

**ATLAS OF THERMAL ANALYSIS
AND CHEMILUMINESCENCE
MEASUREMENTS ON THE SET OF
POLYMERS FROM
POPART PROJECT**

The graphical records that may be on the request complemented by the numerical data of thermal analysis and chemiluminescence (non-isothermal mode) from polymers involved in the resin kit (50 samples) and Smile polymers (35 polymers) represent here the original position for:

- a) Identification of unknown plastic samples
- b) Round robin test in thermal analysis
- c) Characterization of subsequently aged samples aimed at the determination of their trajectory of life with applicability for museum plastics artefacts

The Atlas will be step-wisely complemented by experiments under different conditions as well as by characterization of other materials which might be independent continuation of the Popart project.

The Atlas is targeted for research scientists at the universities, academic and industrial institutions as well as for those who like to work with plastics in museums and galleries

Measurements and collection of data were performed by Jozef Rychlý, Lyda Rychlá, Ivica Janigová, Katarína Csomorová and Marta Malíková from PISAS Bratislava on following instruments:

Chemiluminescence - spectrometer Lumipol 3, product of PISAS Bratislava

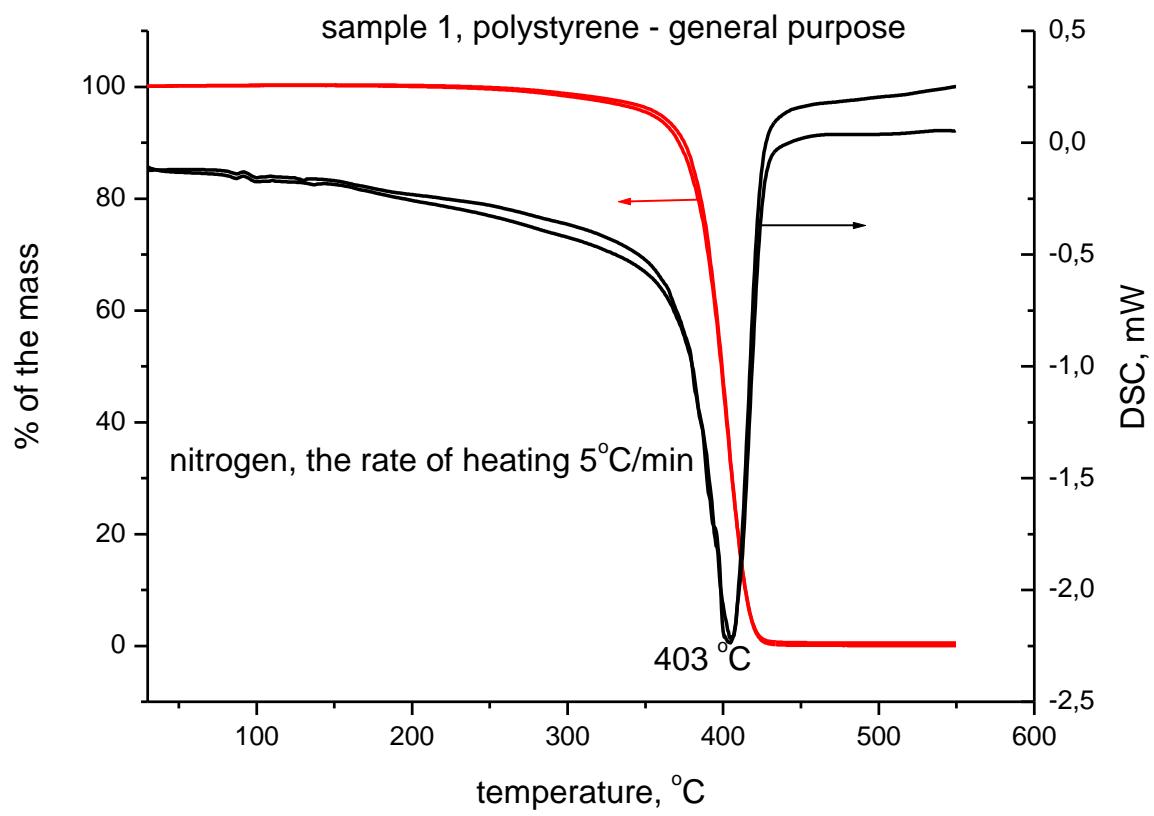
DSC – Mettler Toledo DSC 821^e differential scanning calorimeter

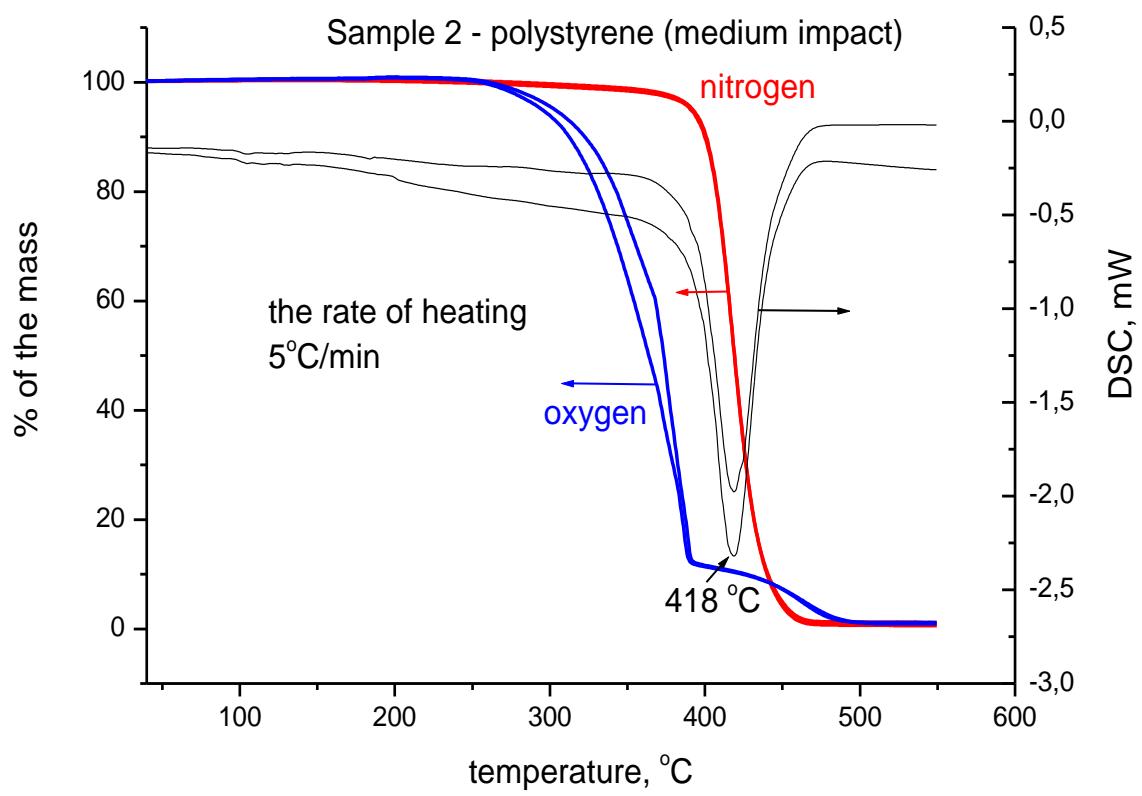
Thermogravimetry - Mettler Toledo TGA/SDTA 851^e

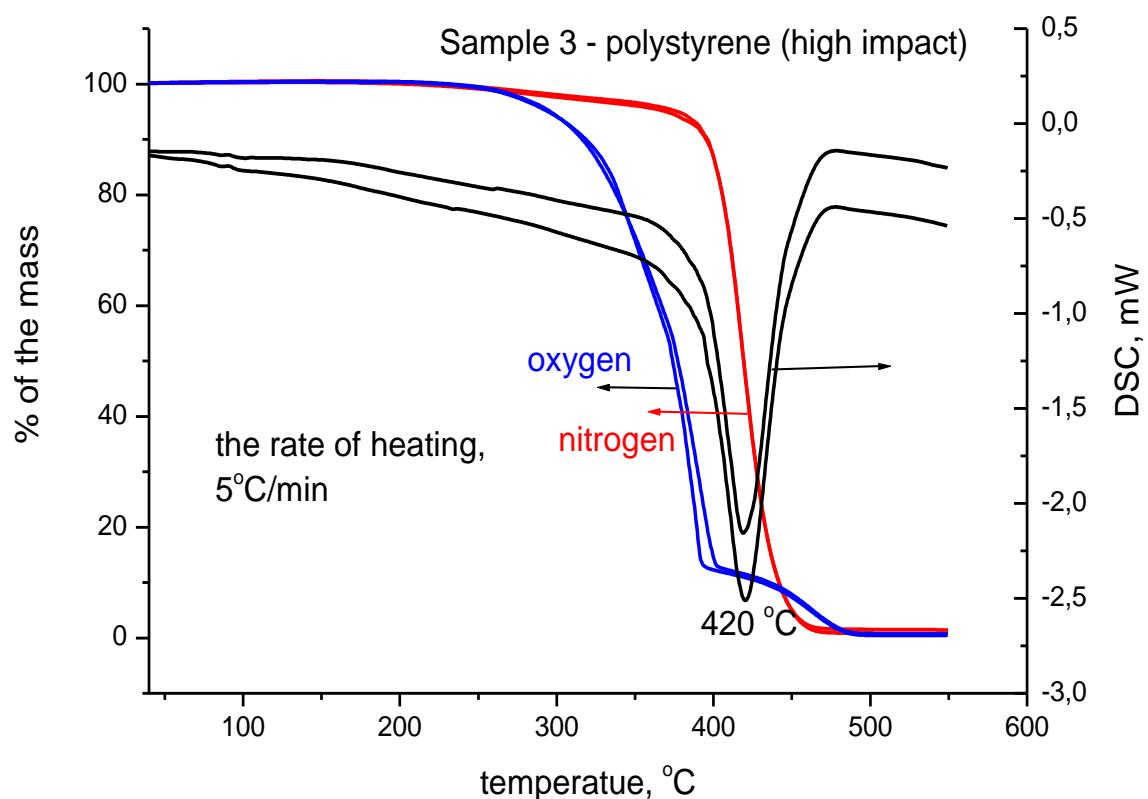
Heats of combustion – IKA calorimetric bomb C 200

