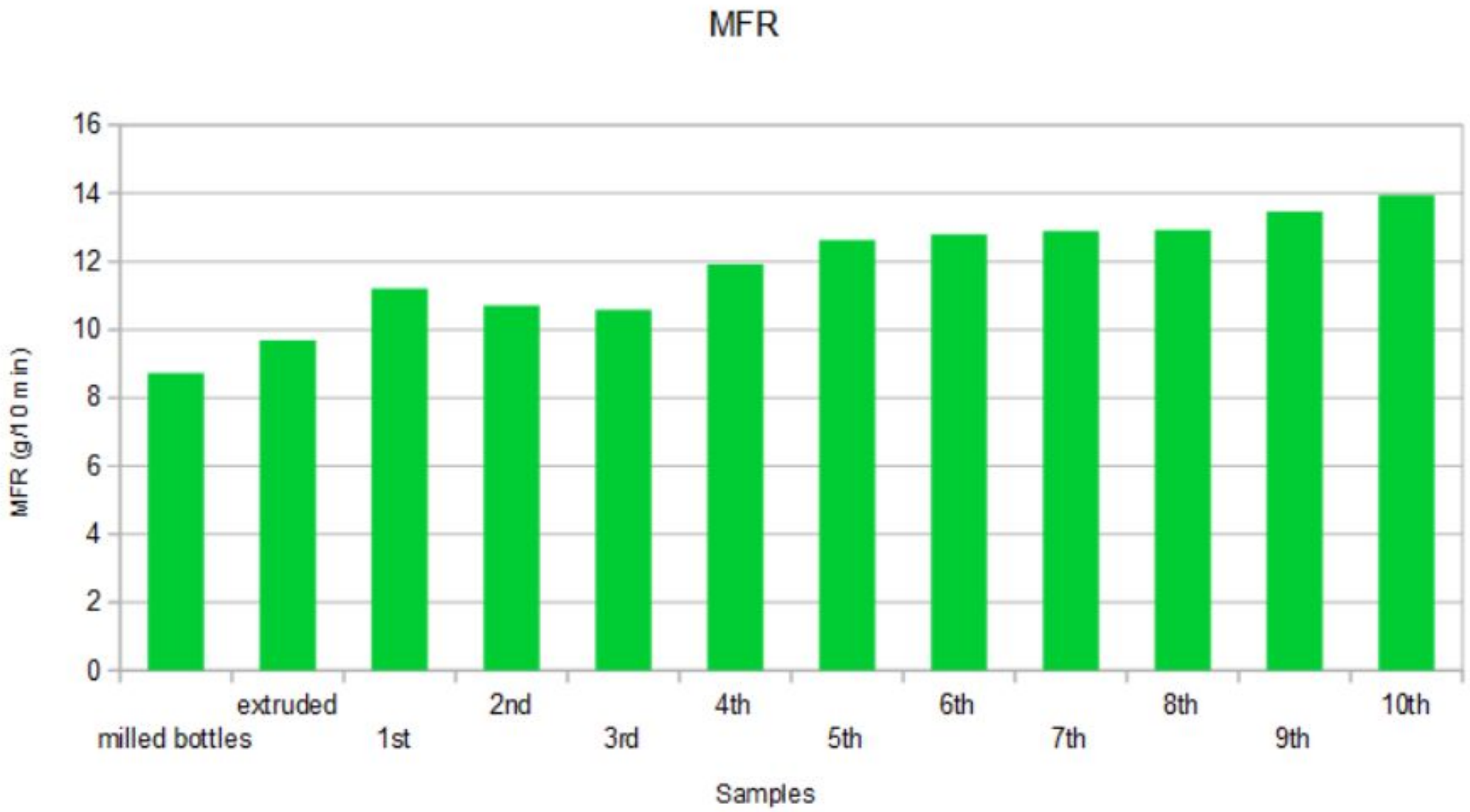


Characterization:

- MFR
- Tensile test
- DSC
- TGA

All the characterization was done at the FTPO laboratories.

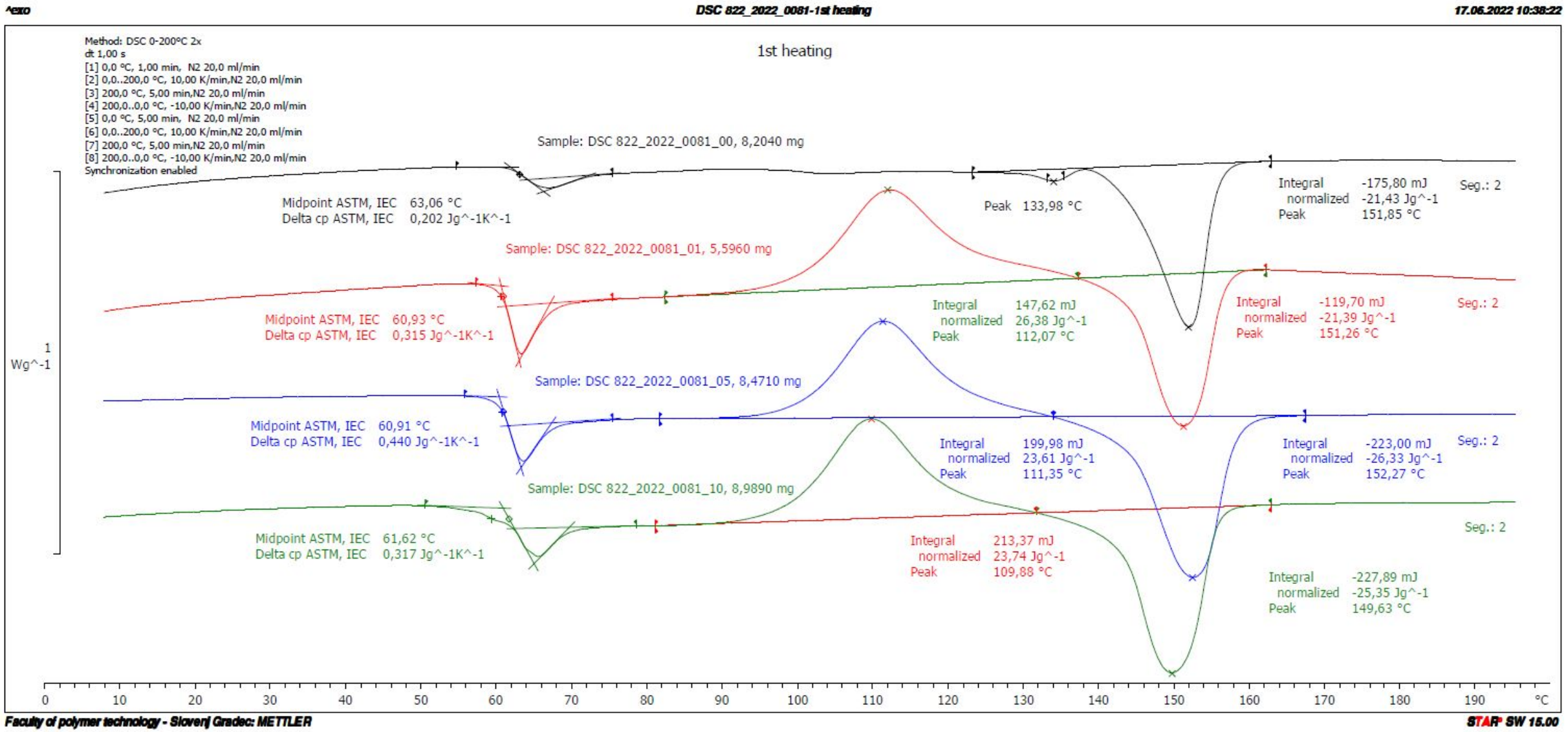
MFR


MFR
MFR (g/10 min)
16
14
12
10
8
6
4
2
0
milled bottles
extruded
1st
2nd
3rd
4th
5th
6th
7th
8th
9th
10th
Samples

Tensile test

Sample	Max stress (MPa)	Break strain (%)
First cycle of IM	68,2 ± 2,72	5,18 ± 0,78
Fifth cycle of IM	67,5 ± 0,85	4,94 ± 0,49
Tenth cycle of IM	67,1 ± 0,80	5,30 ± 0,41