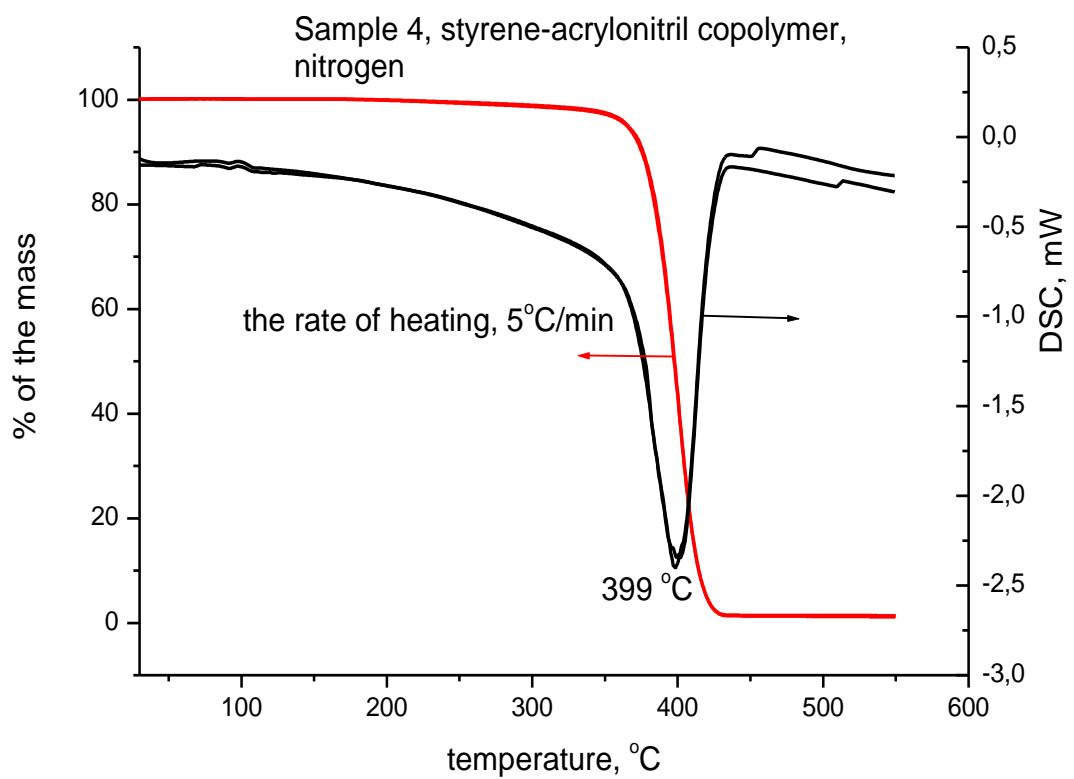
Bratislava, 07.3.2012

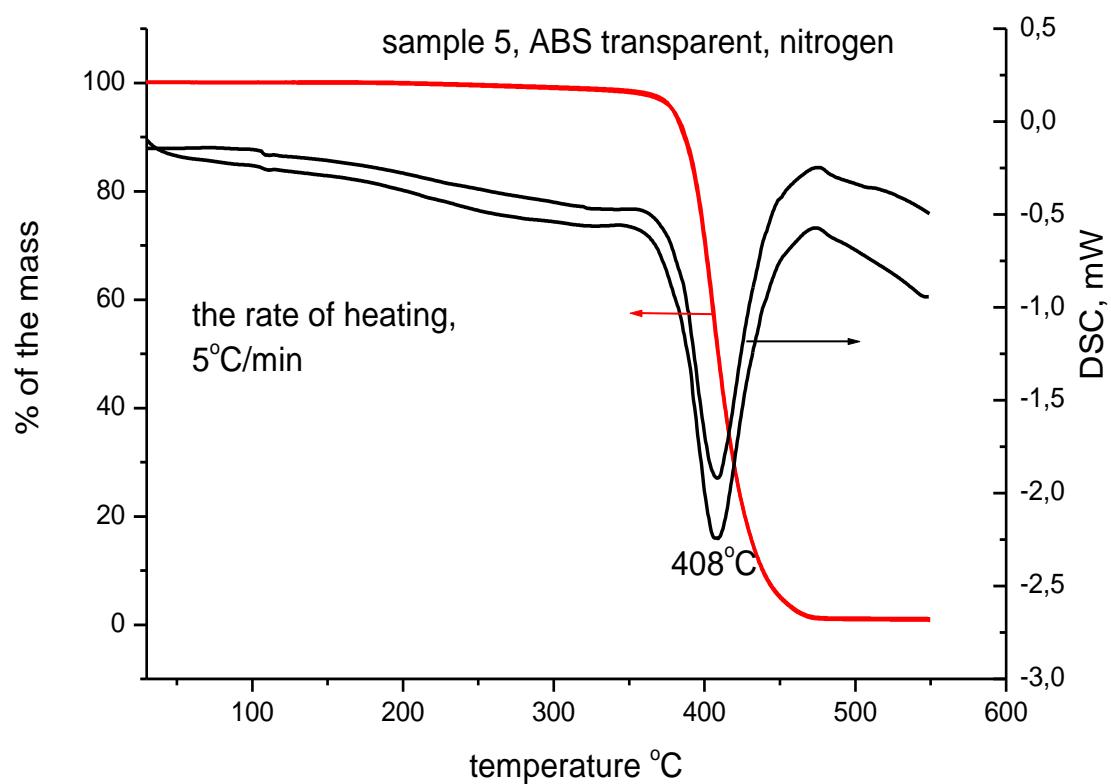
THERMAL ANALYSIS OF RESIN KIT POLYMERS

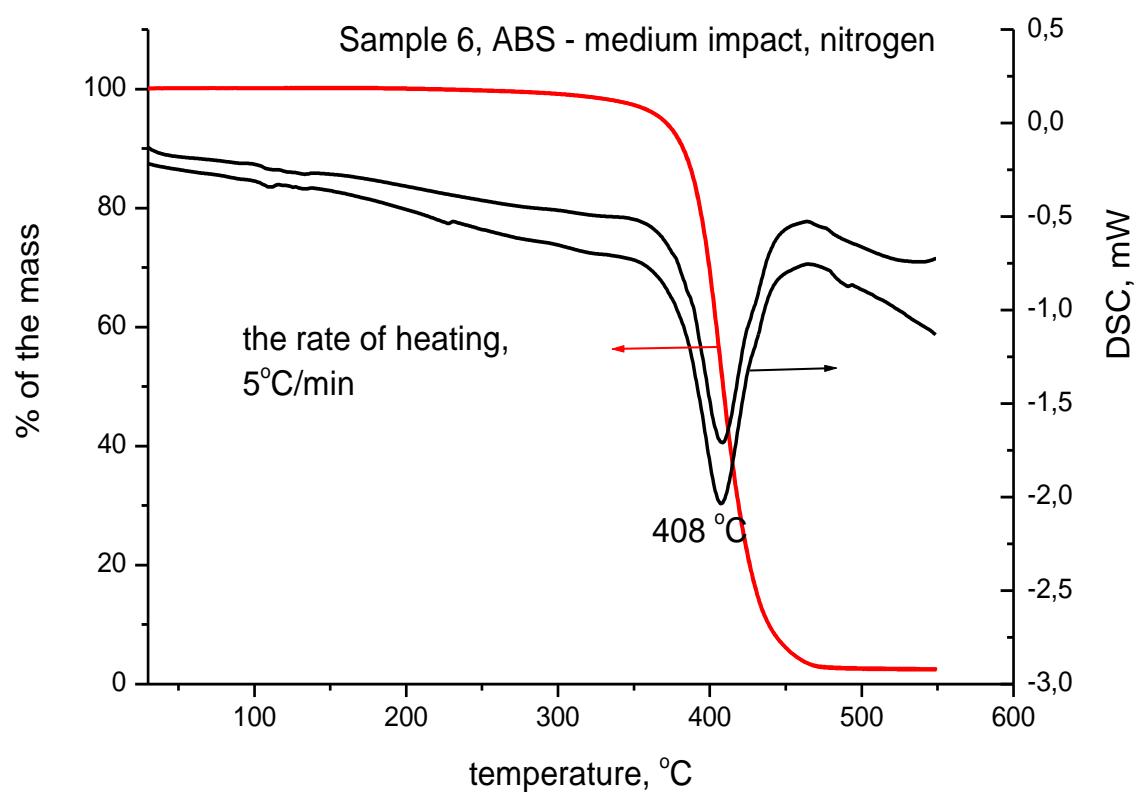


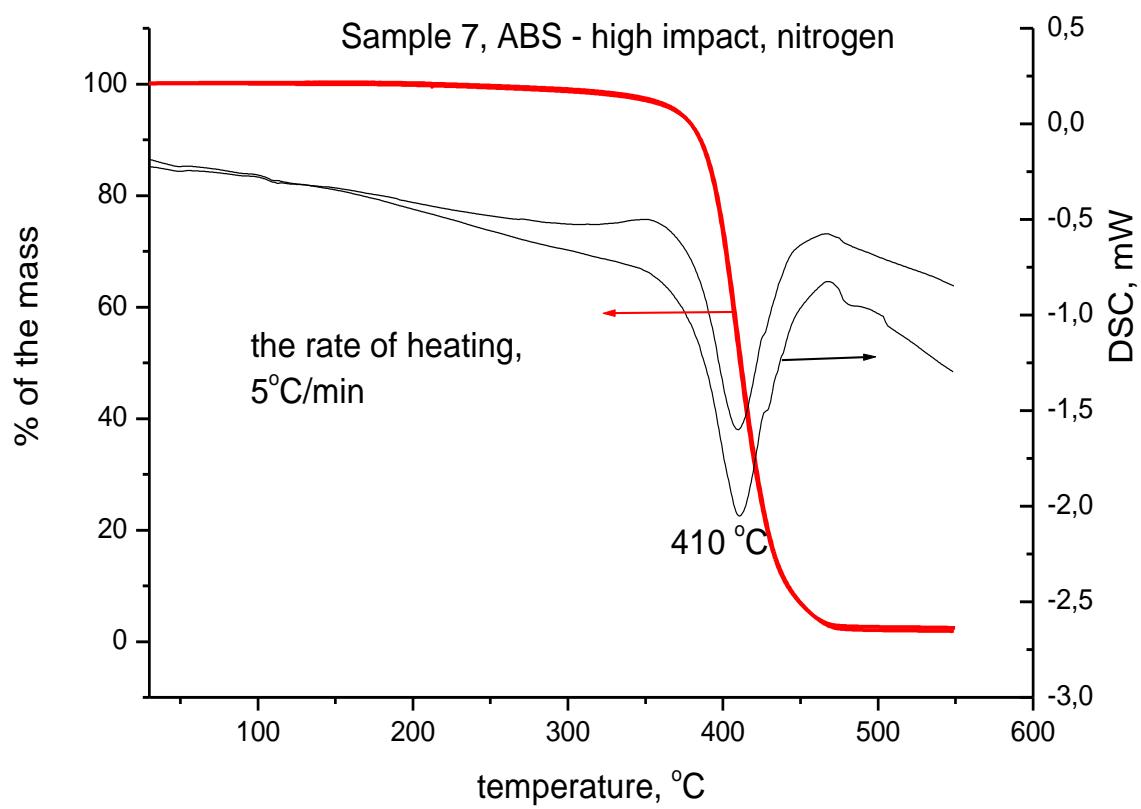


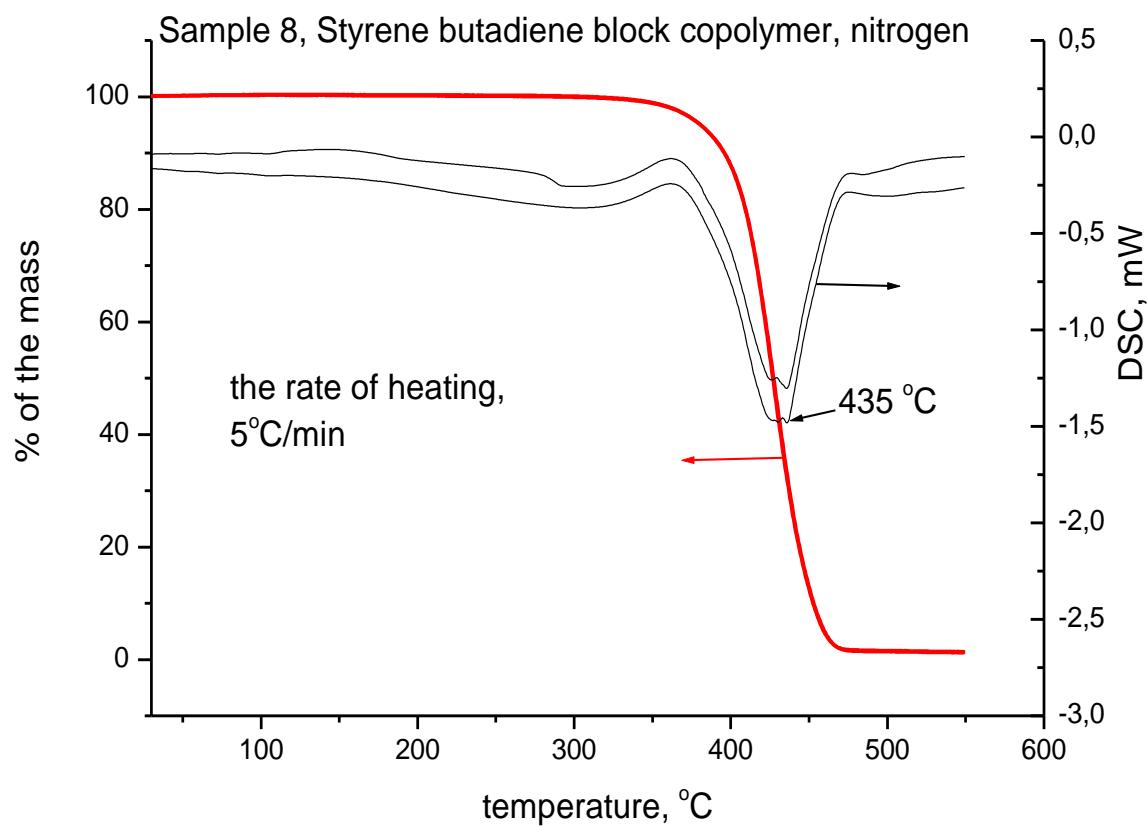


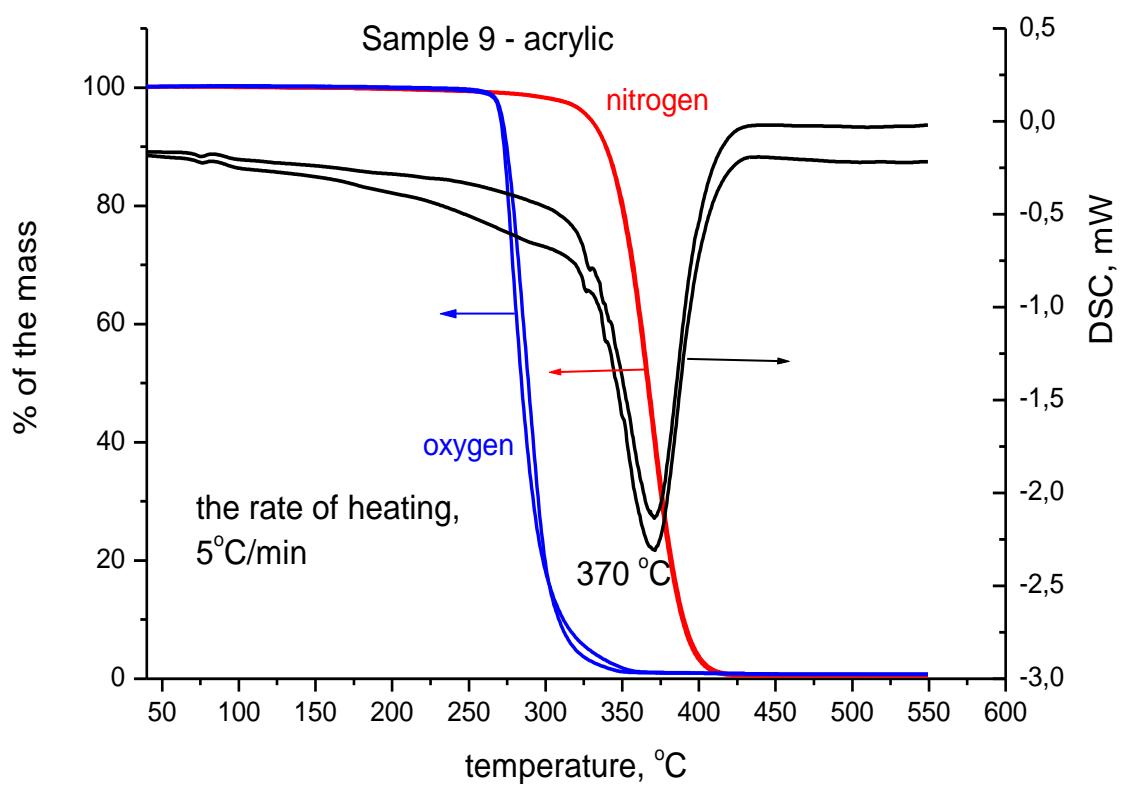


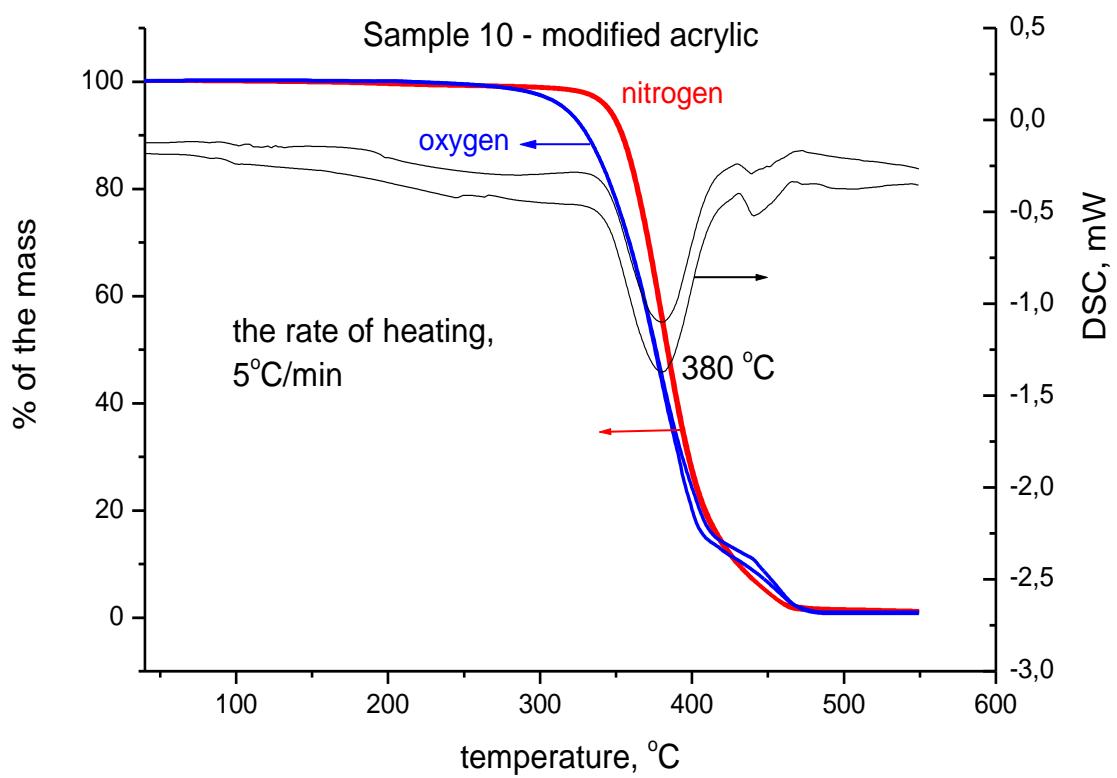


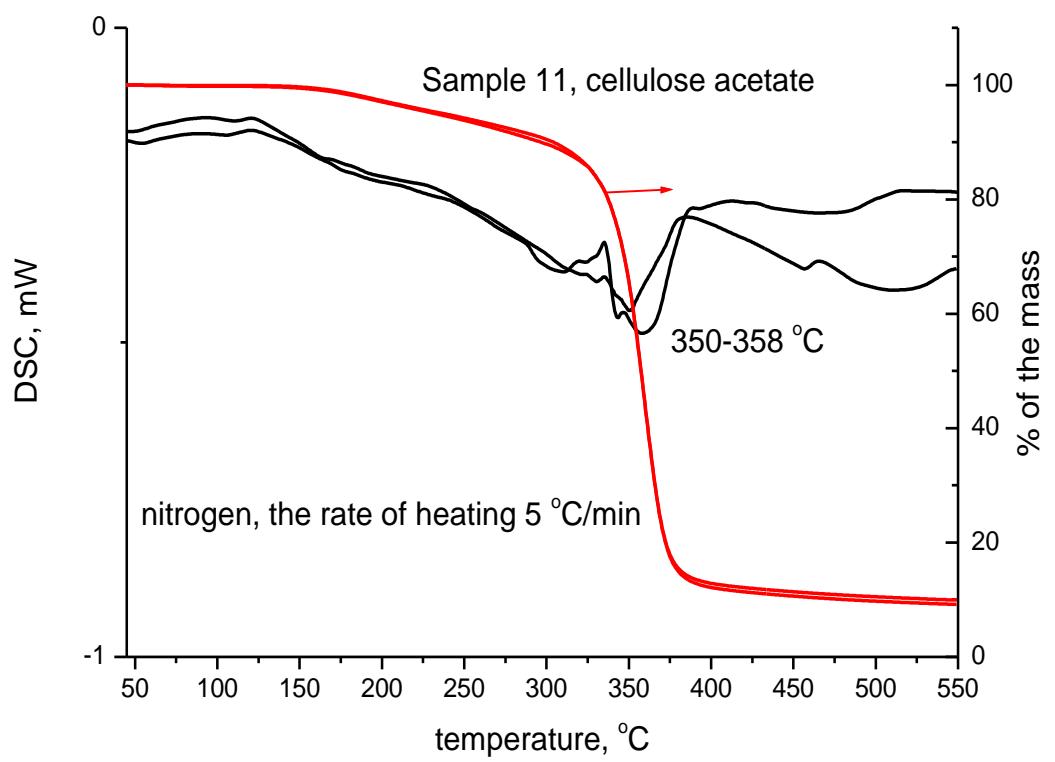


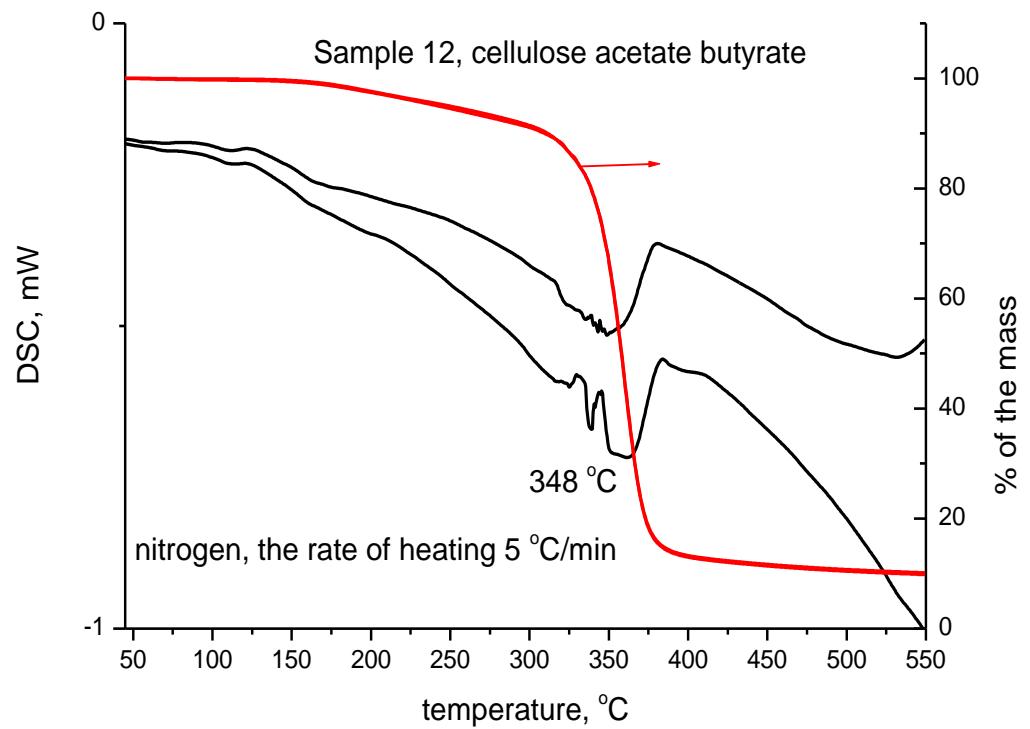


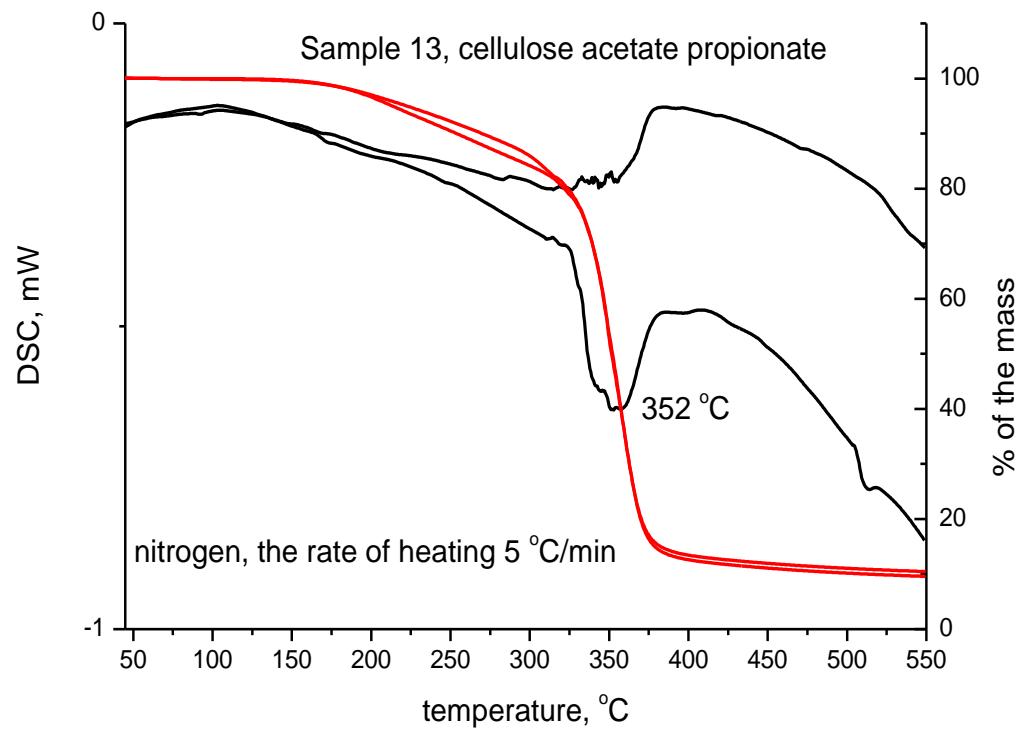


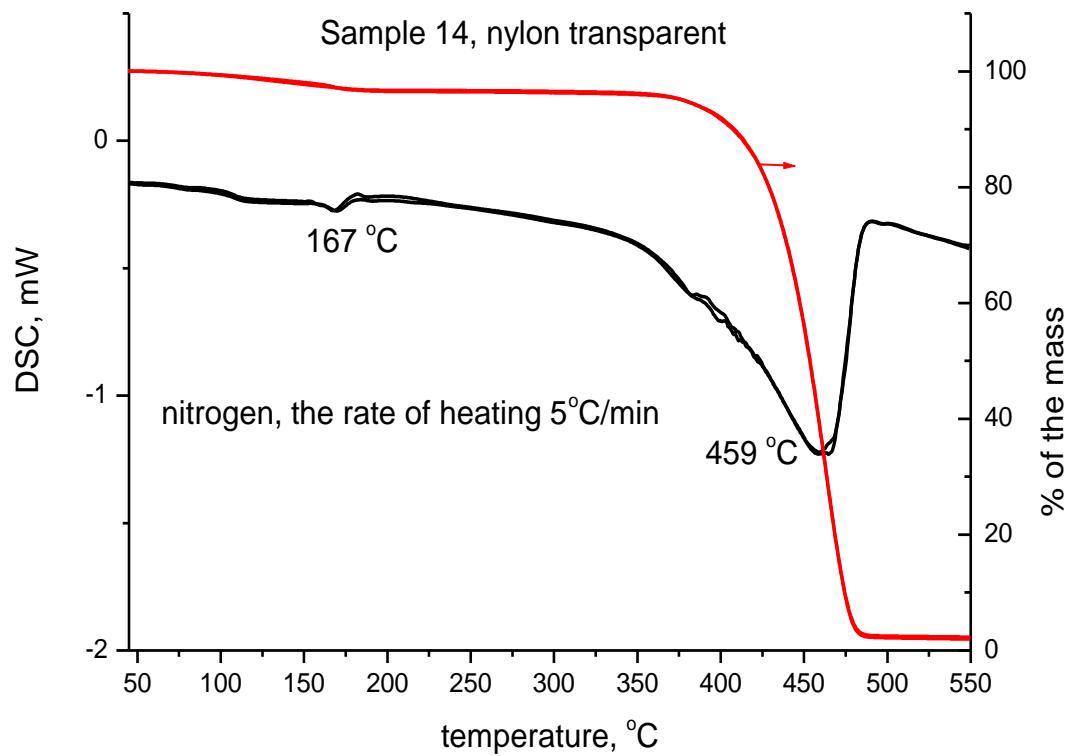


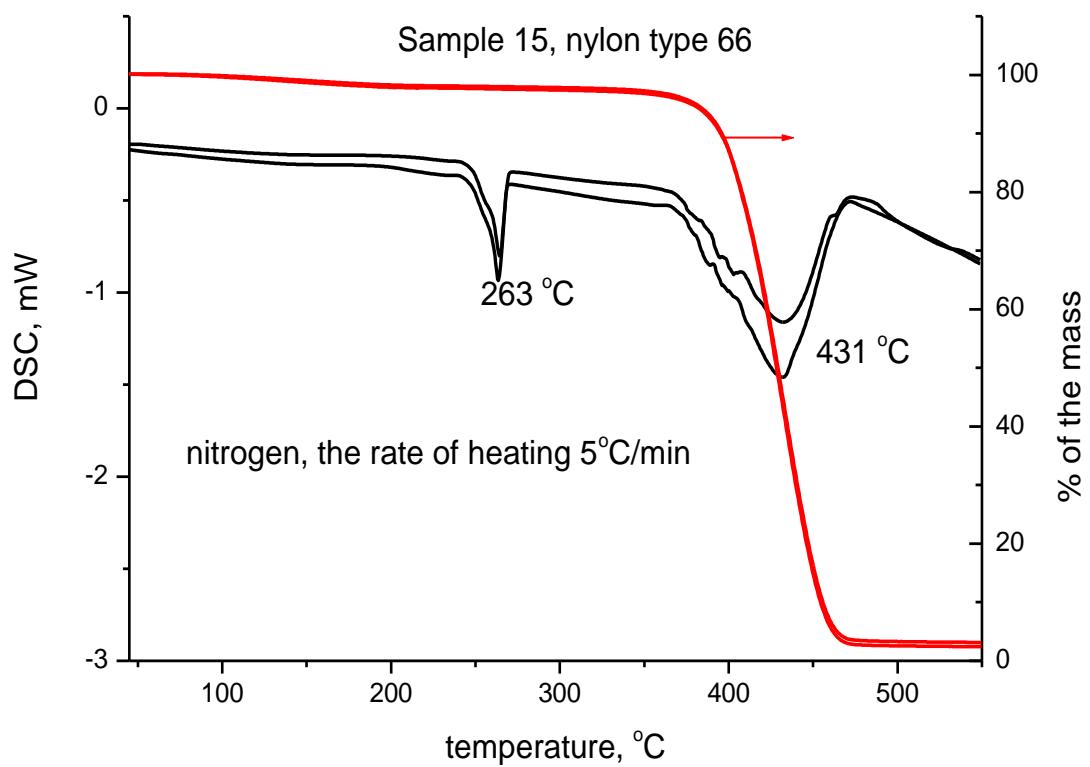


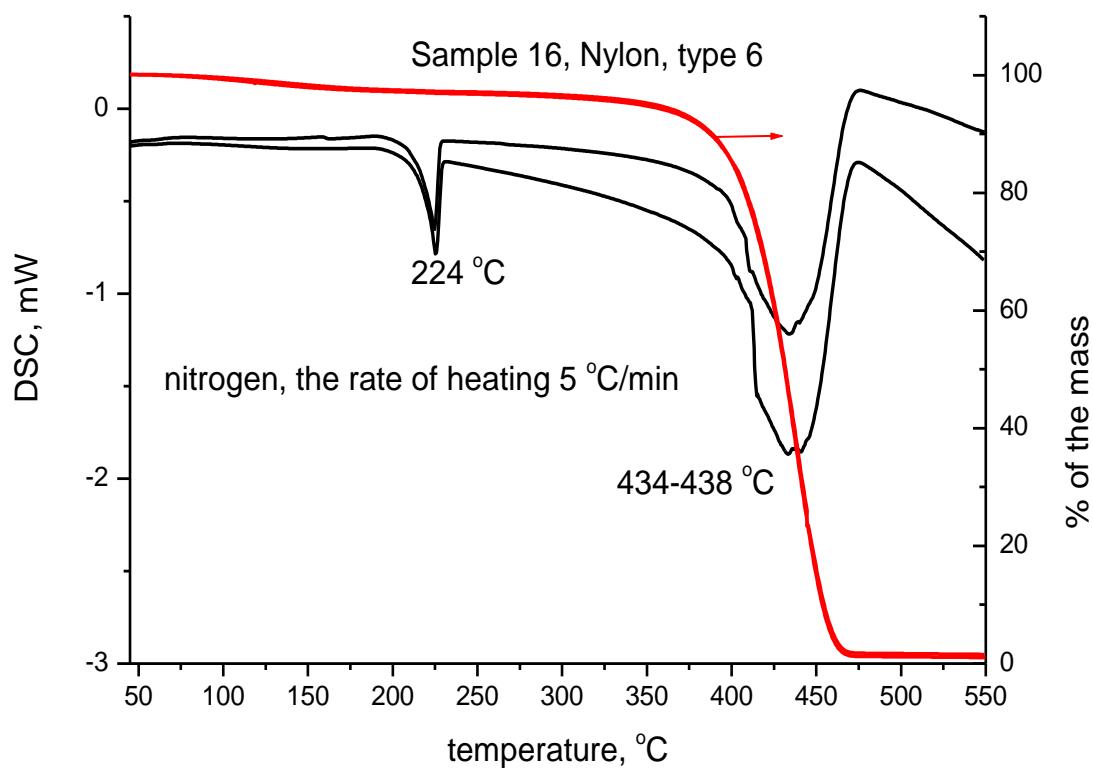


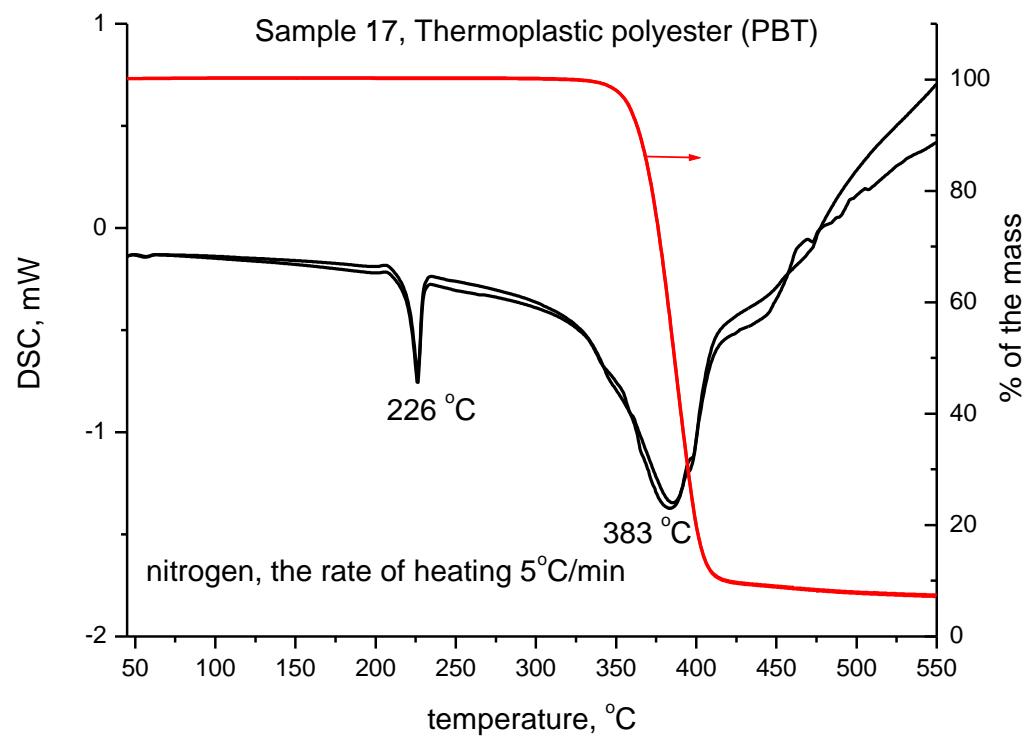


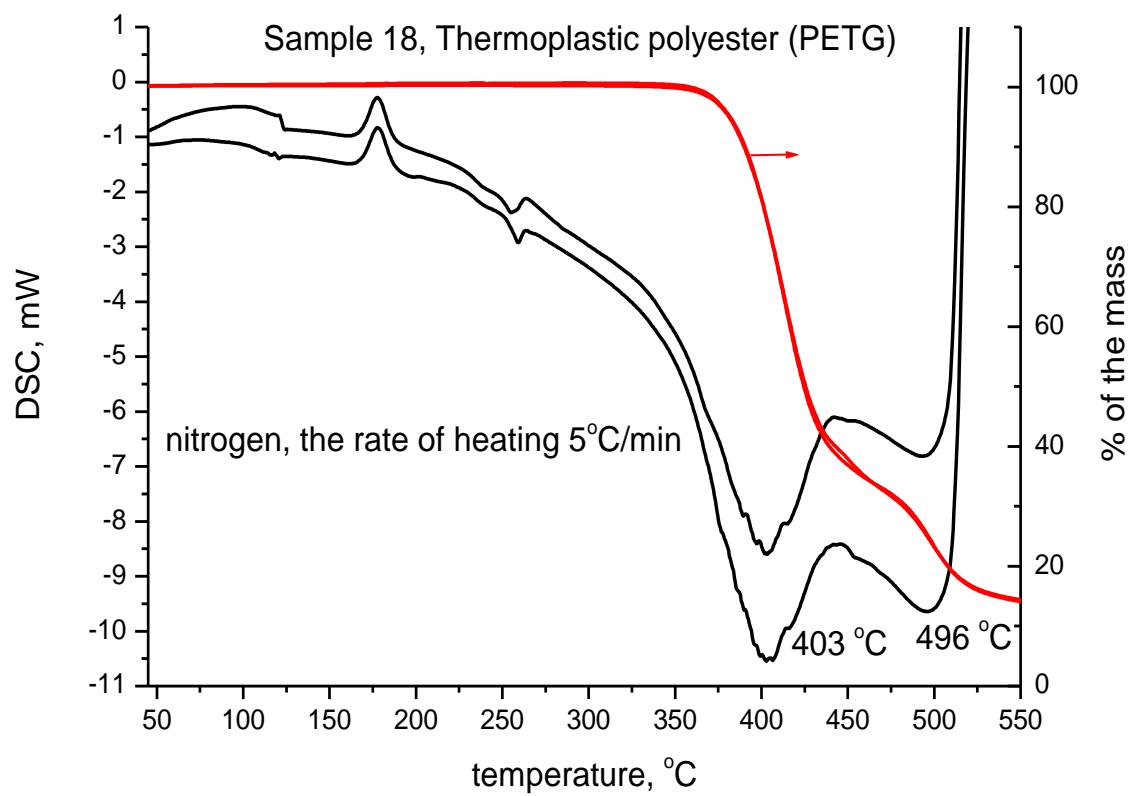


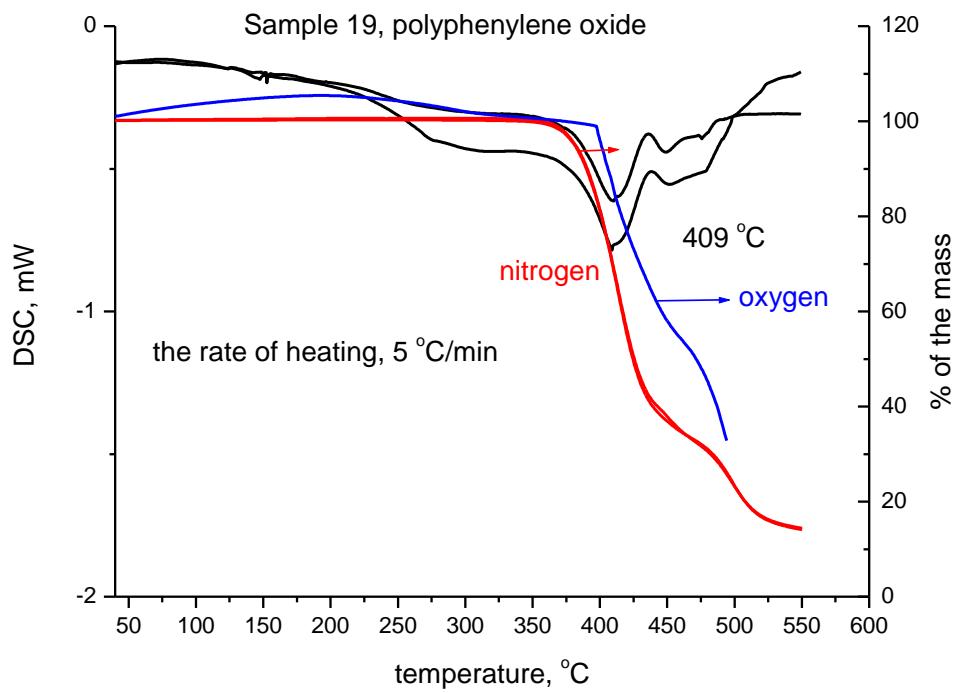


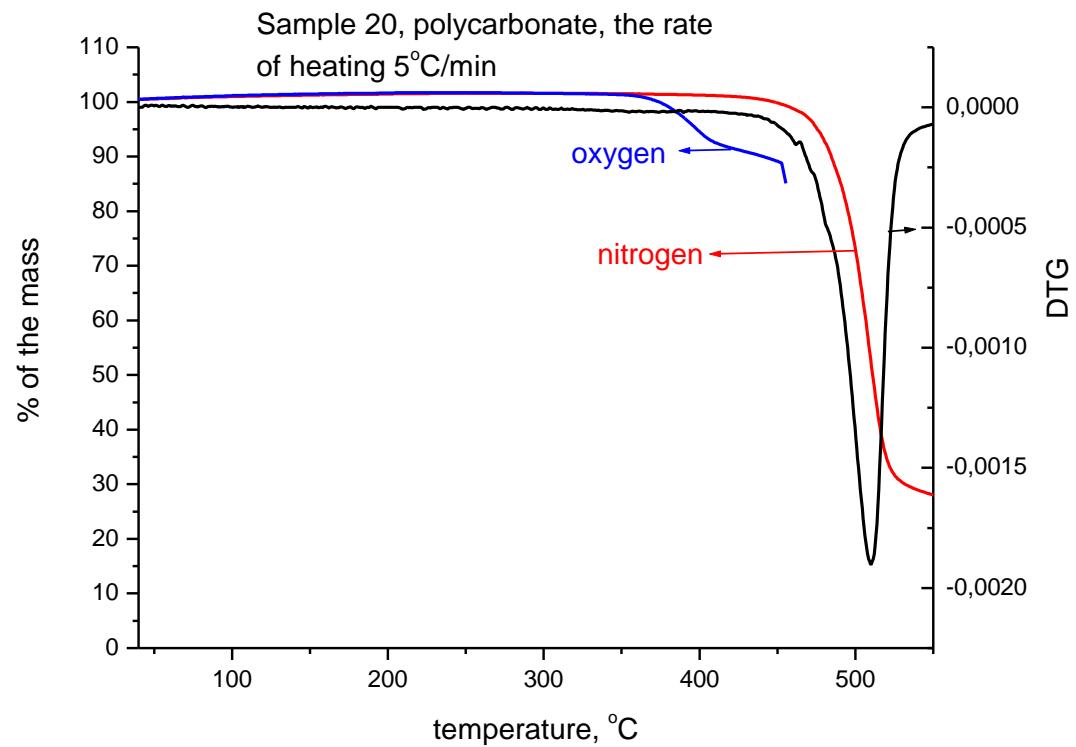


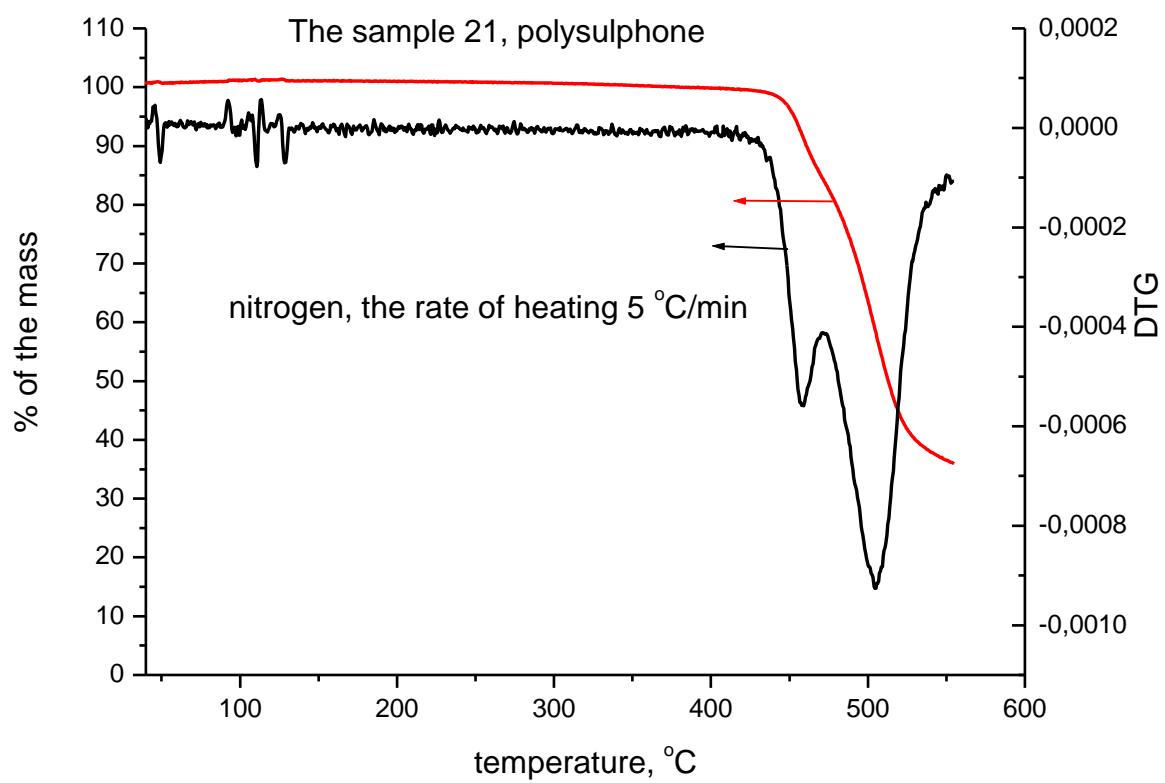


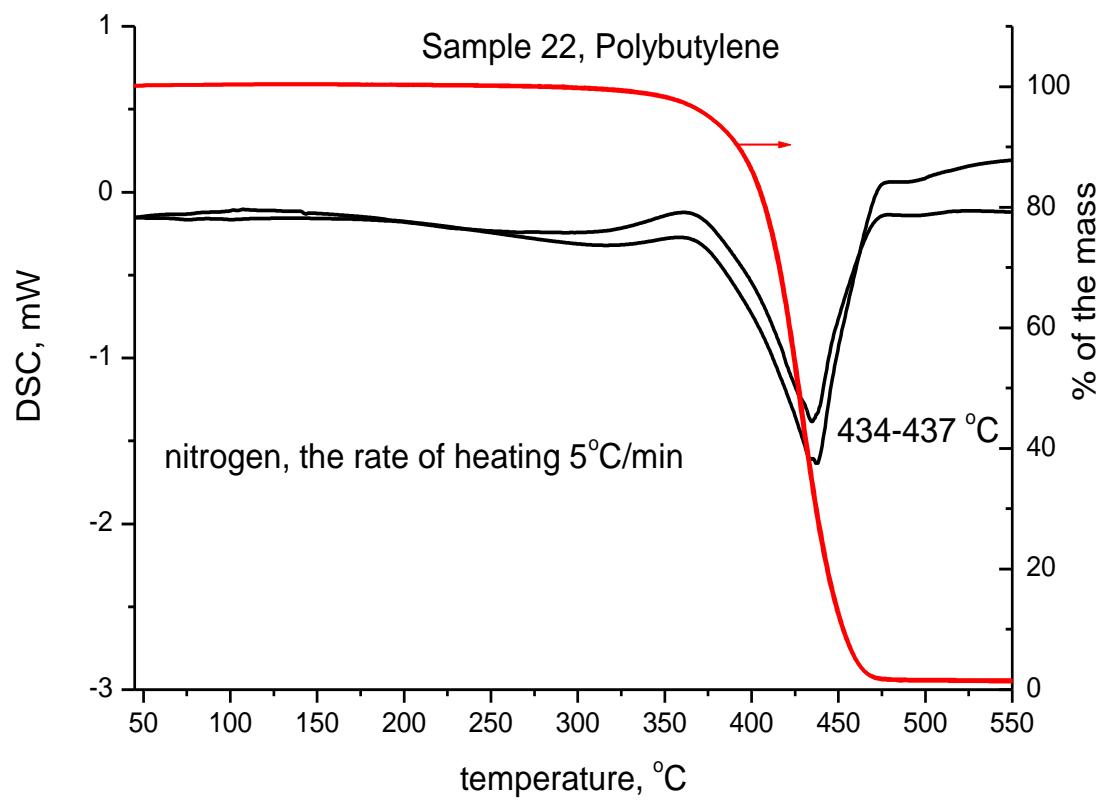


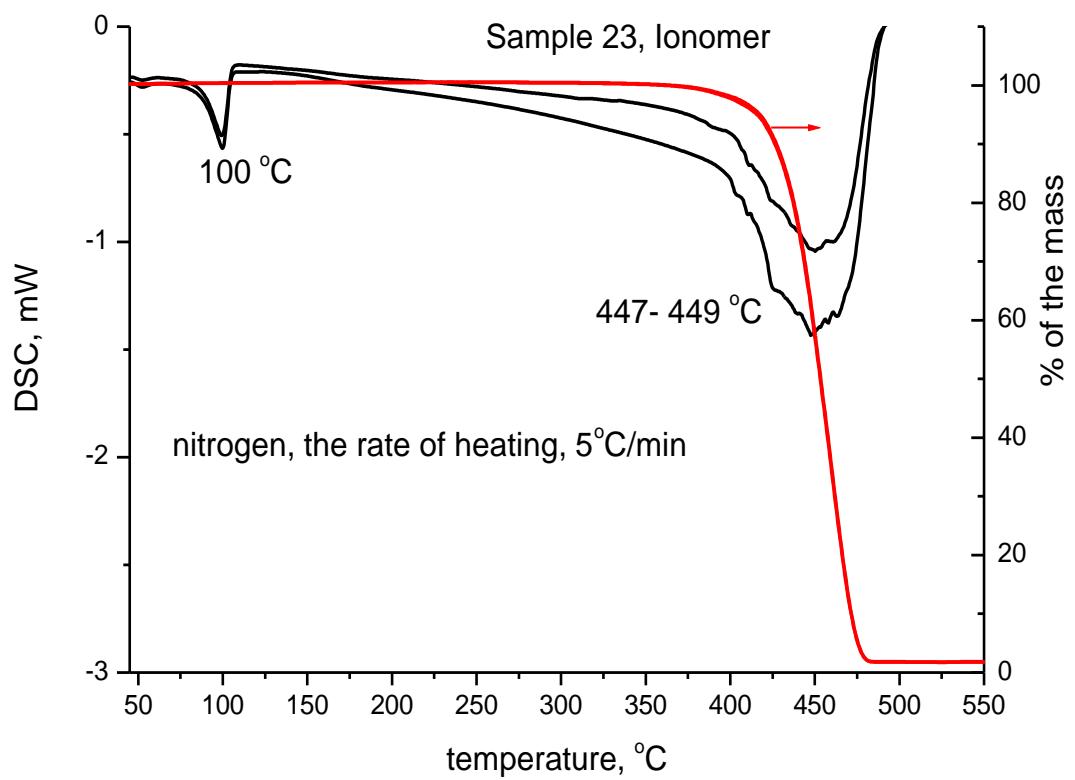


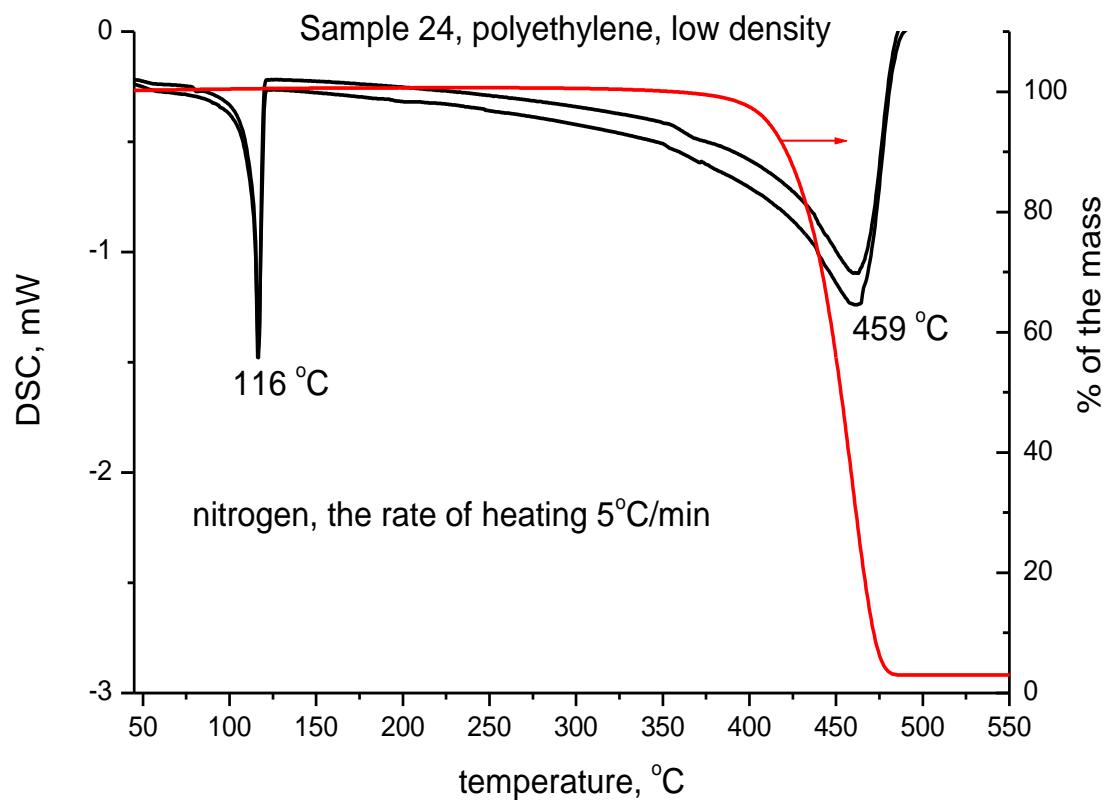