DSC


exo
DSC 822_2022_0081-1st heating
17.06.2022 10:38:22
Method: DSC 0-200°C 2x
dt 1,00 s
[1] 0,0 °C, 1,00 min, N2 20,0 ml/min
[2] 0,0..200,0 °C, 10,00 K/min,N2 20,0 ml/min
[3] 200,0 °C, 5,00 min,N2 20,0 ml/min
[4] 200,0..0,0 °C, -10,00 K/min,N2 20,0 ml/min
[5] 0,0 °C, 5,00 min, N2 20,0 ml/min
[6] 0,0..200,0 °C, 10,00 K/min,N2 20,0 ml/min
[7] 200,0 °C, 5,00 min,N2 20,0 ml/min
[8] 200,0..0,0 °C, -10,00 K/min,N2 20,0 ml/min
Synchronization enabled
1st heating
Sample: DSC 822_2022_0081_00, 8,2040 mg
Midpoint ASTM, IEC 63,06 °C
Delta cp ASTM, IEC 0,202 Jg^-1K^-1
Peak 133,98 °C
Integral -175,80 mJ
normalized -21,43 Jg^-1
Peak 151,85 °C
Seg.: 2
Sample: DSC 822_2022_0081_01, 5,5960 mg
Midpoint ASTM, IEC 60,93 °C
Delta cp ASTM, IEC 0,315 Jg^-1K^-1
Integral 147,62 mJ
normalized 26,38 Jg^-1
Peak 112,07 °C
Integral -119,70 mJ
normalized -21,39 Jg^-1
Peak 151,26 °C
Seg.: 2
Sample: DSC 822_2022_0081_05, 8,4710 mg
Midpoint ASTM, IEC 60,91 °C
Delta cp ASTM, IEC 0,440 Jg^-1K^-1
Integral 199,98 mJ
normalized 23,61 Jg^-1
Peak 111,35 °C
Integral -223,00 mJ
normalized -26,33 Jg^-1
Peak 152,27 °C
Seg.: 2
Sample: DSC 822_2022_0081_10, 8,9890 mg
Midpoint ASTM, IEC 61,62 °C
Delta cp ASTM, IEC 0,317 Jg^-1K^-1
Integral 213,37 mJ
normalized 23,74 Jg^-1
Peak 109,88 °C
Integral -227,89 mJ
normalized -25,35 Jg^-1
Peak 149,63 °C
Seg.: 2
1
Wg^-1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 °C
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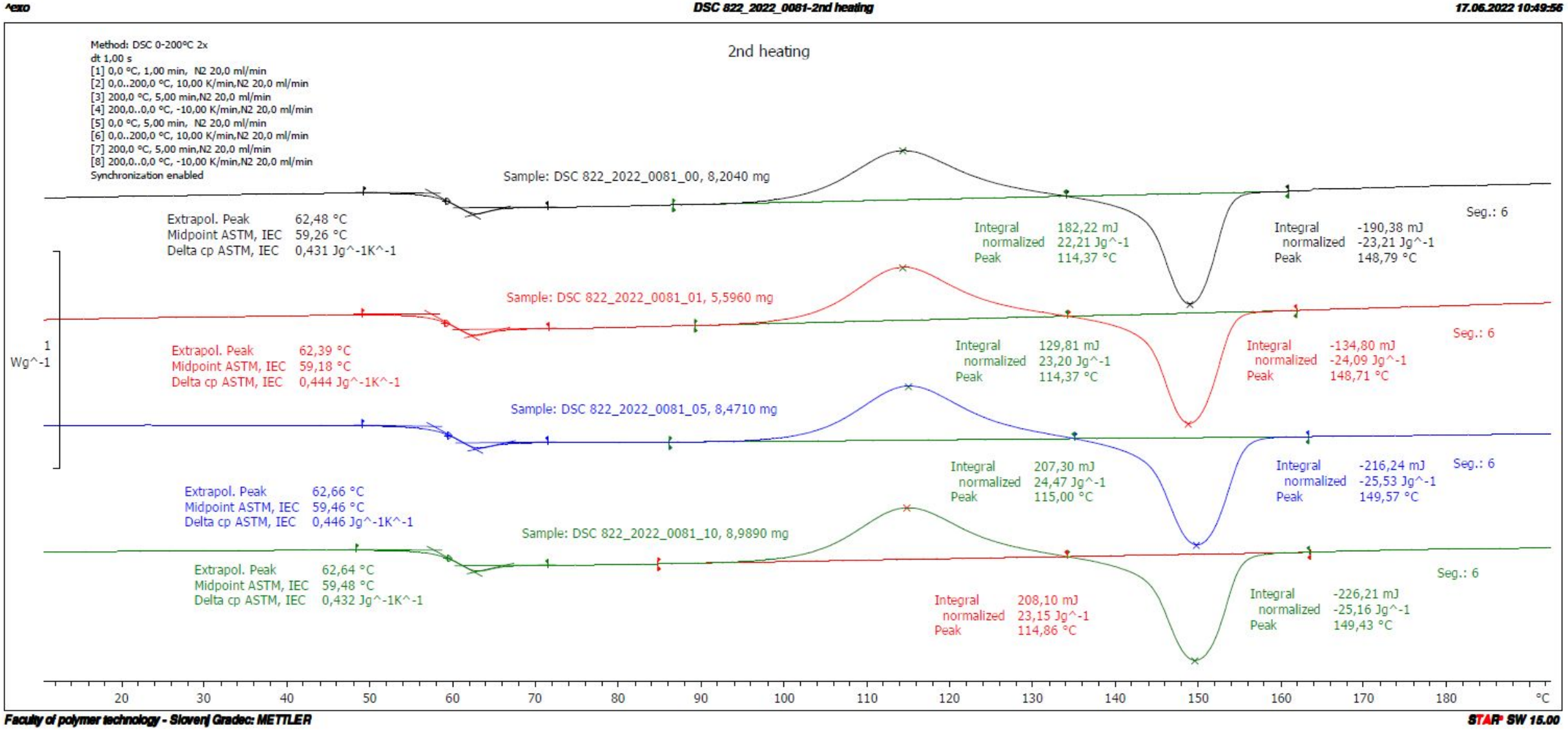
STAR SW 15.00