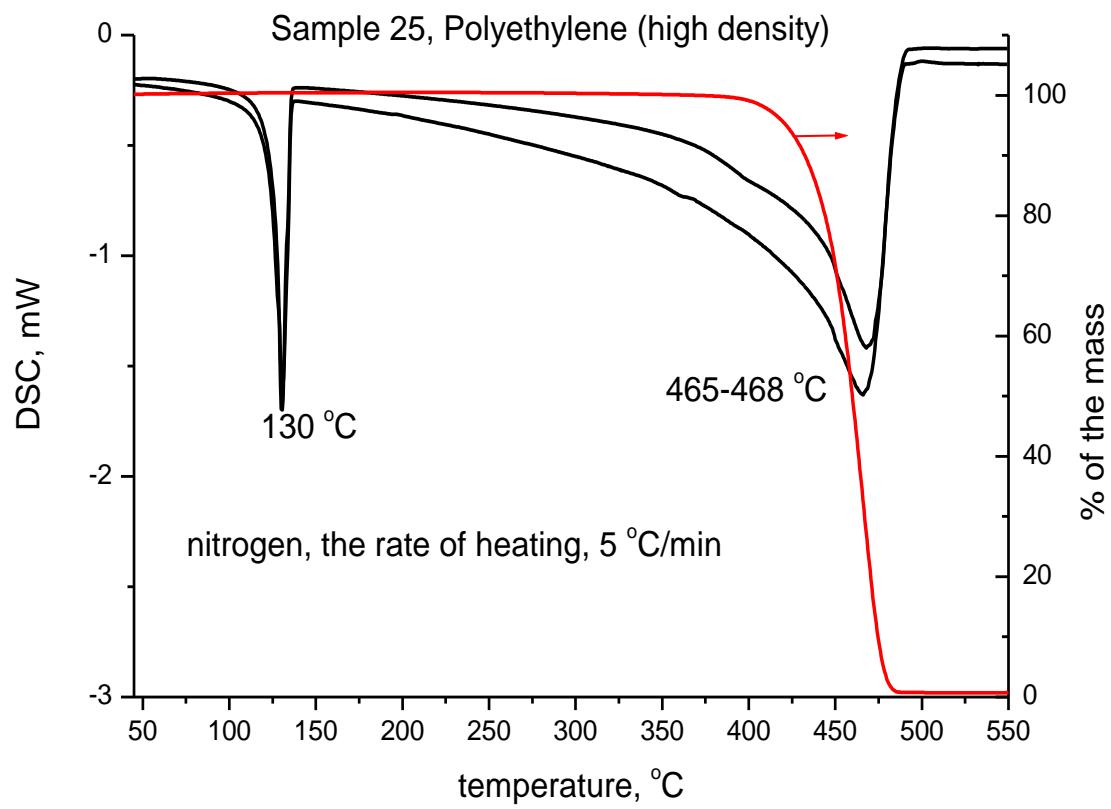


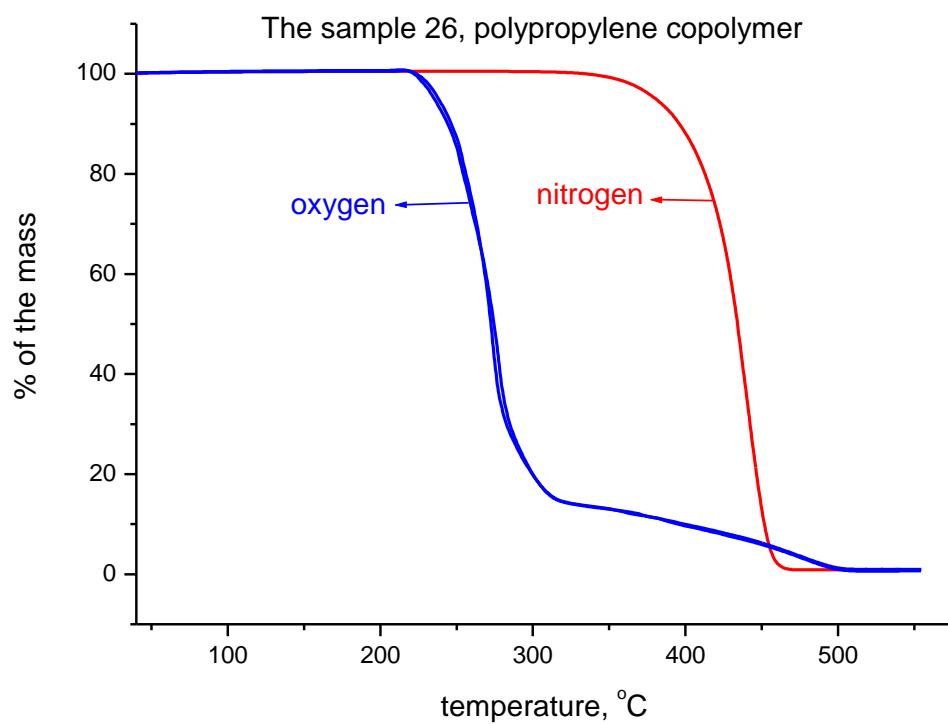


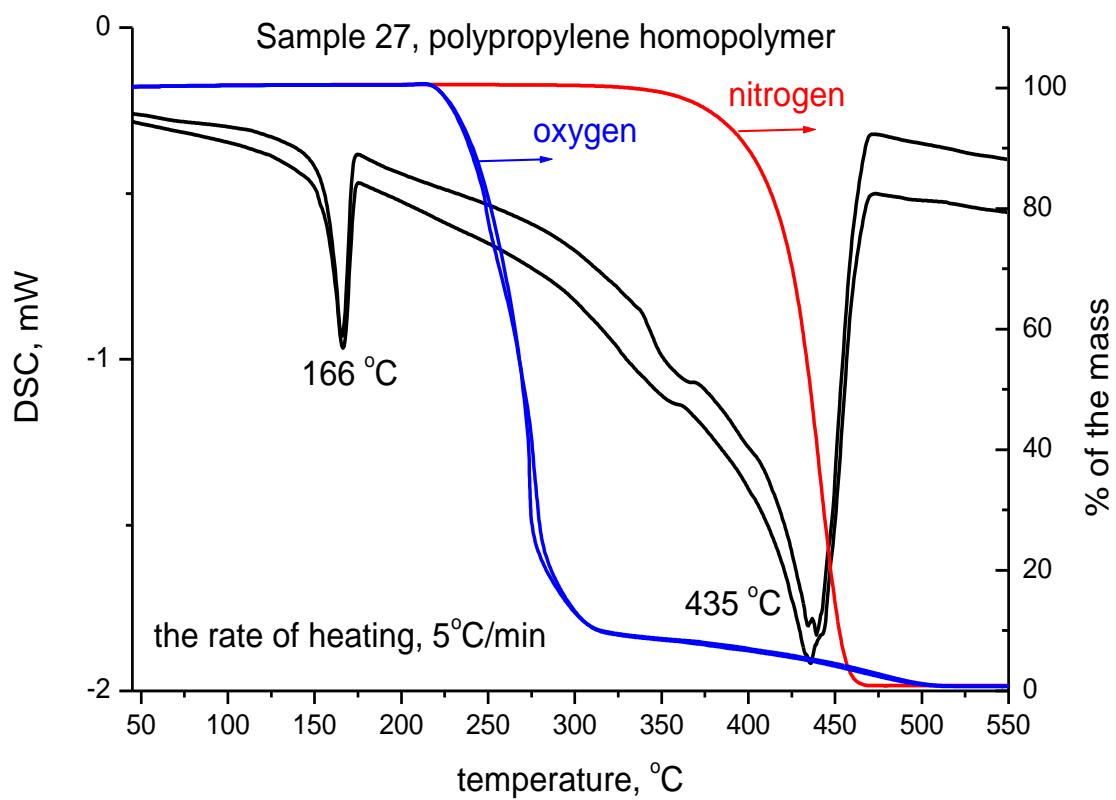


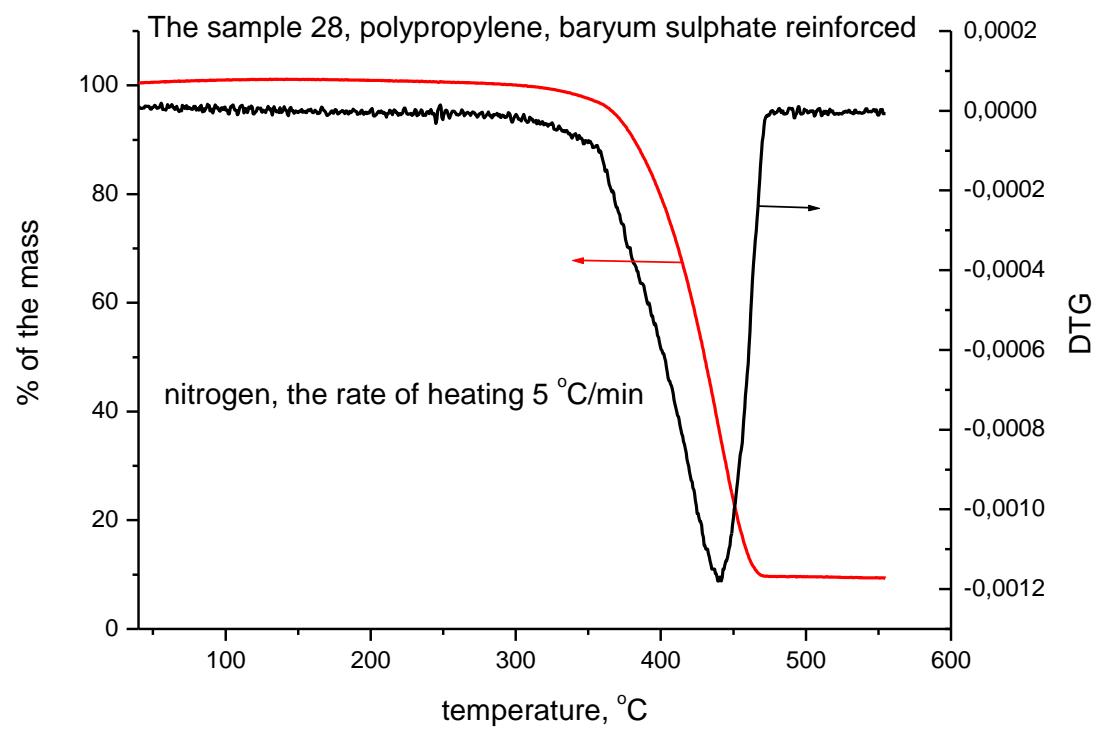


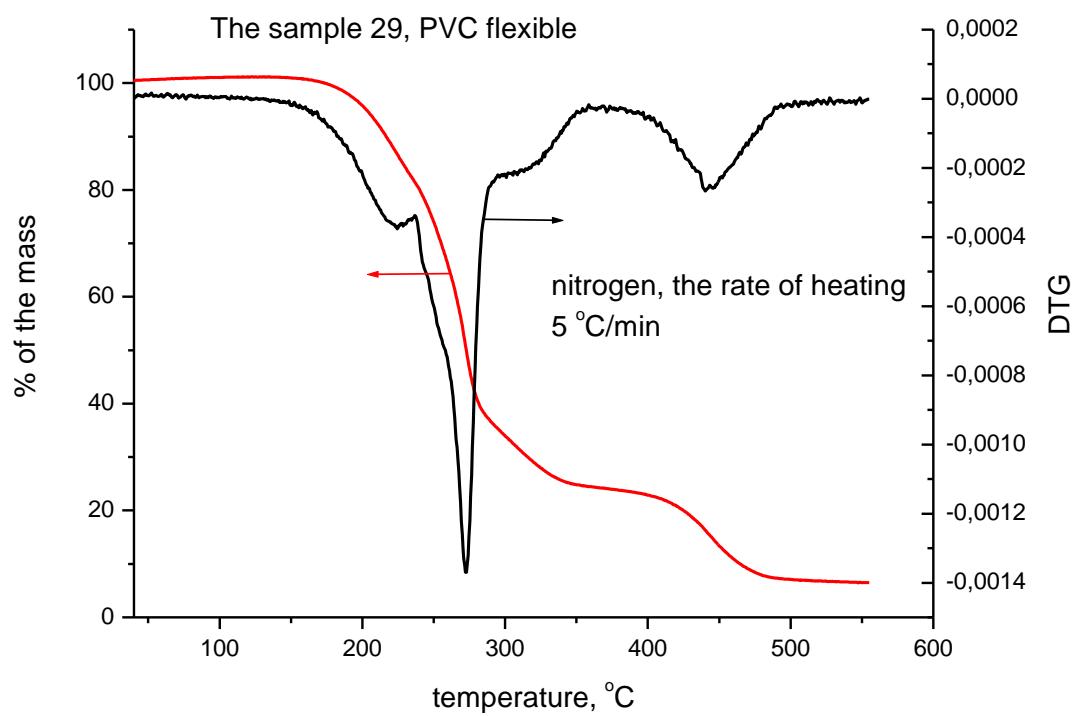


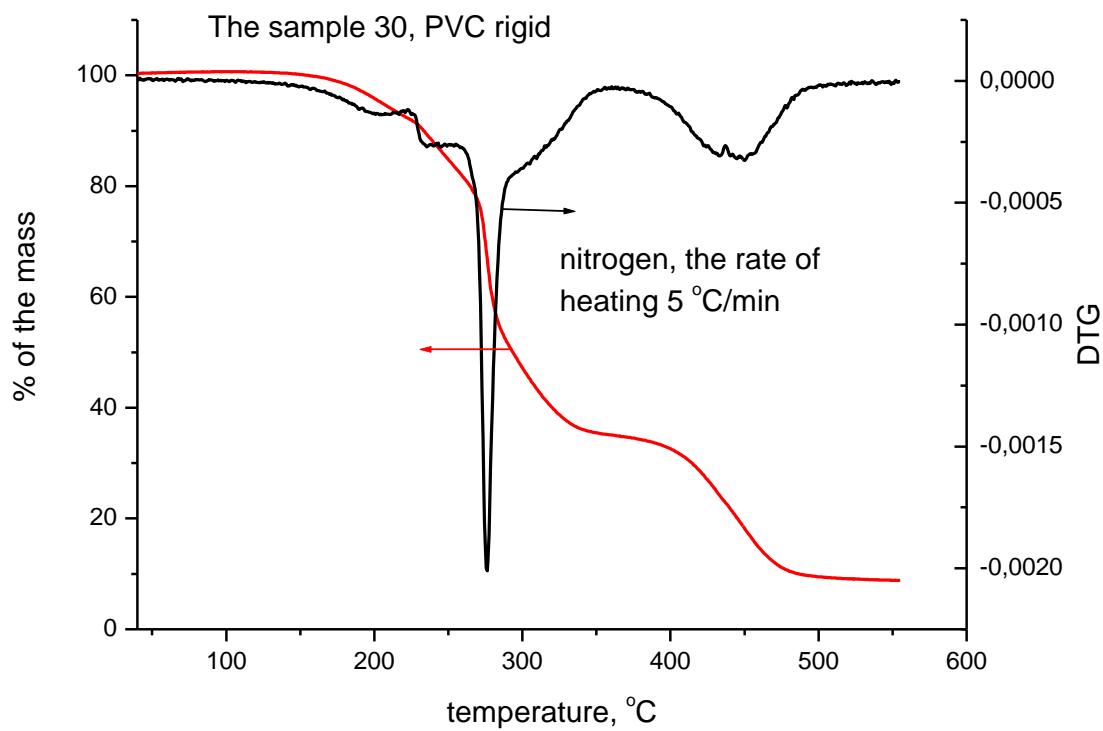


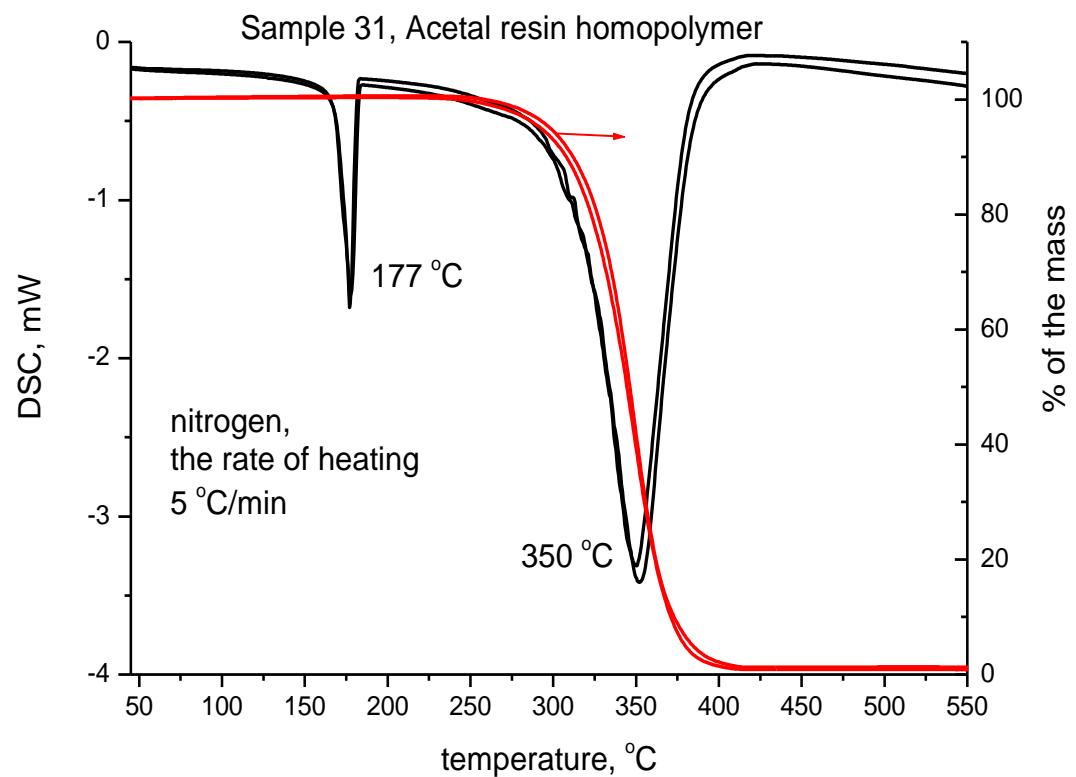


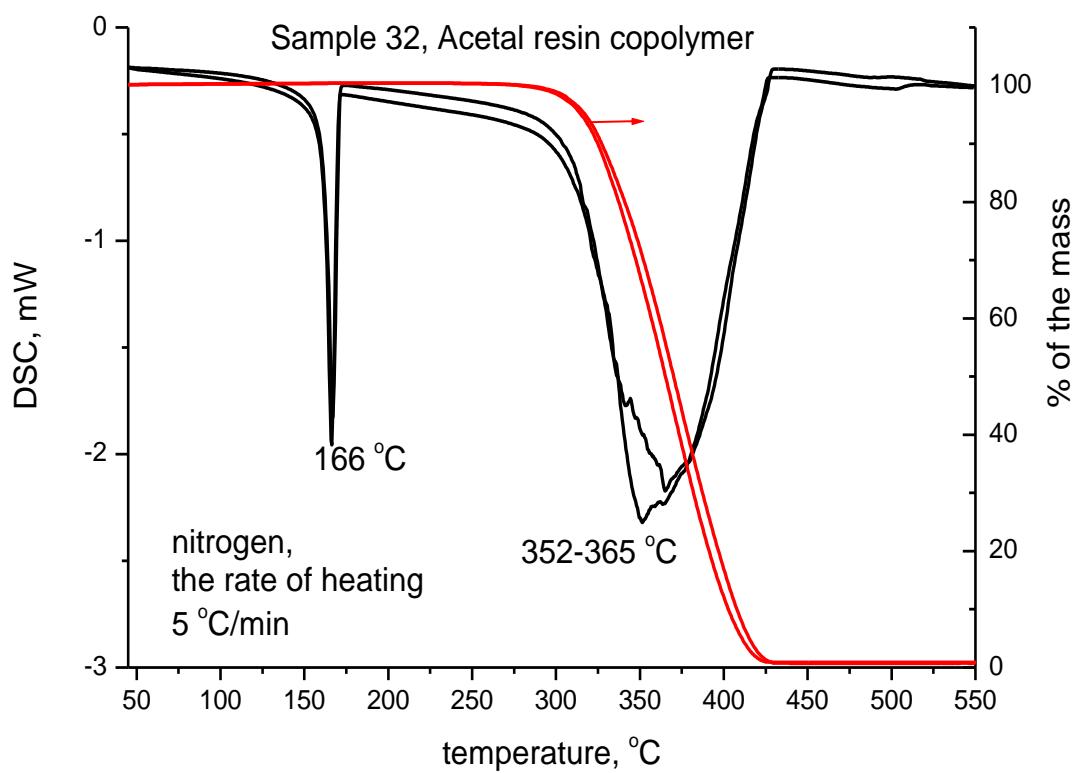


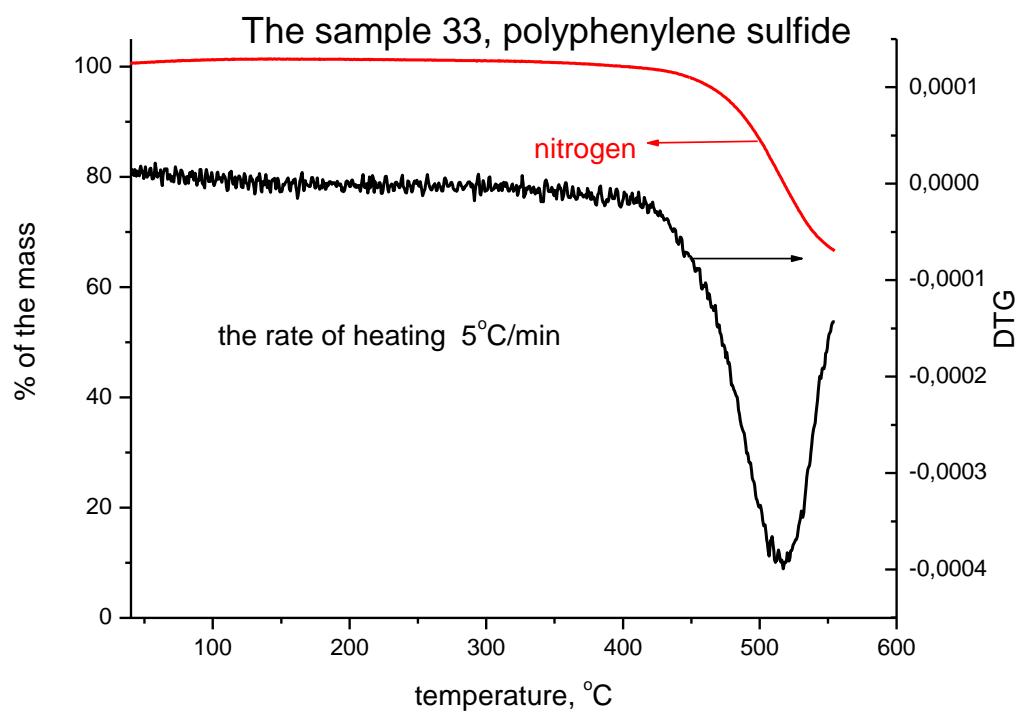


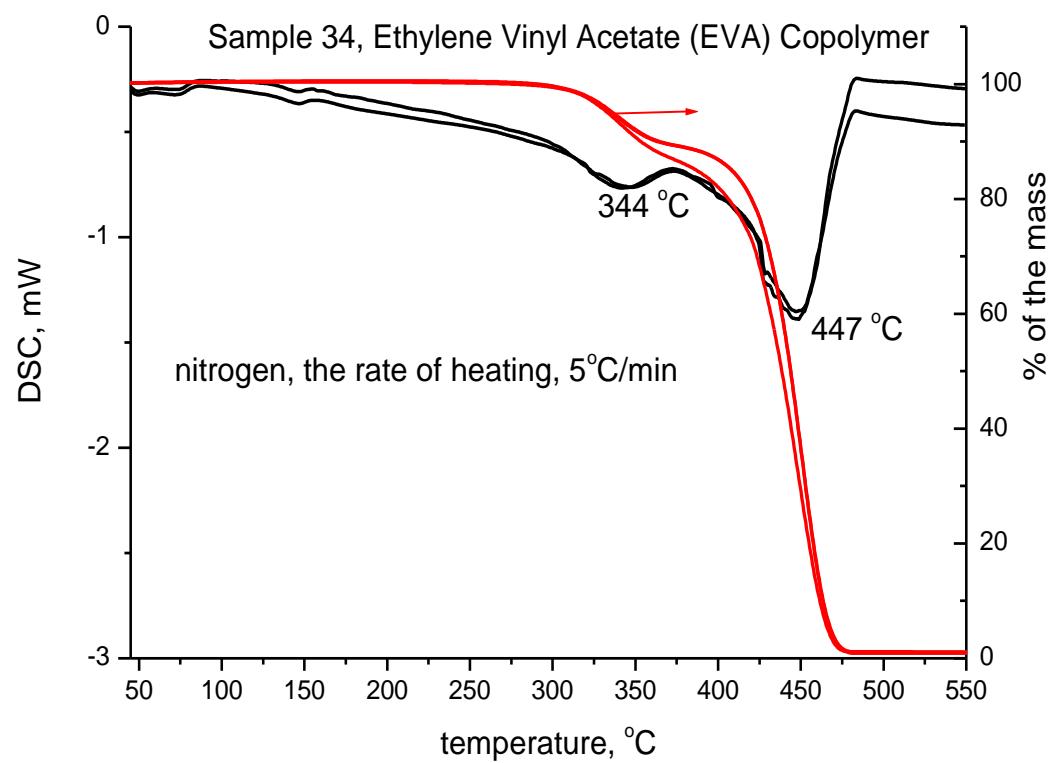


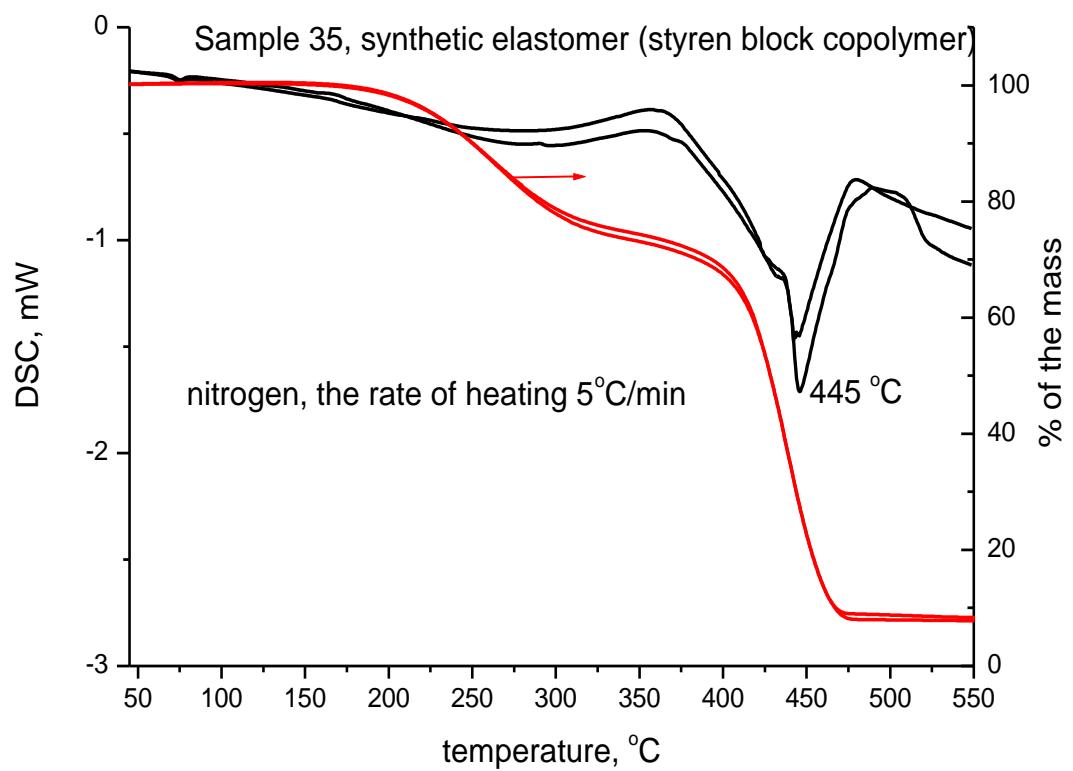


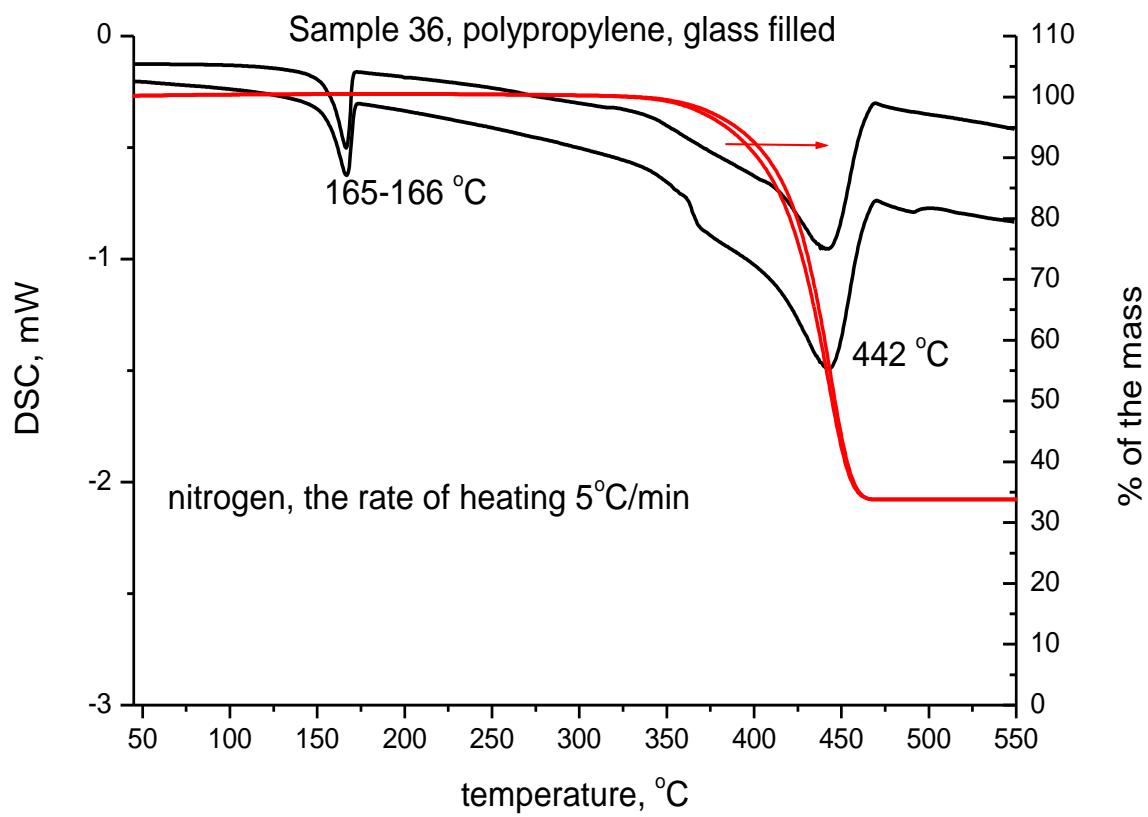


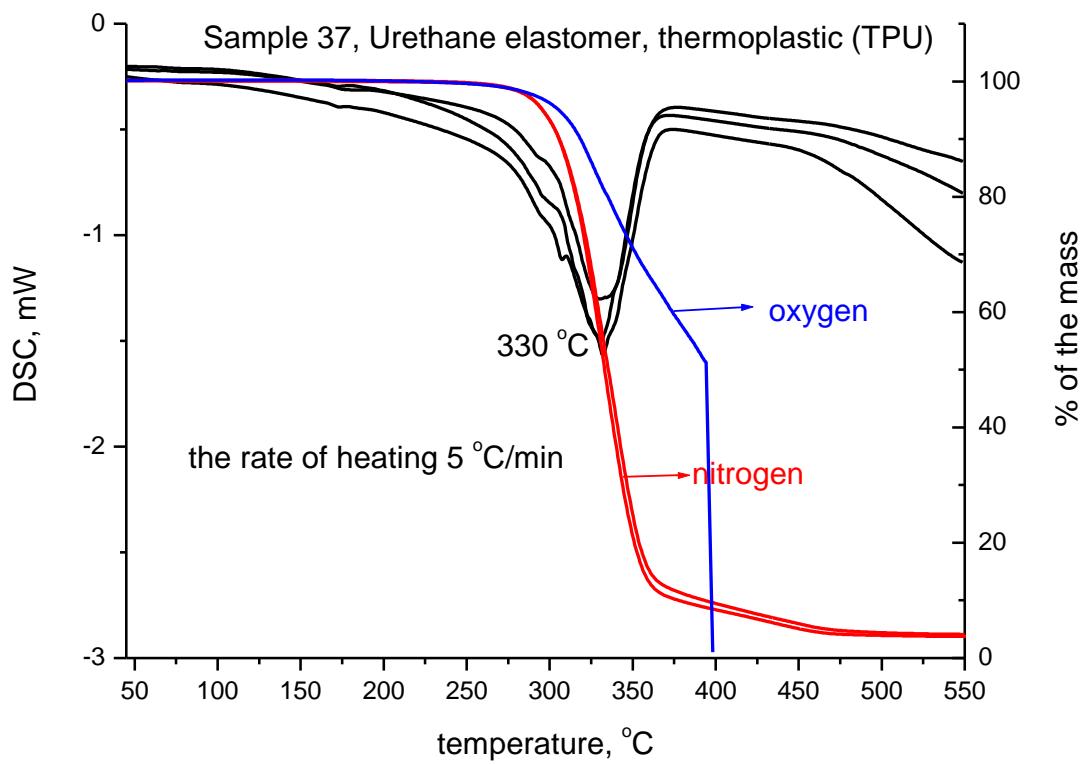


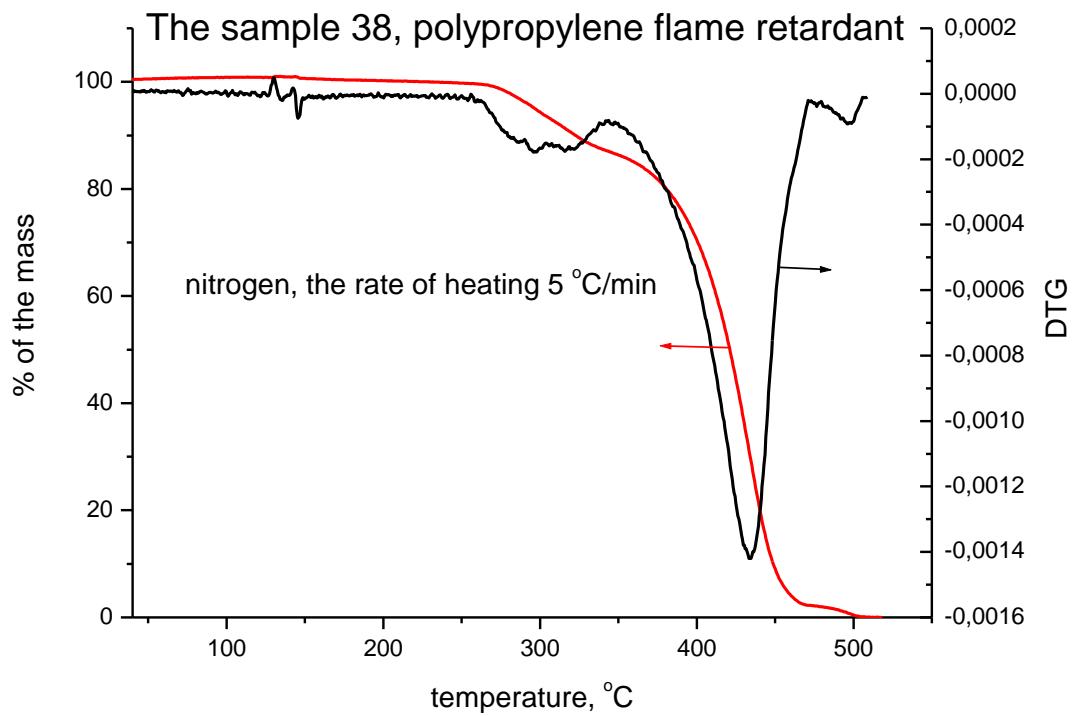


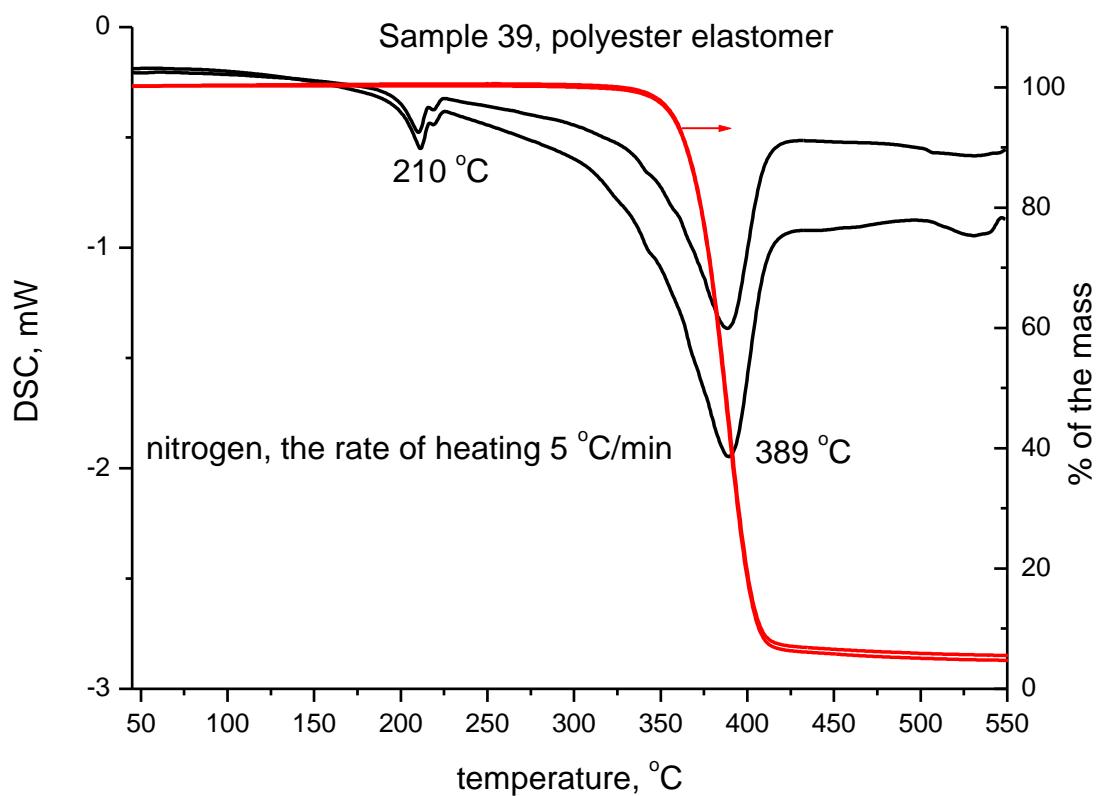


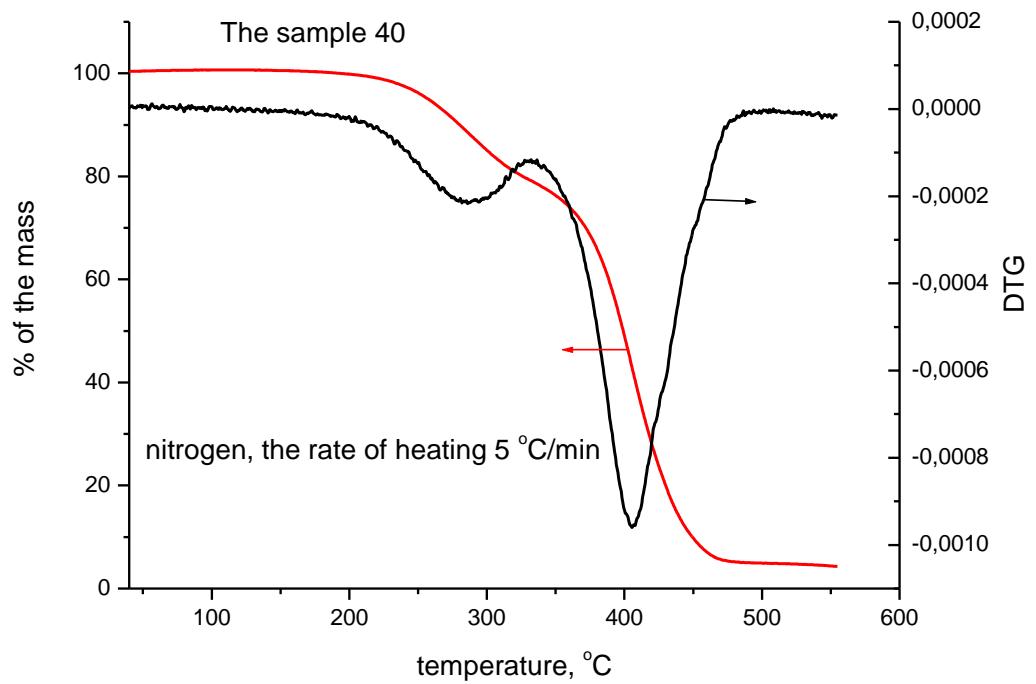


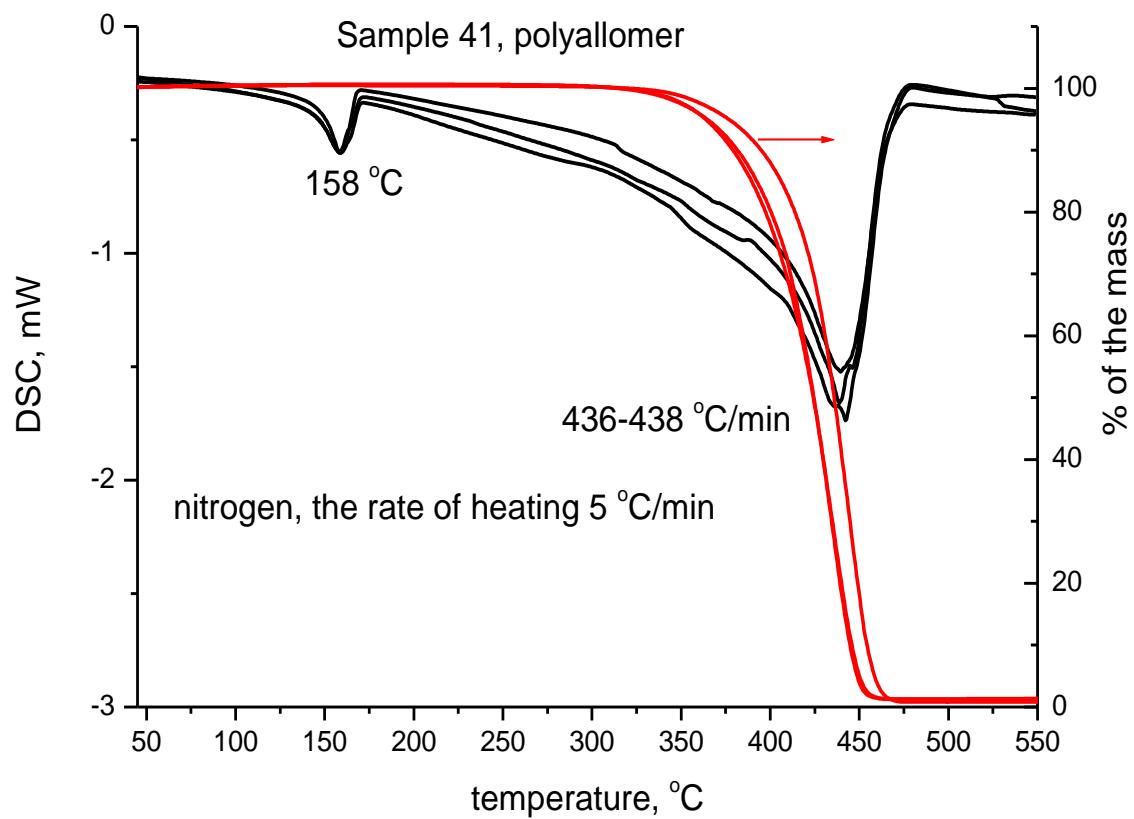


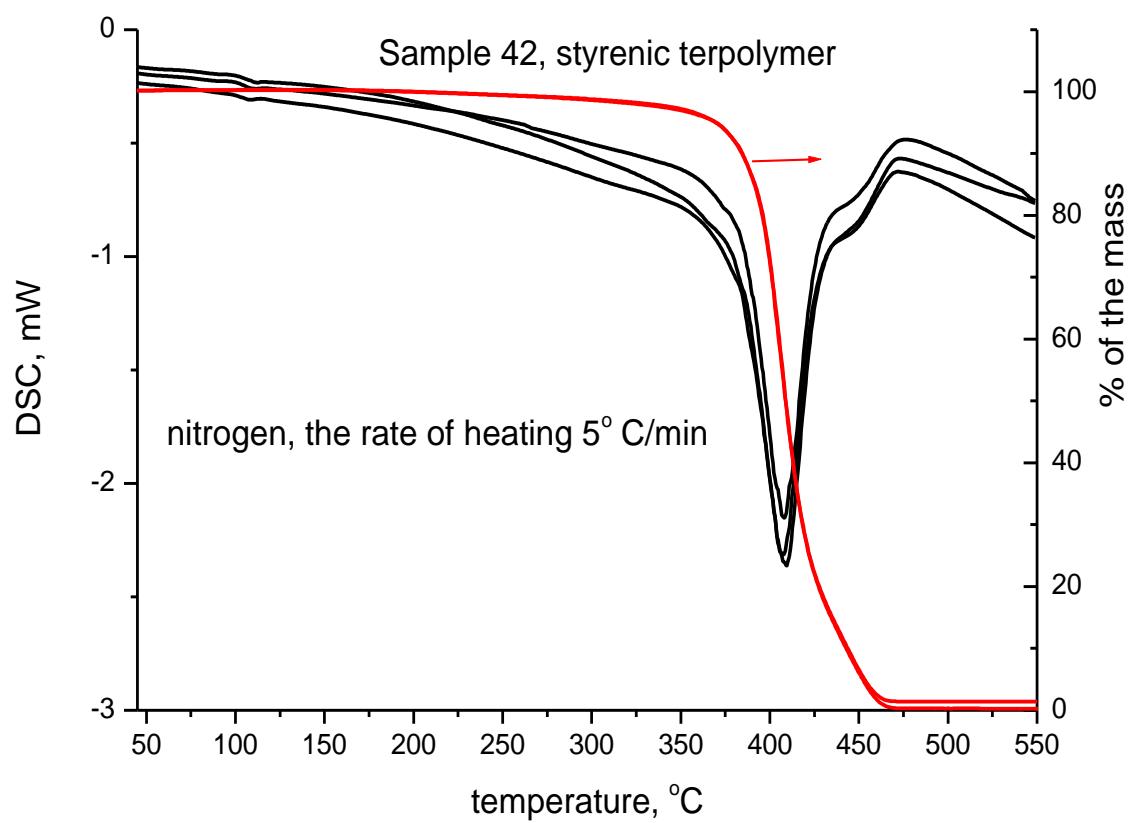


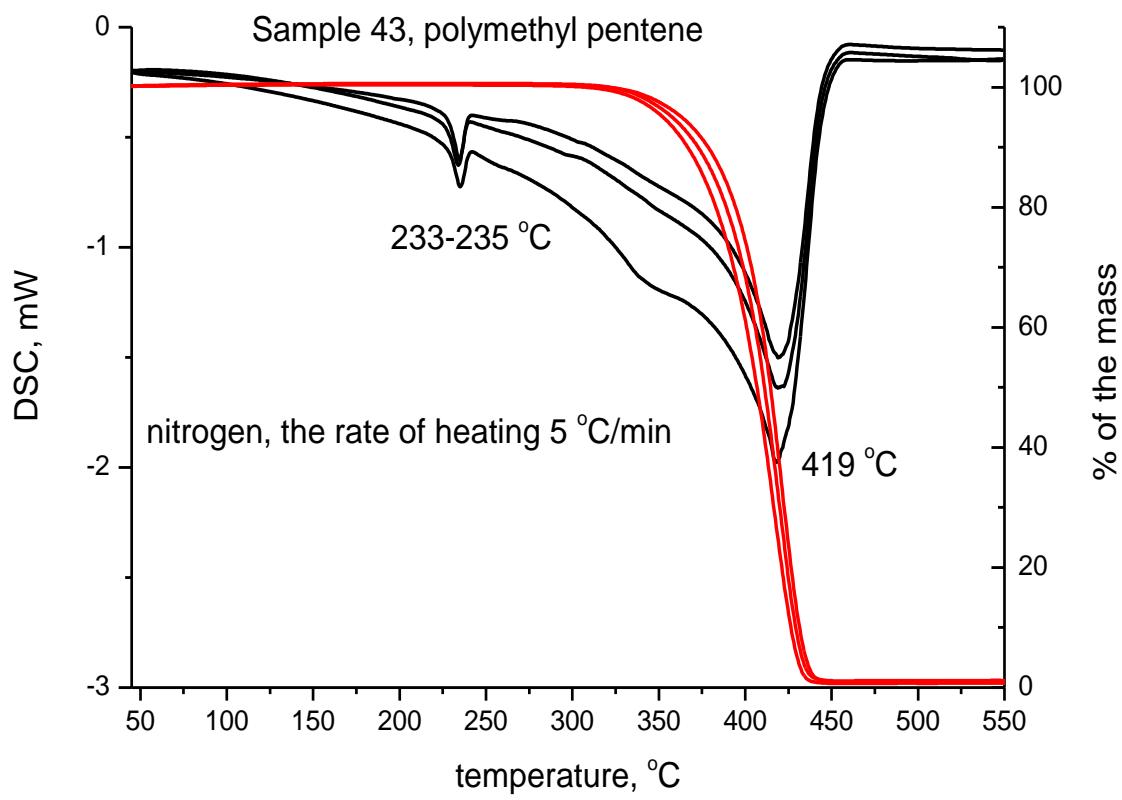


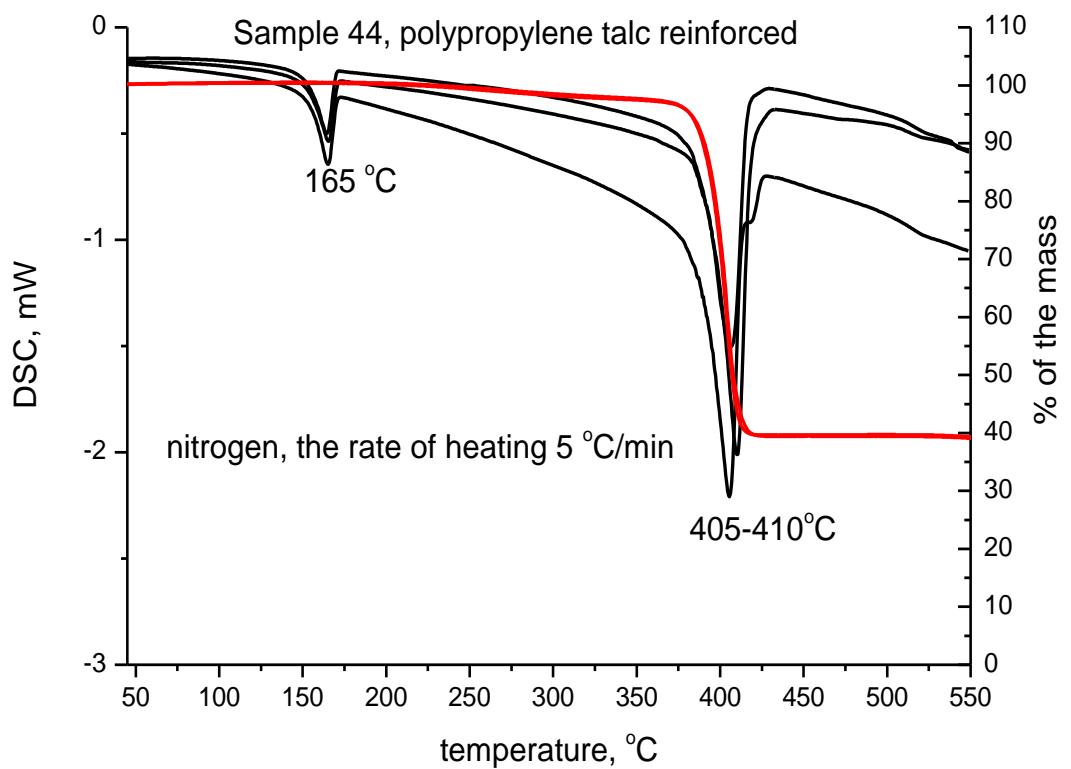


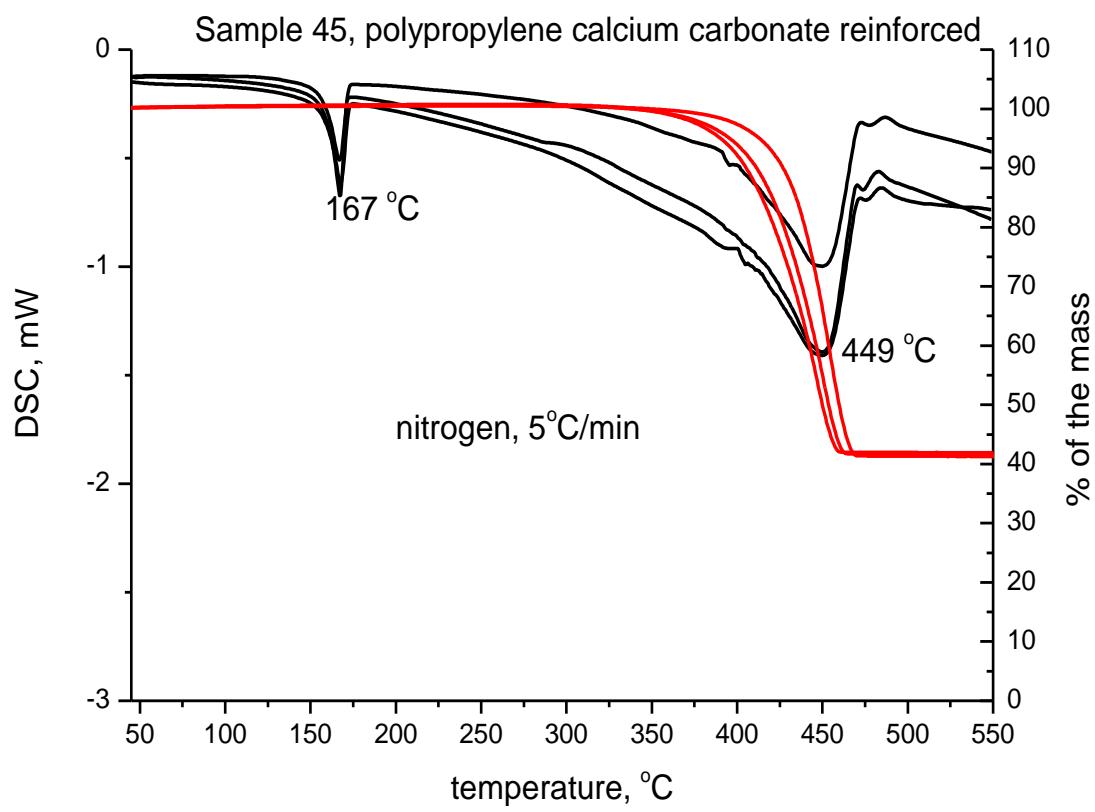


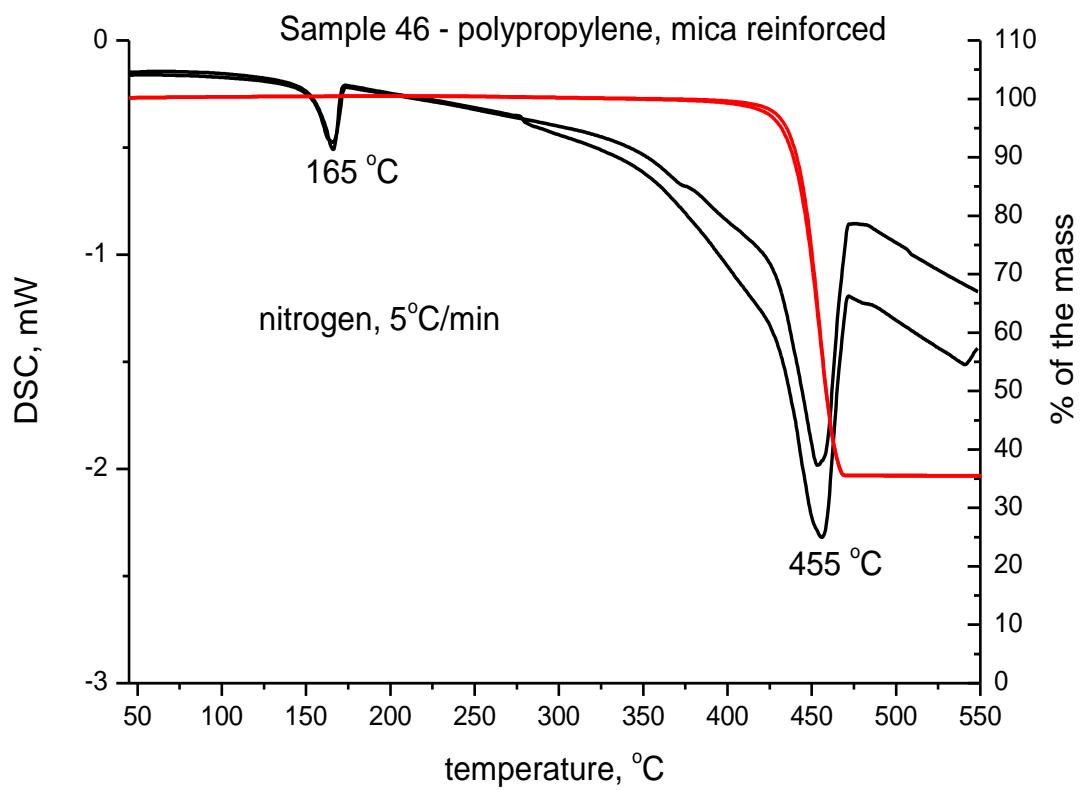


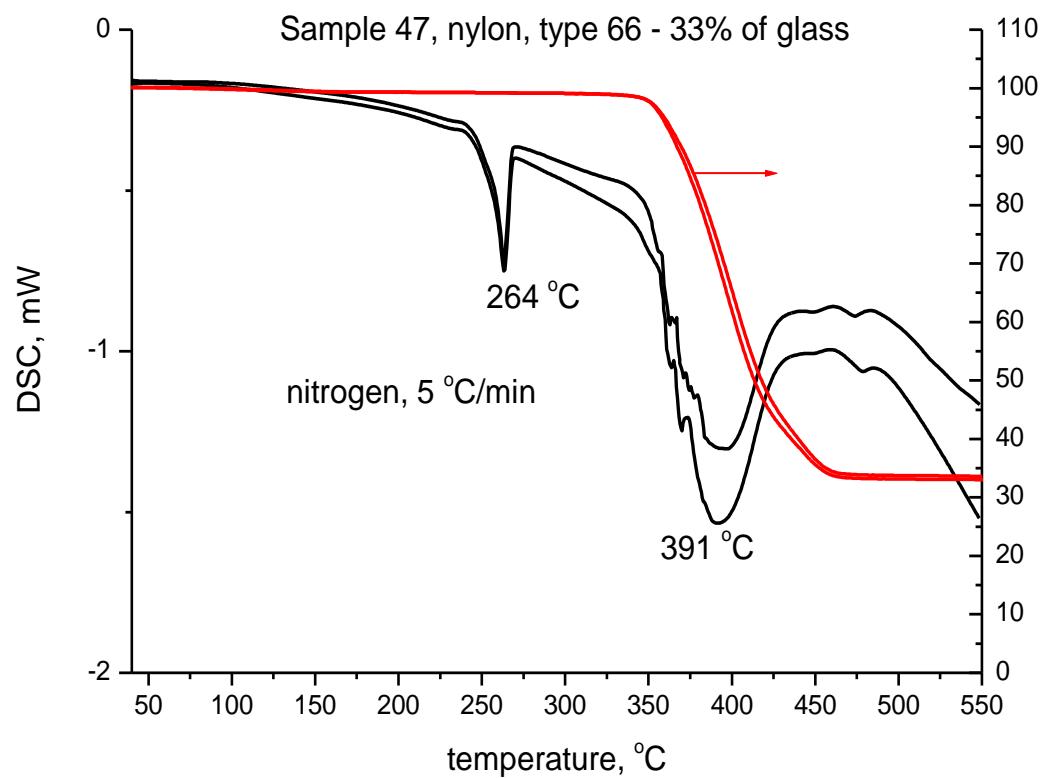