DSC


^exo
DSC 822_2022_0081-2nd heating
17.06.2022 10:49:56
Method: DSC 0-200°C 2x
dt 1,00 s
[1] 0,0 °C, 1,00 min, N2 20,0 ml/min
[2] 0,0..200,0 °C, 10,00 K/min,N2 20,0 ml/min
[3] 200,0 °C, 5,00 min,N2 20,0 ml/min
[4] 200,0..0,0 °C, -10,00 K/min,N2 20,0 ml/min
[5] 0,0 °C, 5,00 min, N2 20,0 ml/min
[6] 0,0..200,0 °C, 10,00 K/min,N2 20,0 ml/min
[7] 200,0 °C, 5,00 min,N2 20,0 ml/min
[8] 200,0..0,0 °C, -10,00 K/min,N2 20,0 ml/min
Synchronization enabled
2nd heating
Sample: DSC 822_2022_0081_00, 8,2040 mg
Extrapol. Peak 62,48 °C
Midpoint ASTM, IEC 59,26 °C
Delta cp ASTM, IEC 0,431 Jg^-1K^-1
Integral 182,22 mJ
normalized 22,21 Jg^-1
Peak 114,37 °C
Integral -190,38 mJ
normalized -23,21 Jg^-1
Peak 148,79 °C
Seg.: 6
Sample: DSC 822_2022_0081_01, 5,5960 mg
Extrapol. Peak 62,39 °C
Midpoint ASTM, IEC 59,18 °C
Delta cp ASTM, IEC 0,444 Jg^-1K^-1
Integral 129,81 mJ
normalized 23,20 Jg^-1
Peak 114,37 °C
Integral -134,80 mJ
normalized -24,09 Jg^-1
Peak 148,71 °C
Seg.: 6
1
Wg^-1
Sample: DSC 822_2022_0081_05, 8,4710 mg
Extrapol. Peak 62,66 °C
Midpoint ASTM, IEC 59,46 °C
Delta cp ASTM, IEC 0,446 Jg^-1K^-1
Integral 207,30 mJ
normalized 24,47 Jg^-1
Peak 115,00 °C
Integral -216,24 mJ
normalized -25,53 Jg^-1
Peak 149,57 °C
Seg.: 6
Sample: DSC 822_2022_0081_10, 8,9890 mg
Extrapol. Peak 62,64 °C
Midpoint ASTM, IEC 59,48 °C
Delta cp ASTM, IEC 0,432 Jg^-1K^-1
Integral 208,10 mJ
normalized 23,15 Jg^-1
Peak 114,86 °C
Integral -226,21 mJ
normalized -25,16 Jg^-1
Peak 149,43 °C
Seg.: 6
20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 °C
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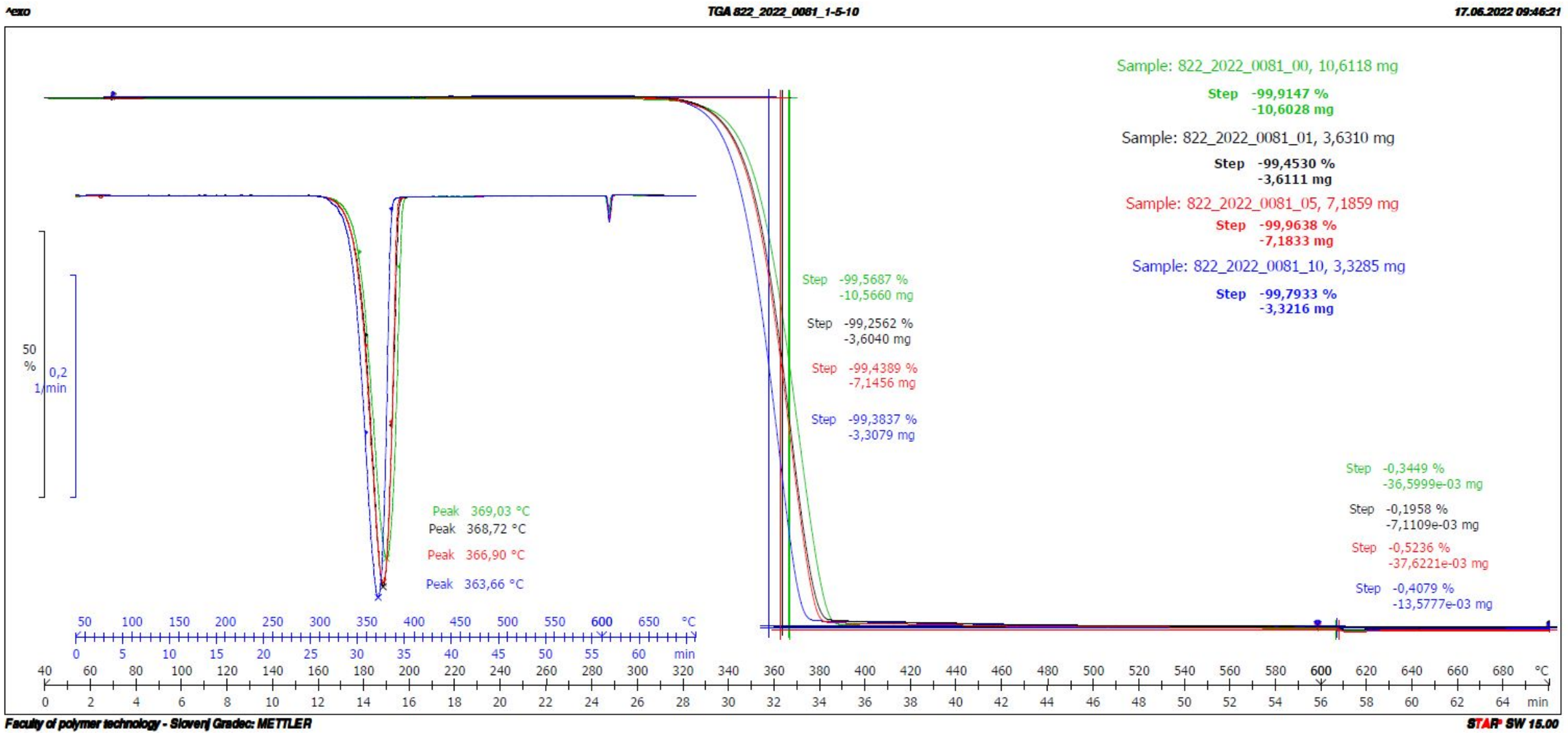
STAR° SW 16.00