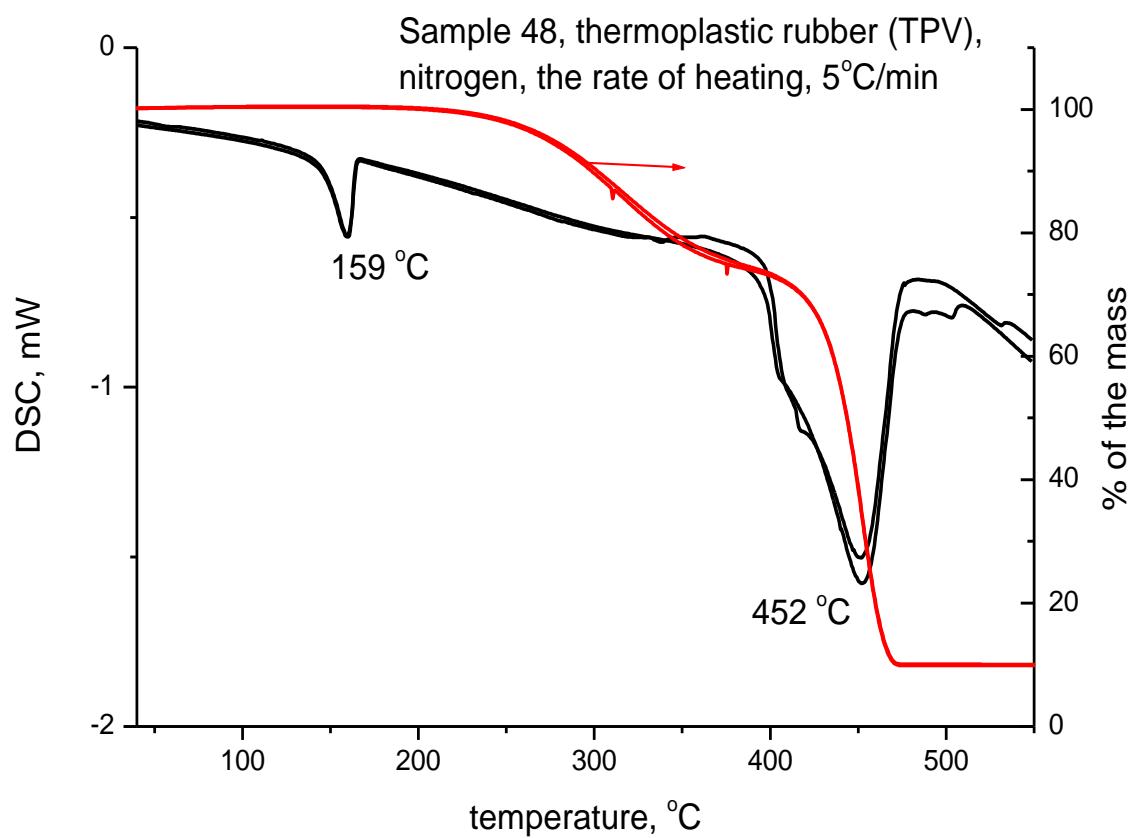


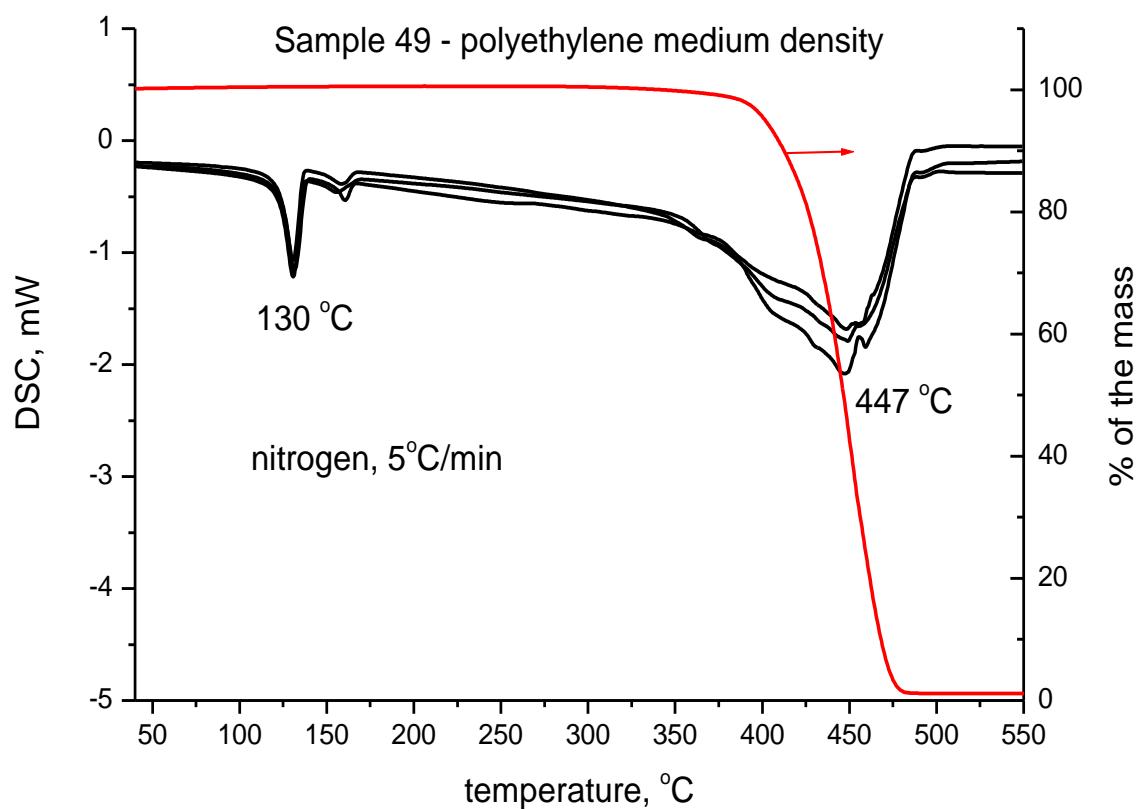


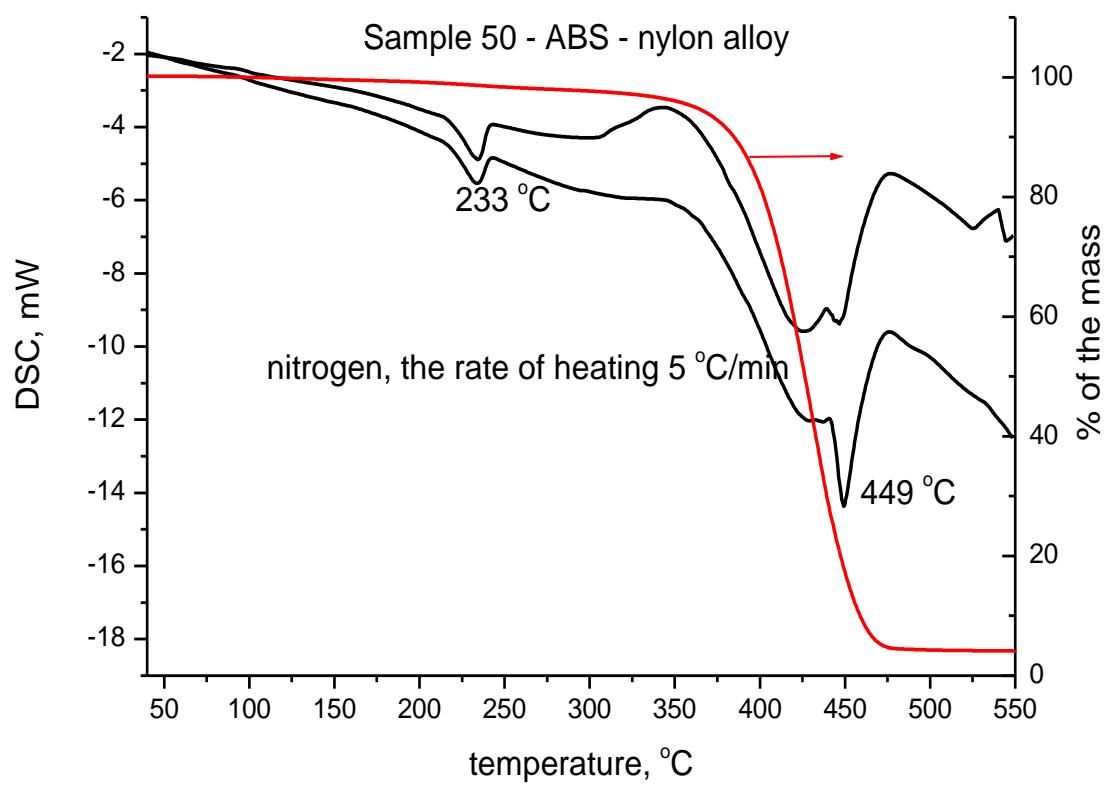








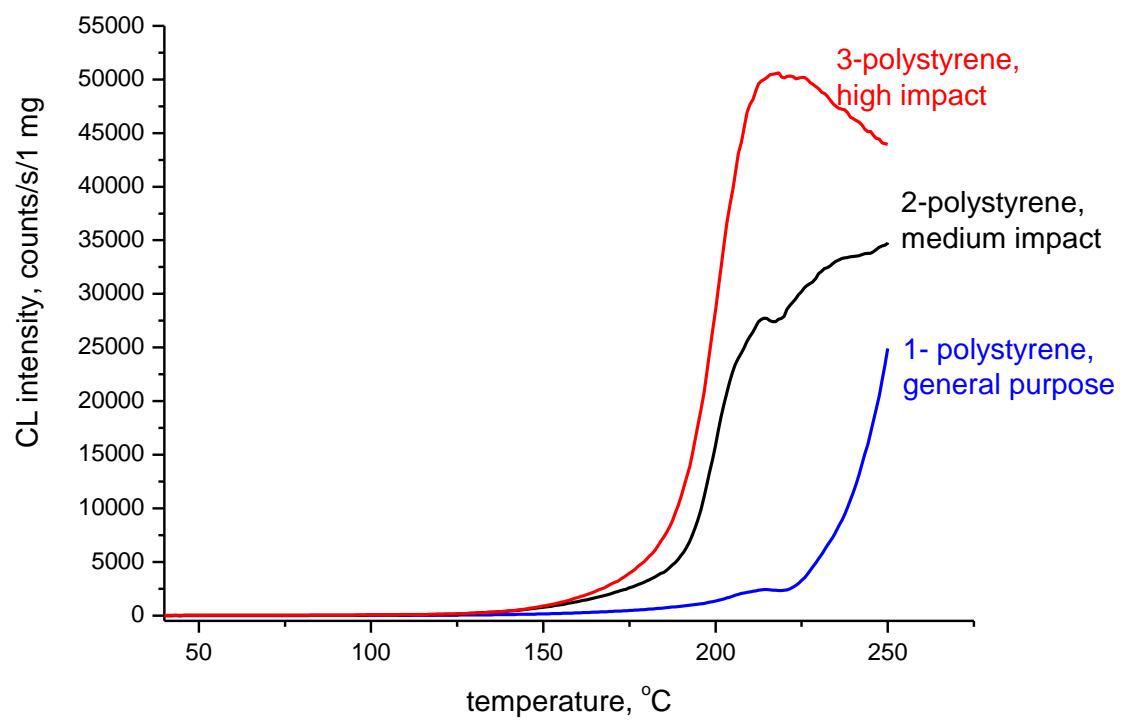


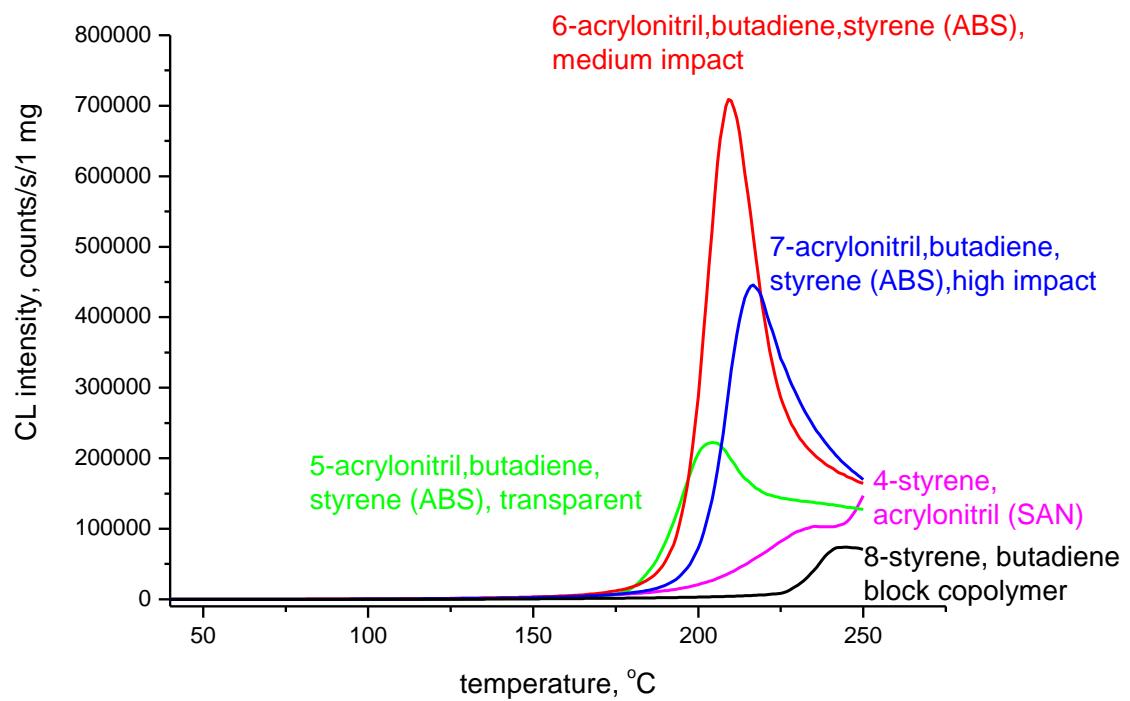


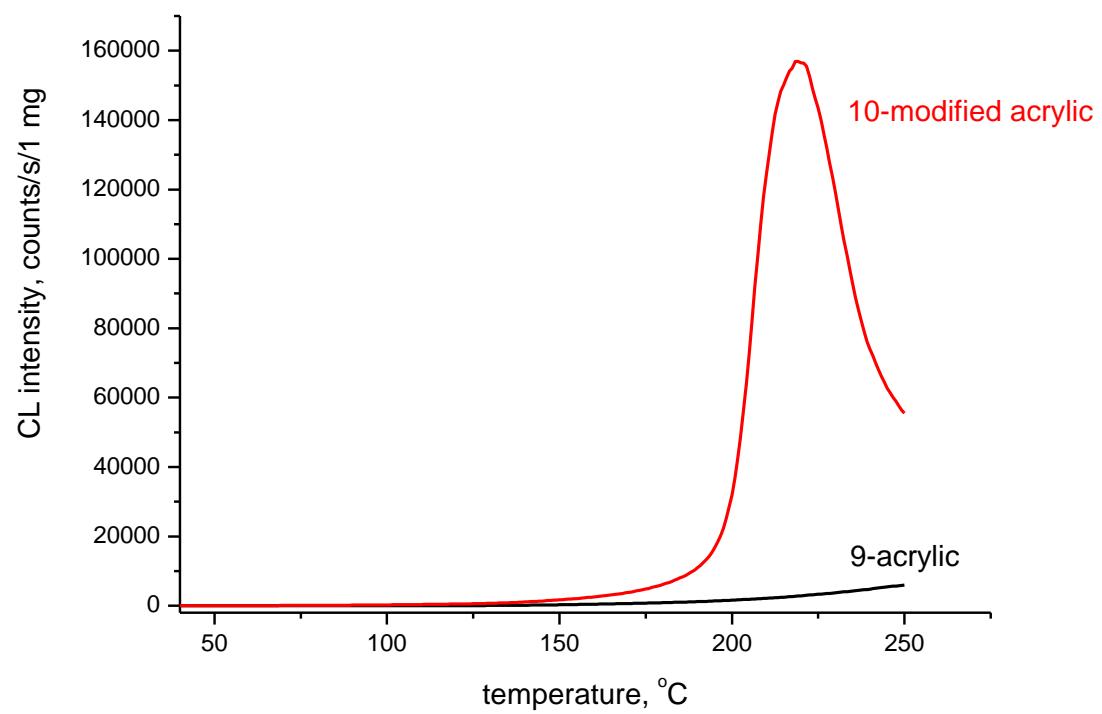
Chemiluminescence

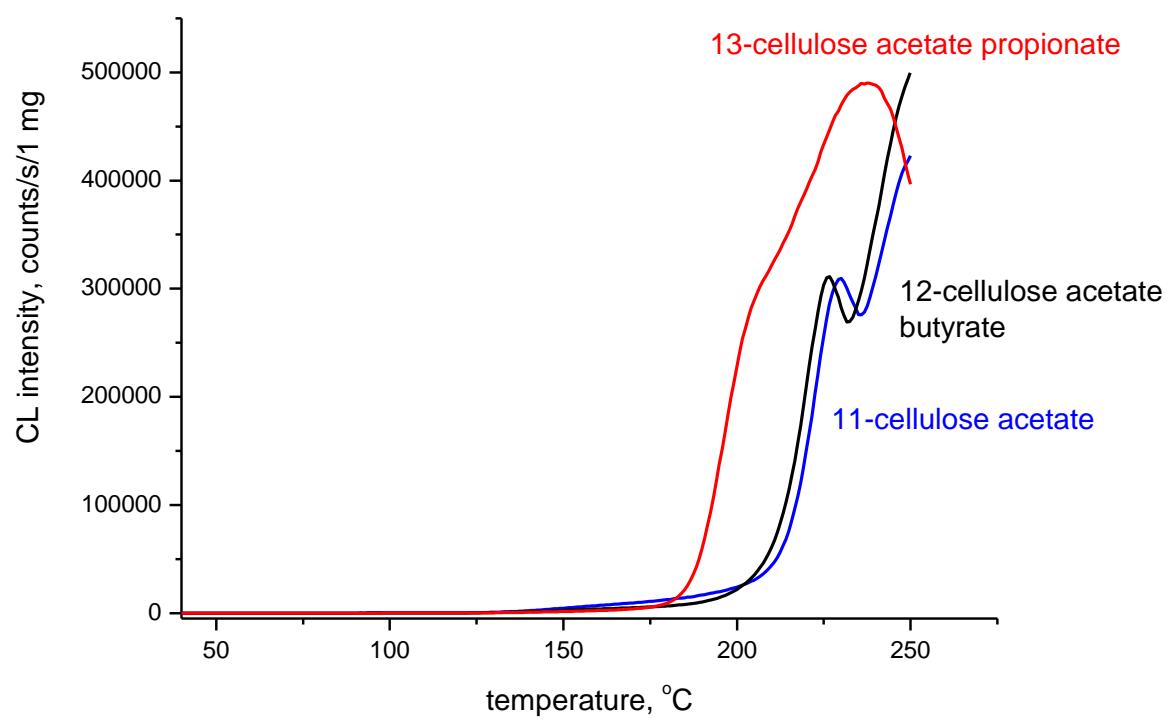
from Resin Kit polymers

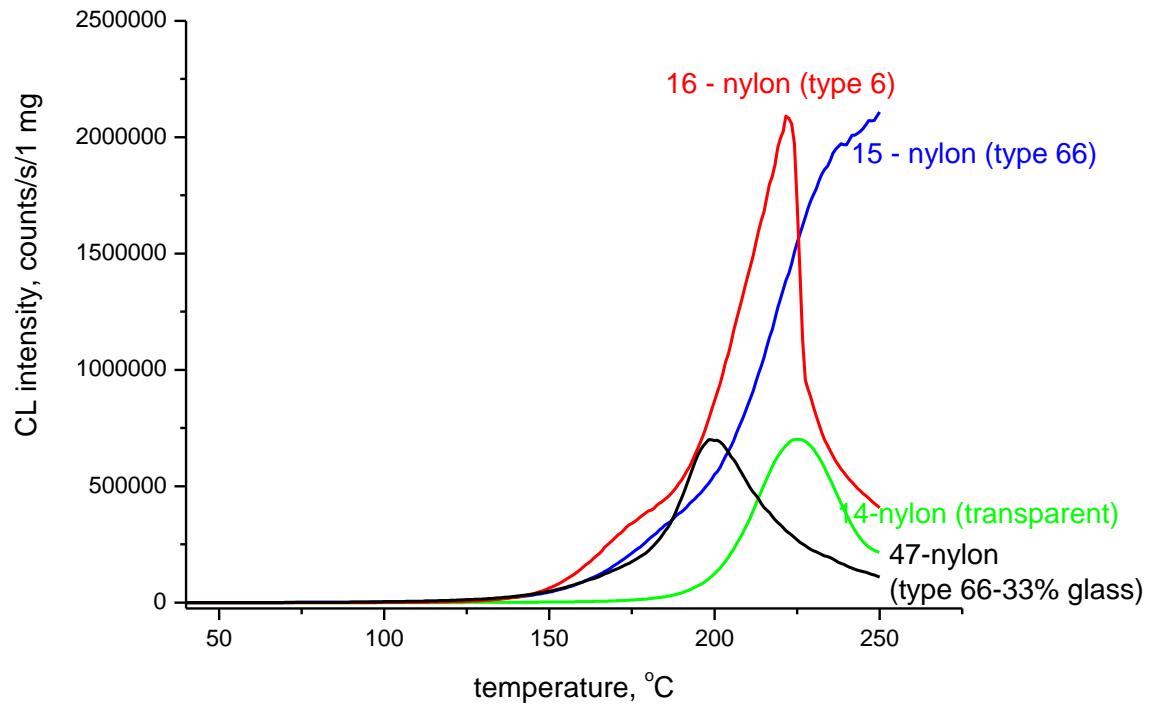
All chemiluminescence experiments were carried out in oxygen atmosphere and at the rate of heating 5 °C/min.

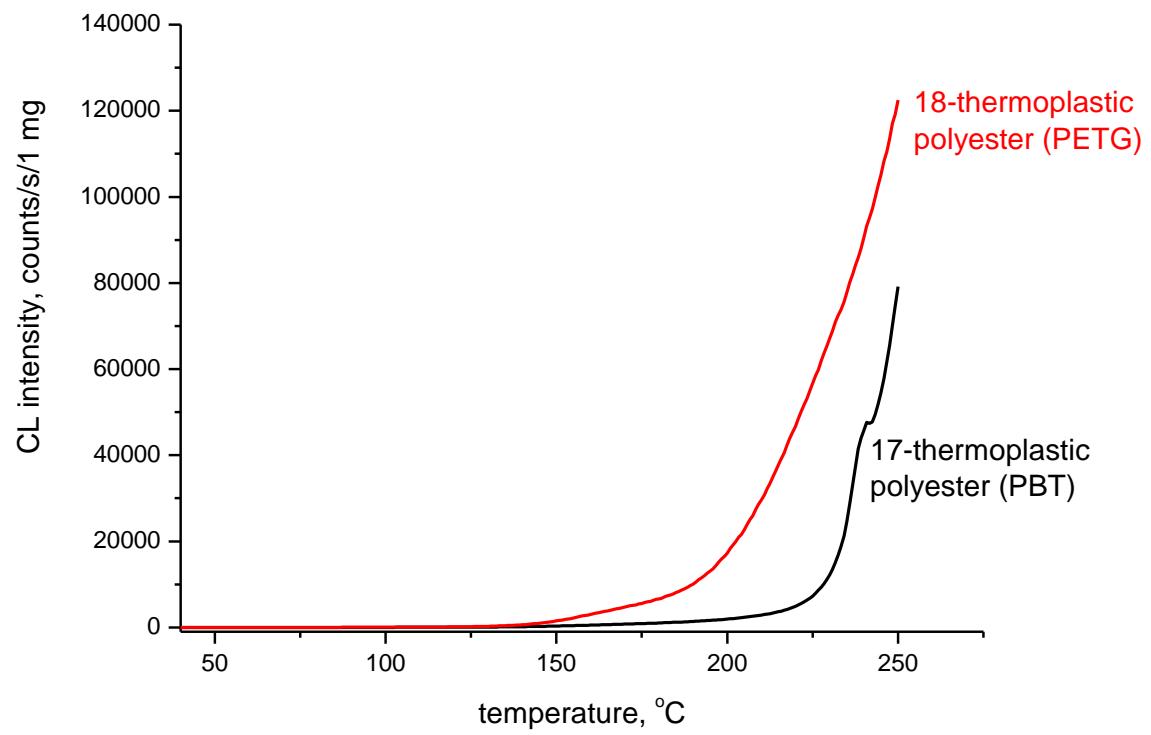


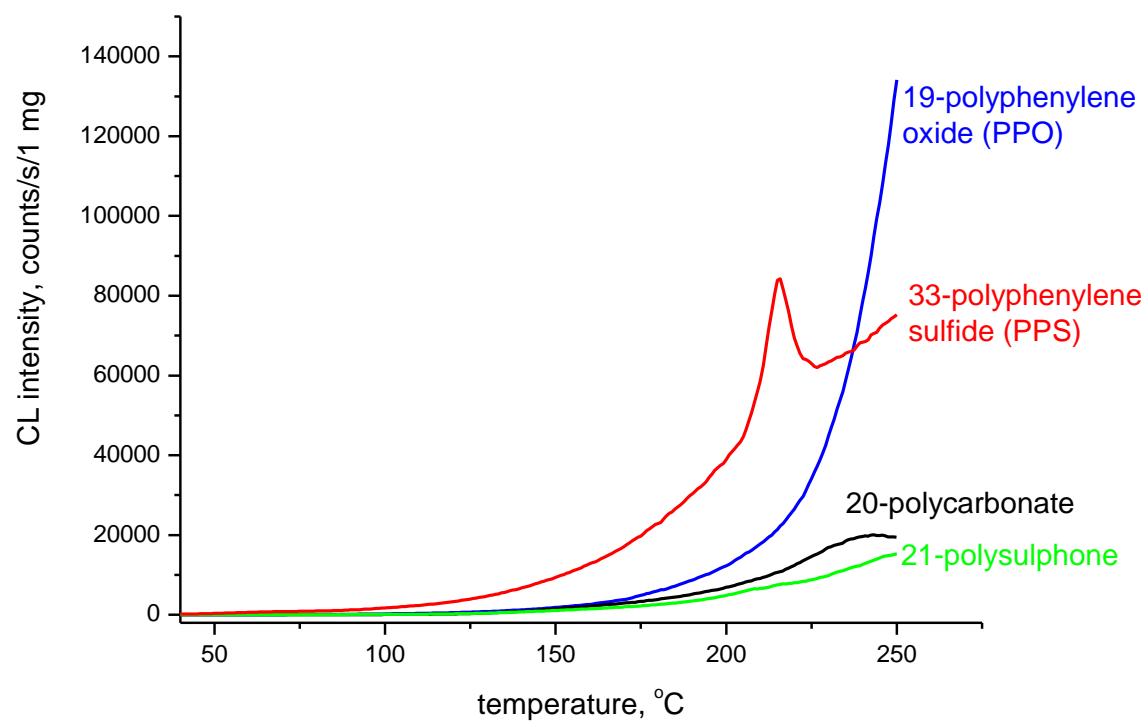


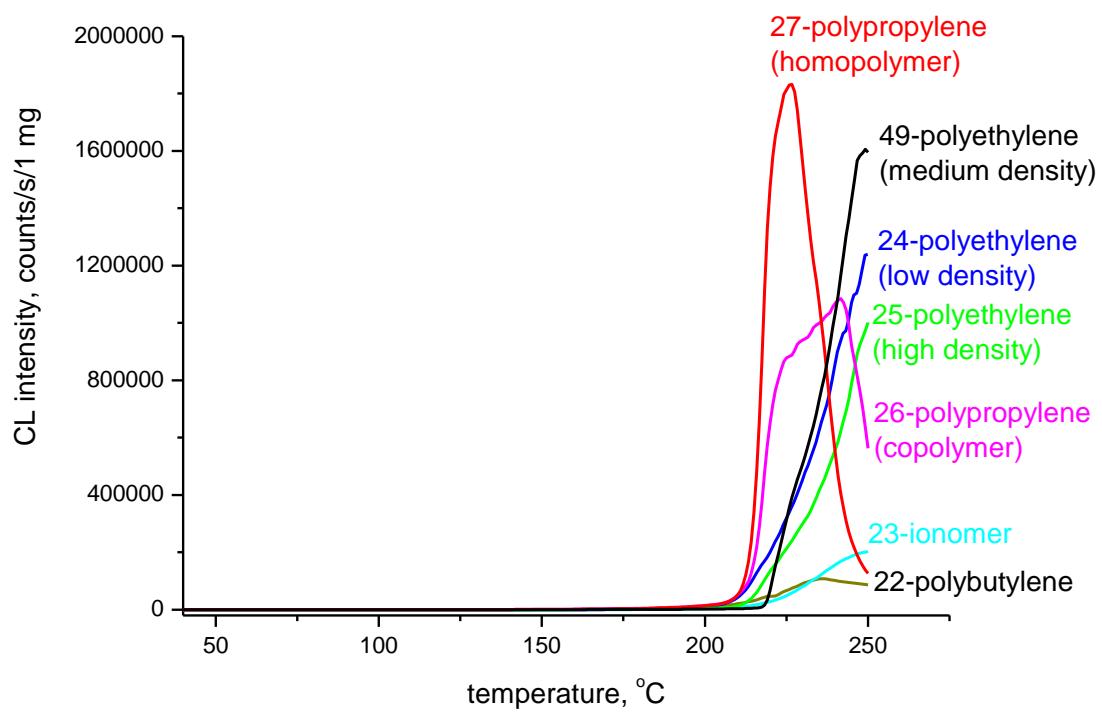


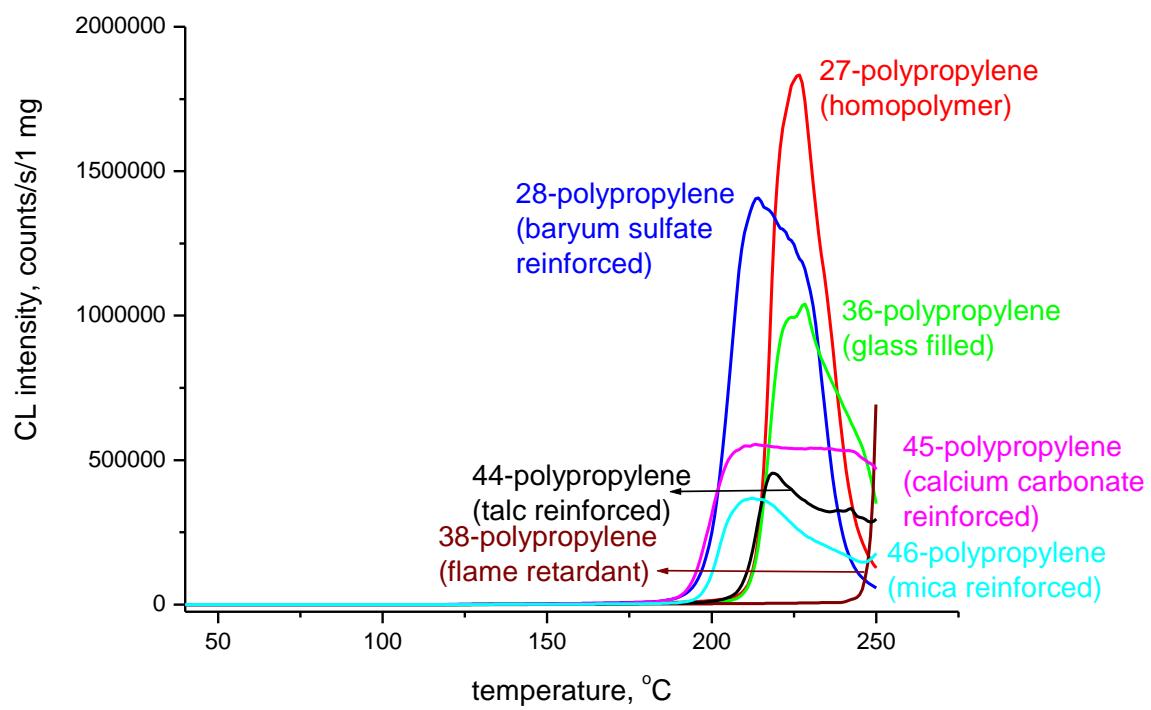


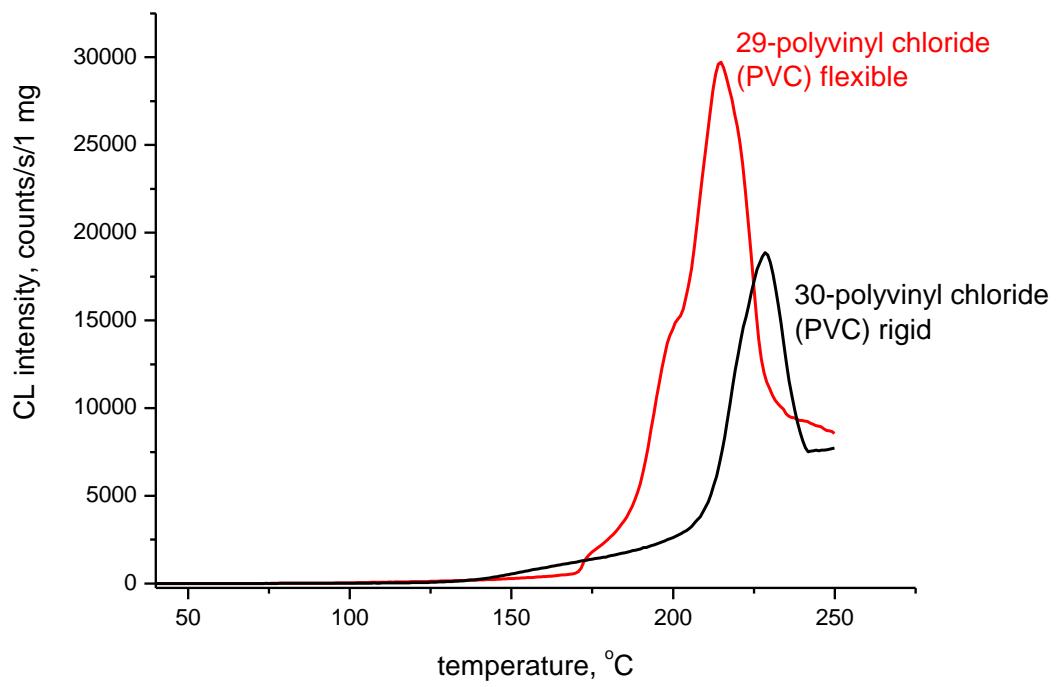


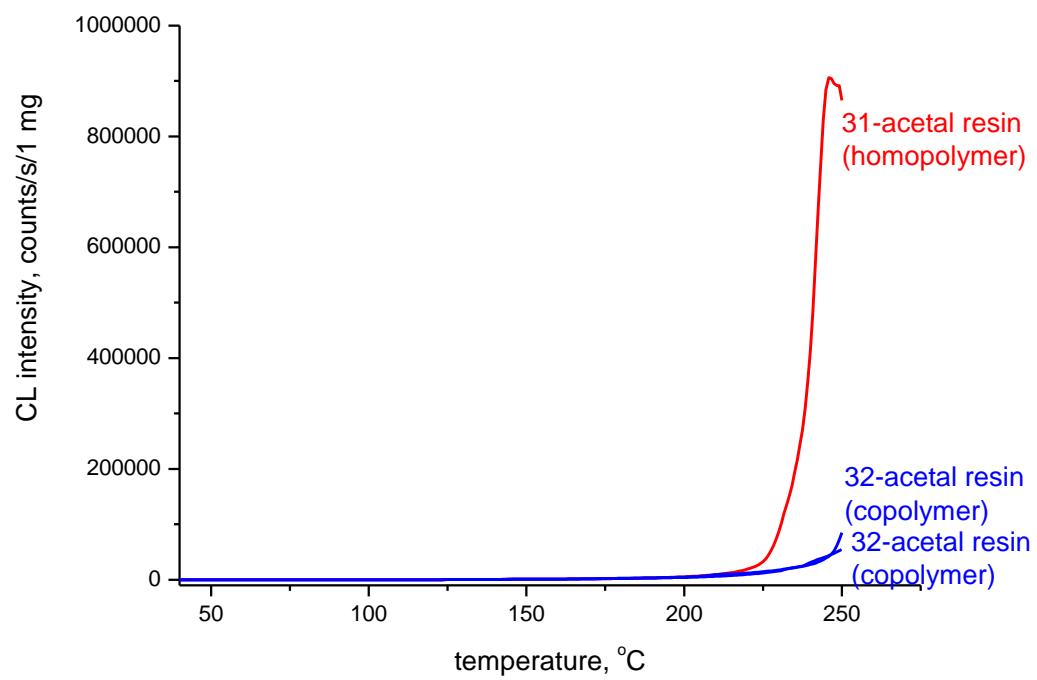


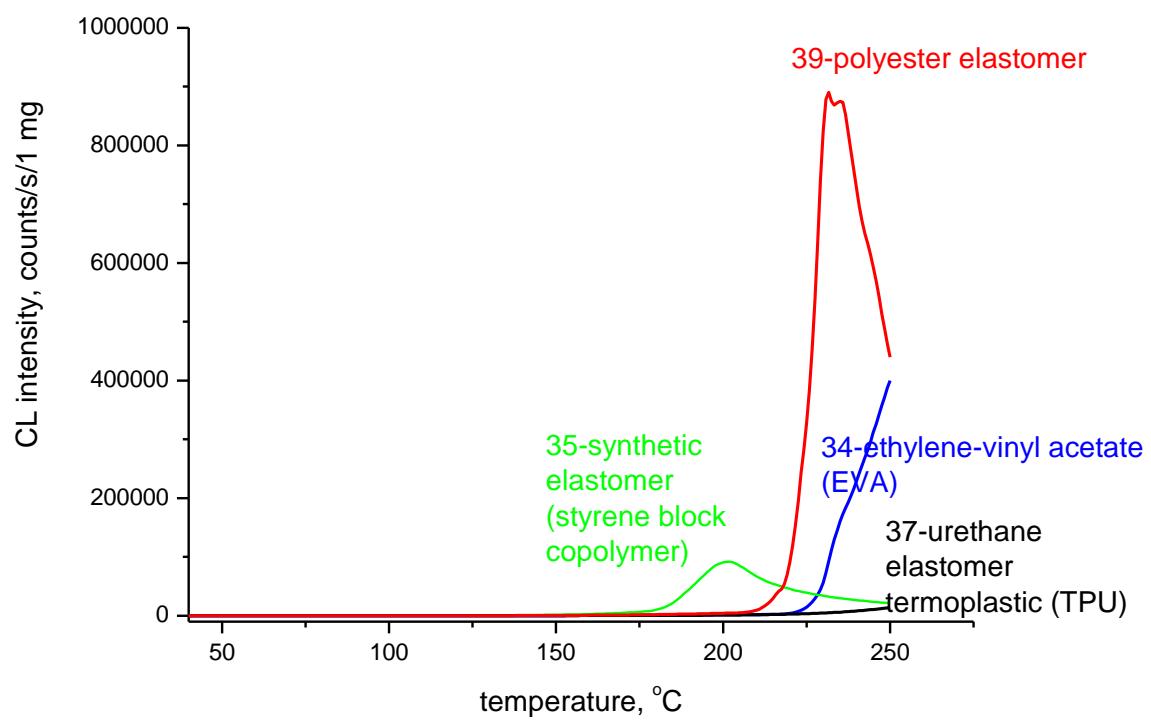


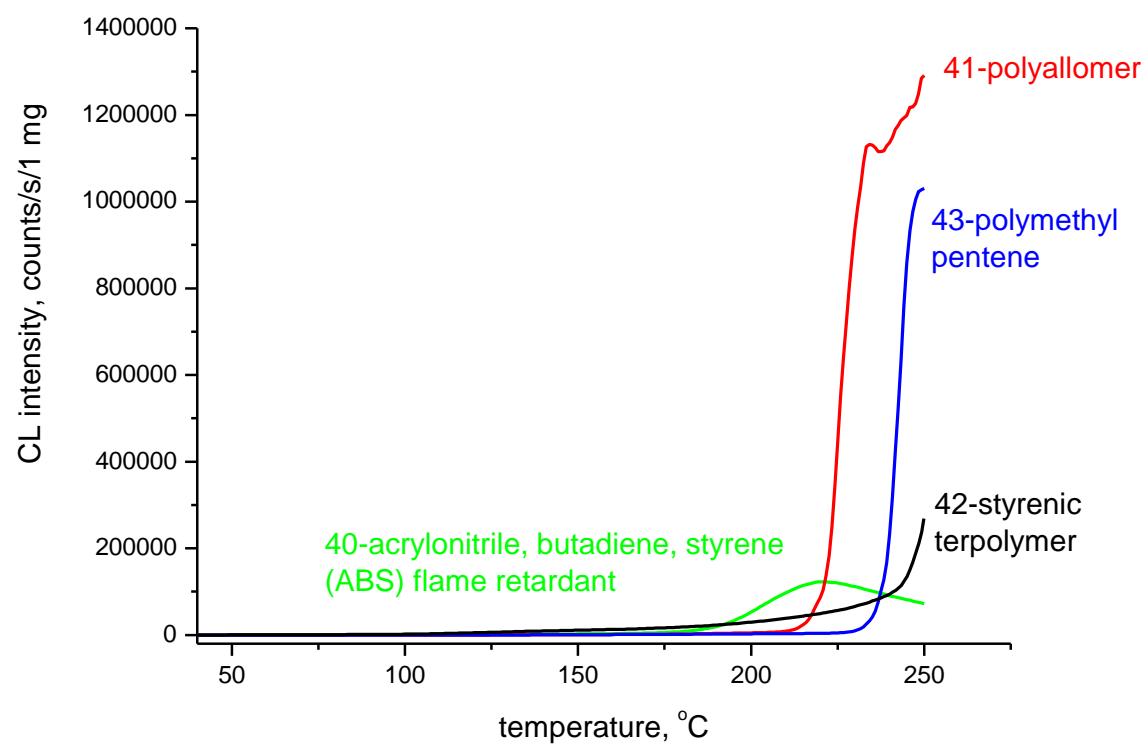


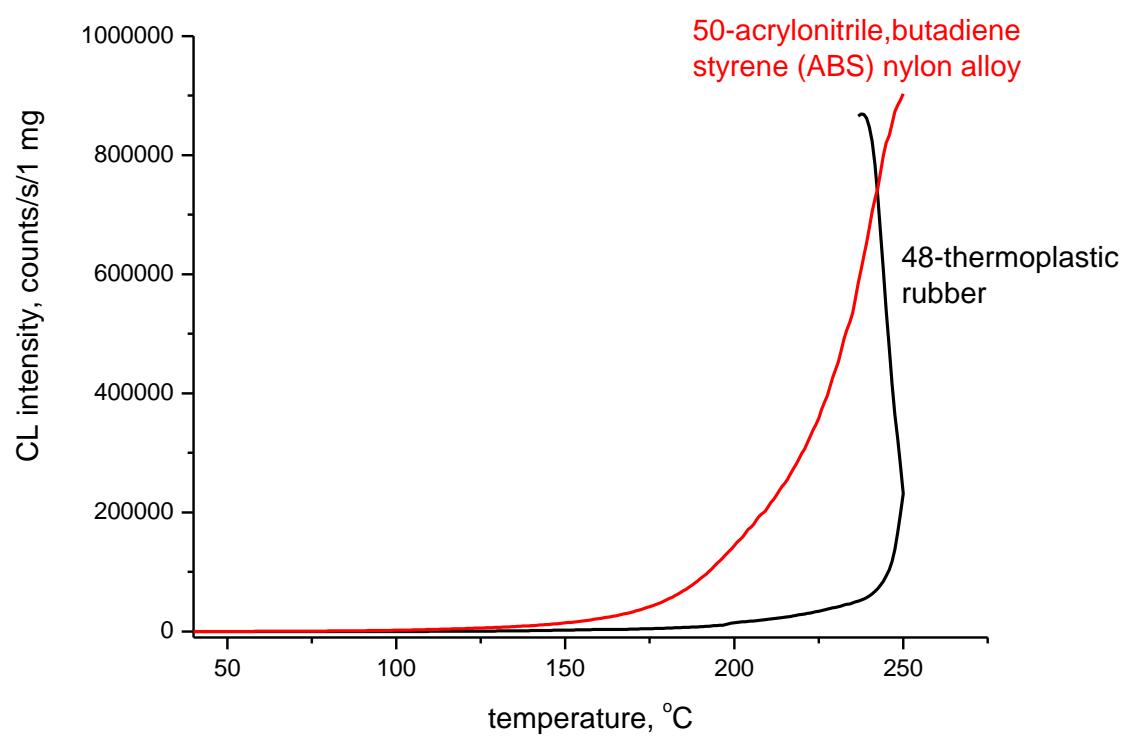




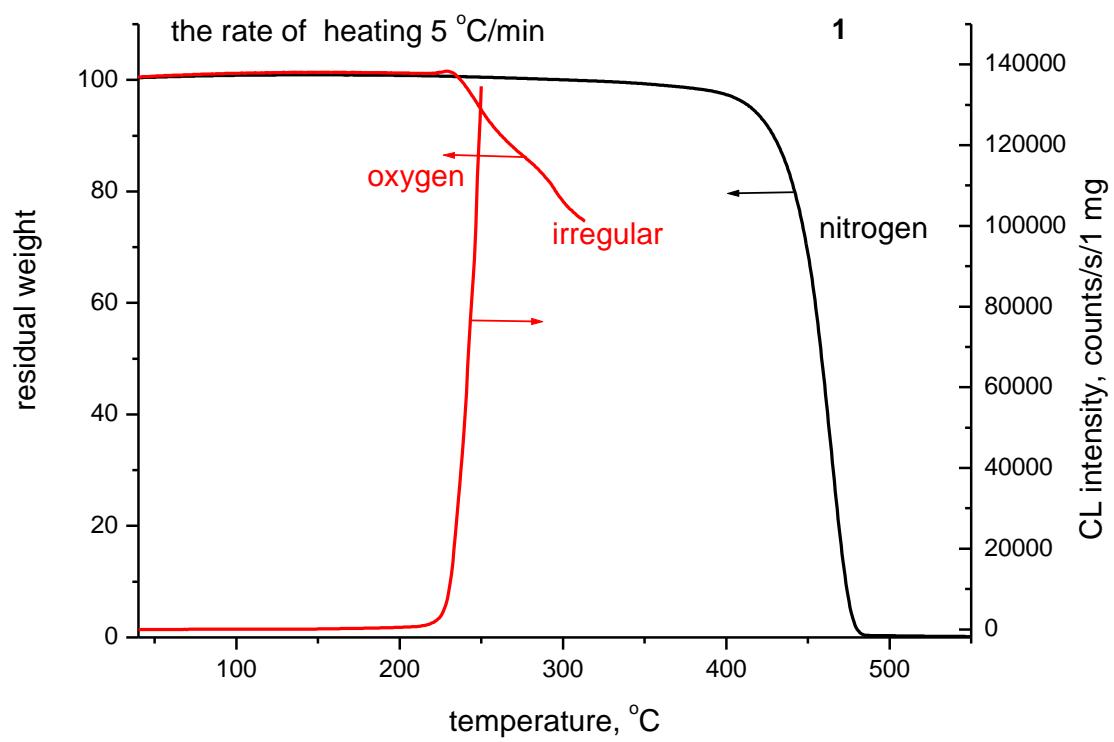


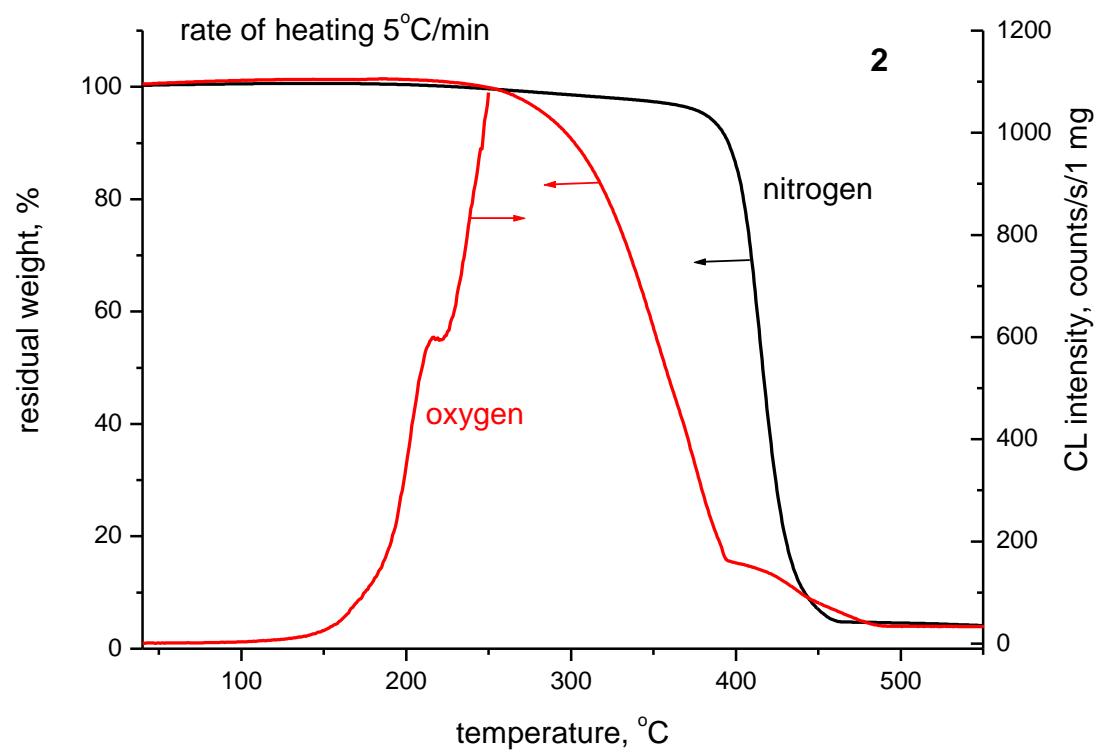