TGA


^exo
TGA 822_2022_0081_1-5-10
17.06.2022 09:46:21
Sample: 822_2022_0081_00, 10,6118 mg
Step -99,9147 %
-10,6028 mg
Sample: 822_2022_0081_01, 3,6310 mg
Step -99,4530 %
-3,6111 mg
Sample: 822_2022_0081_05, 7,1859 mg
Step -99,9638 %
-7,1833 mg
Sample: 822_2022_0081_10, 3,3285 mg
Step -99,7933 %
-3,3216 mg
Step -99,5687 %
-10,5660 mg
Step -99,2562 %
-3,6040 mg
Step -99,4389 %
-7,1456 mg
Step -99,3837 %
-3,3079 mg
Step -0,3449 %
-36,5999e-03 mg
Step -0,1958 %
-7,1109e-03 mg
Step -0,5236 %
-37,6221e-03 mg
Step -0,4079 %
-13,5777e-03 mg
50 %
0,2 1/min
Peak 369,03 °C
Peak 368,72 °C
Peak 366,90 °C
Peak 363,66 °C
50 100 150 200 250 300 350 400 450 500 550 600 650 °C
0 5 10 15 20 25 30 35 40 45 50 55 60 min
40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 °C
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 min
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STAR SW 15.00

Conclusion

Thermo-mechanical properties of the PLA are not affected by multiple processing (injection molding and milling) and PLA can be recycled at least 10 times.

Acknowledgements

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