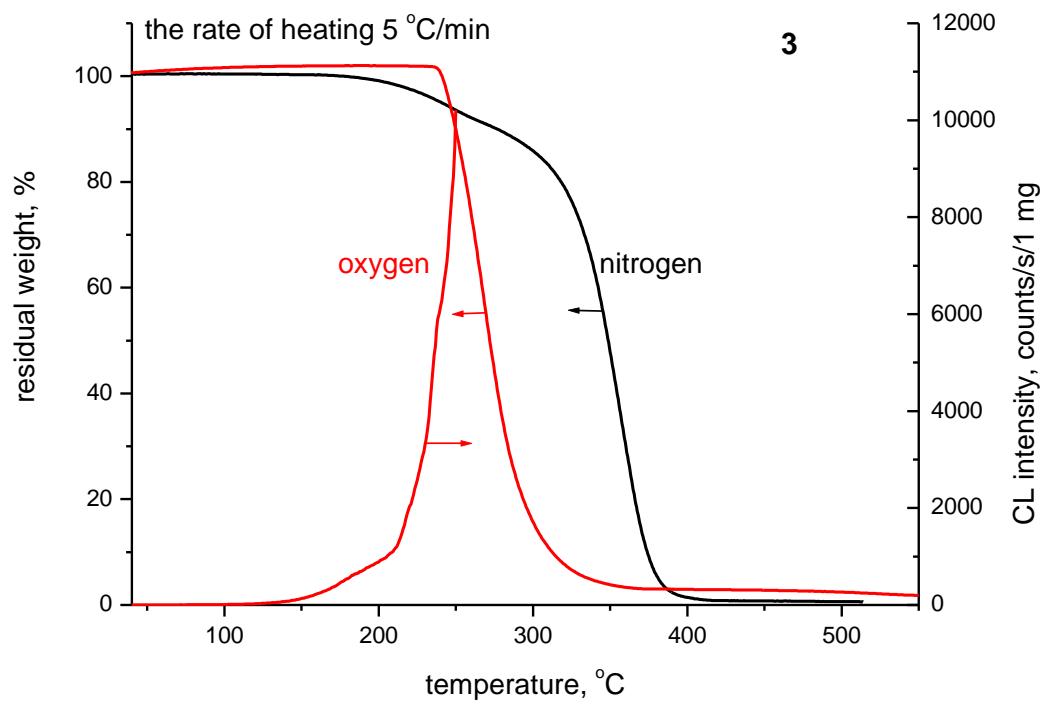


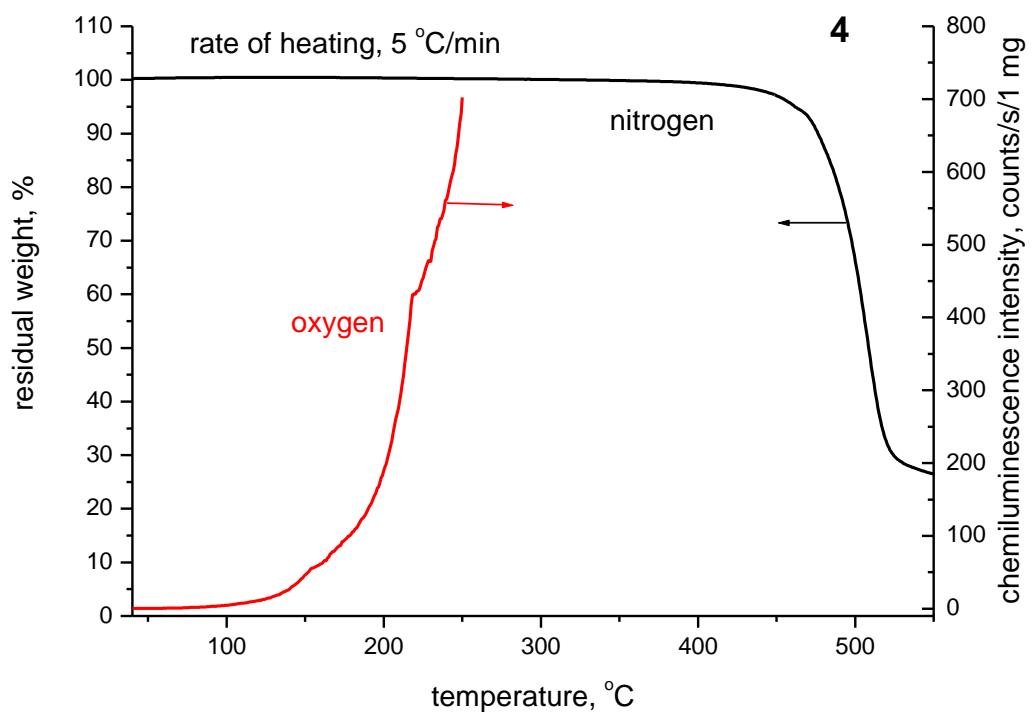


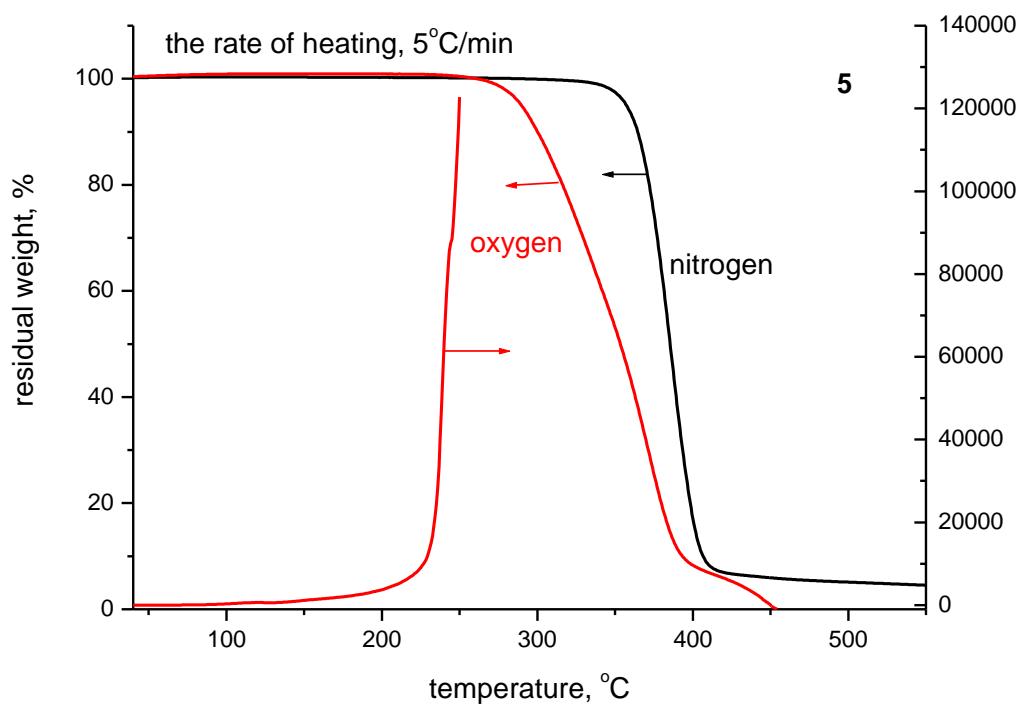
Chemiluminescence, DSC and
thermogravimetry of Smile polymers
supplied by Collin Williamson

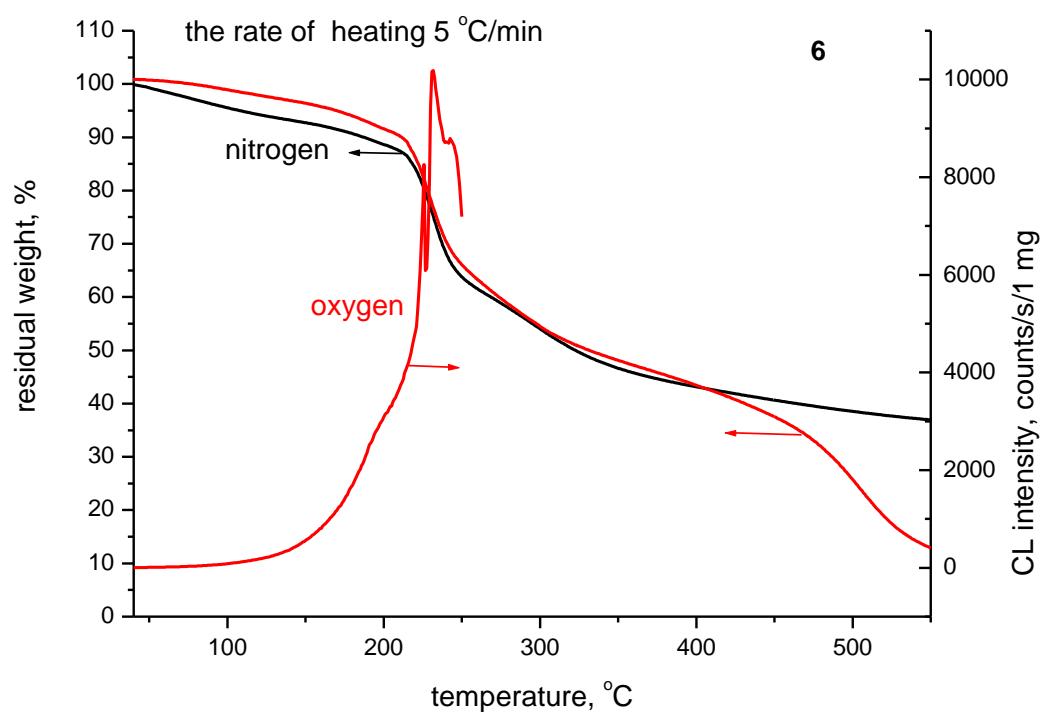


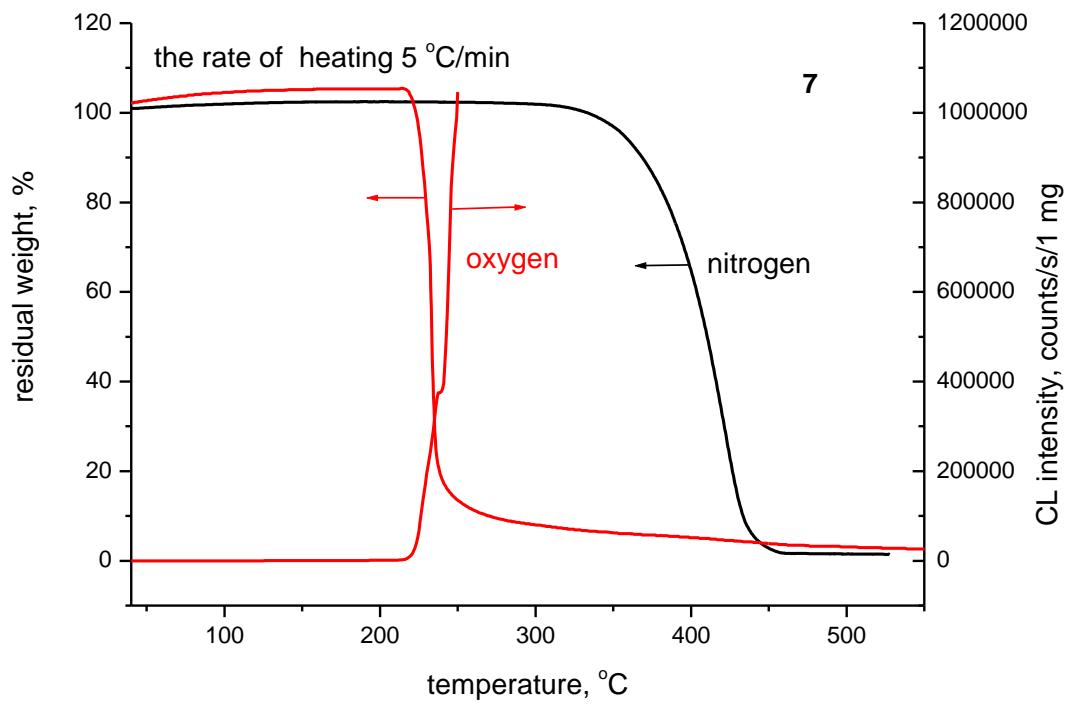


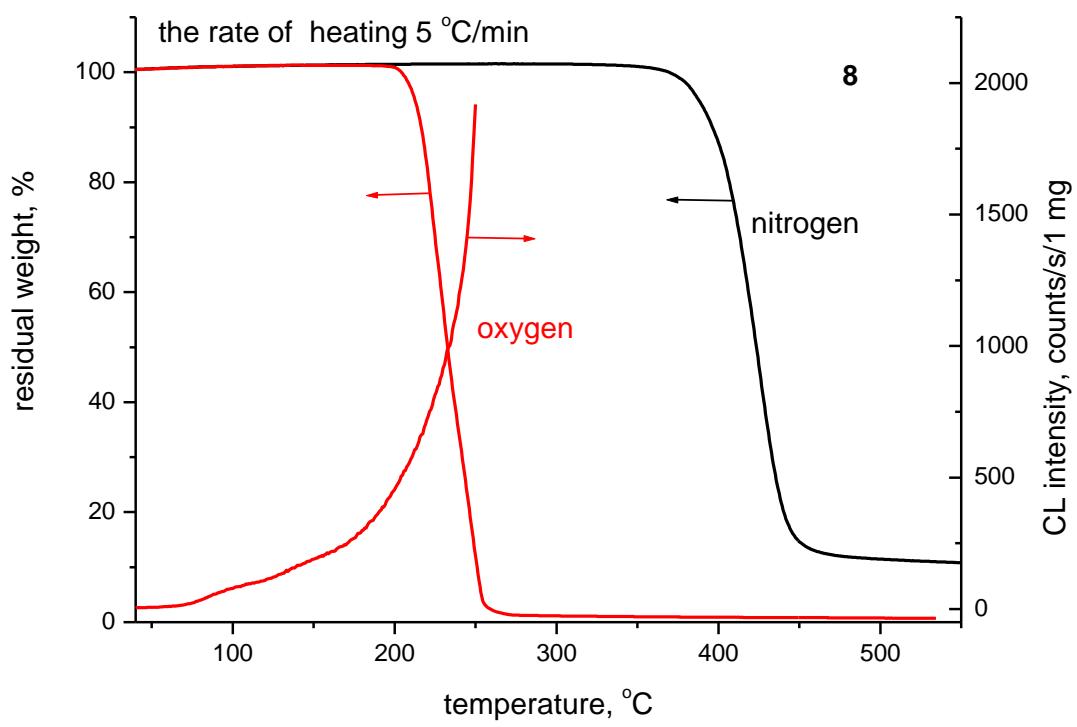


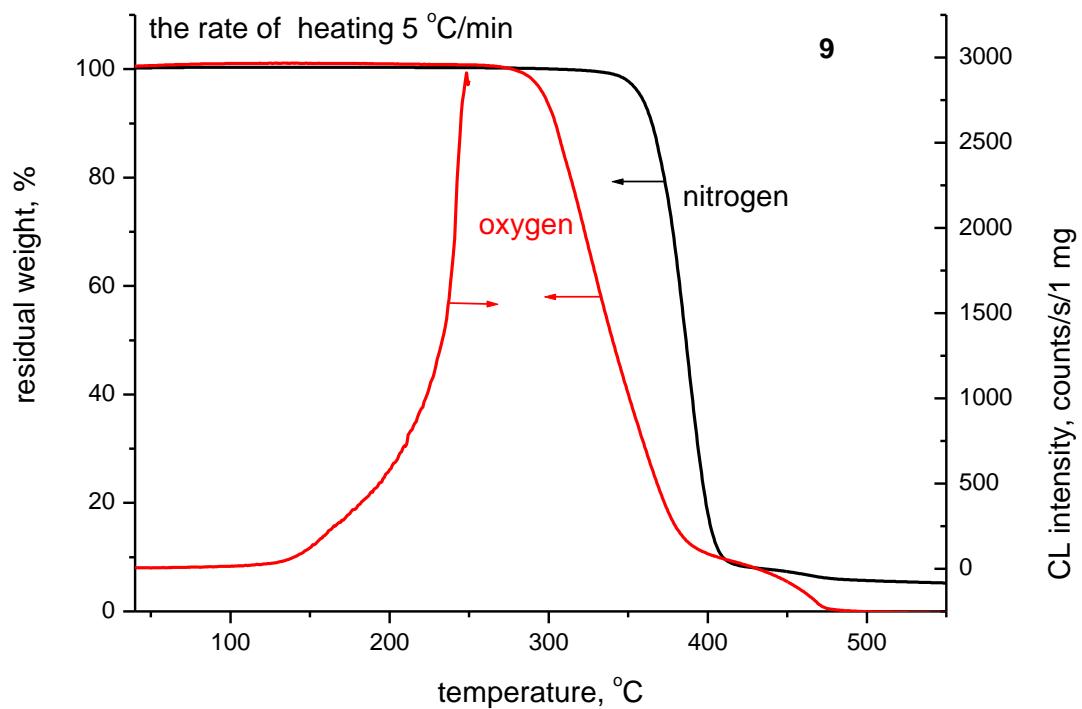


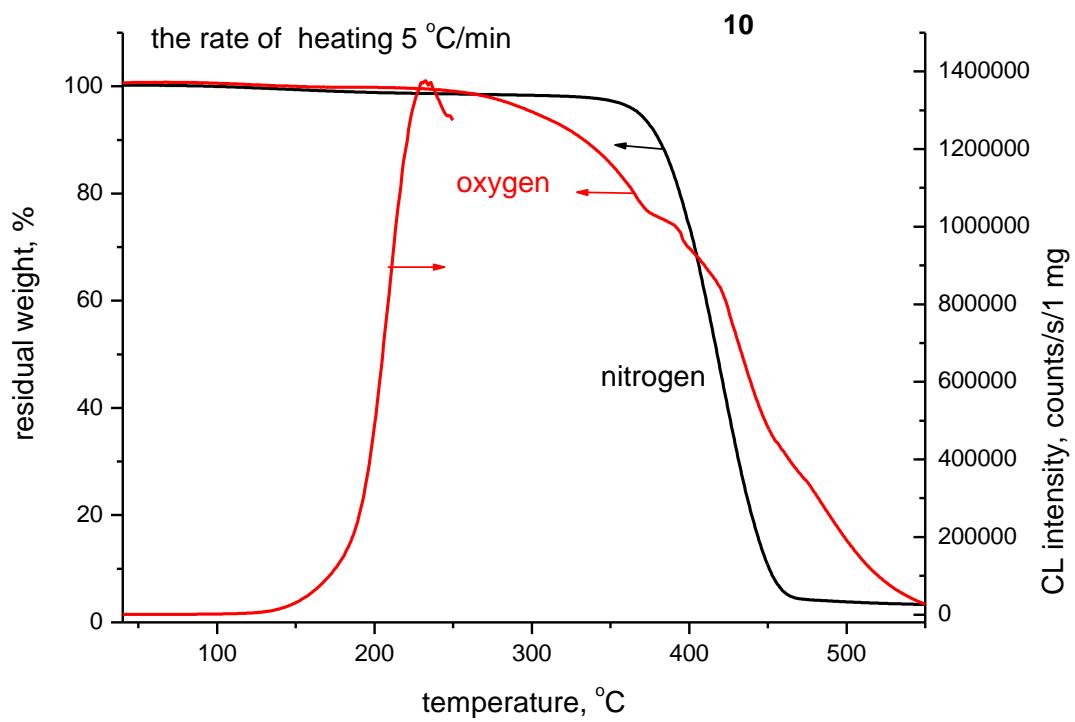


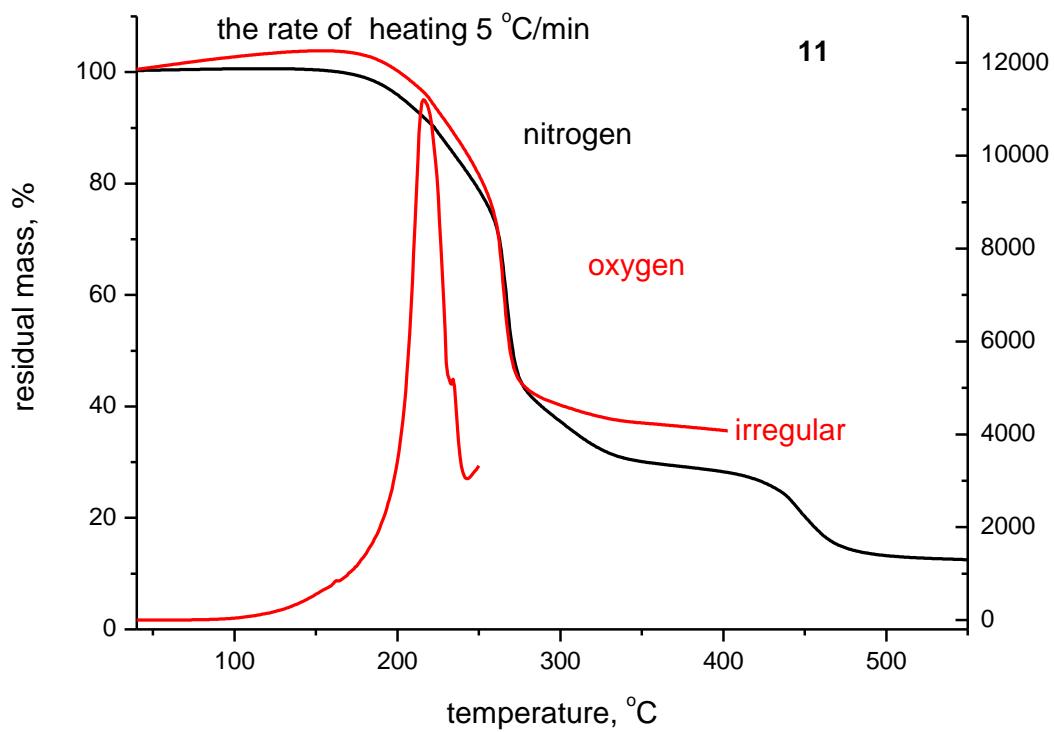


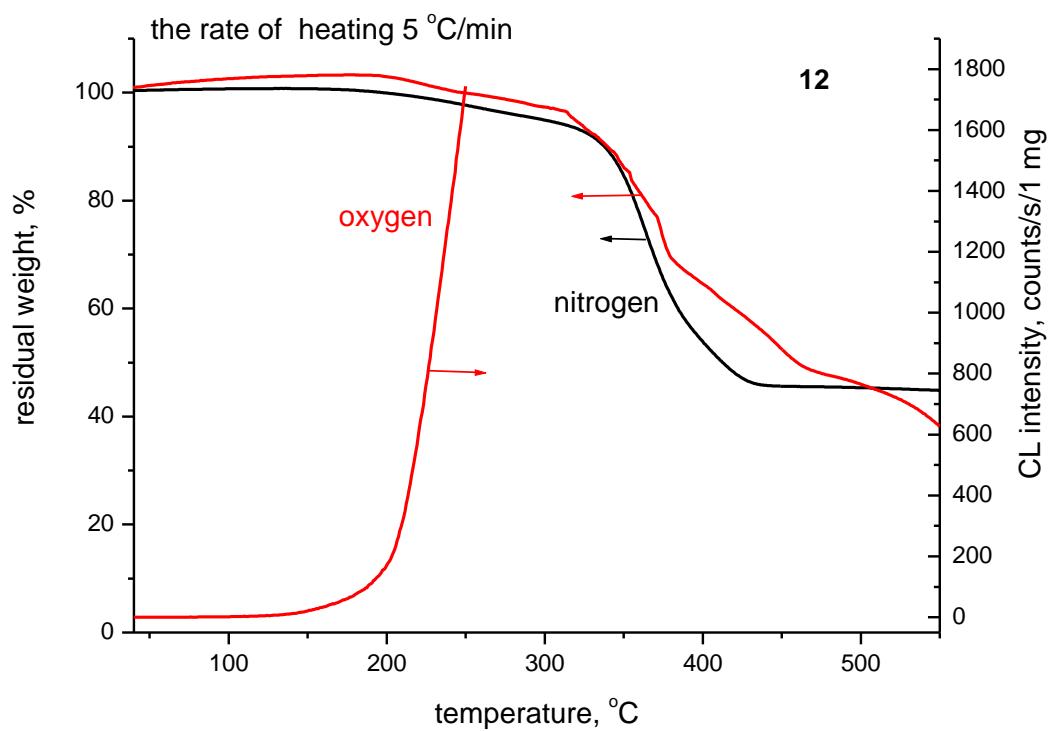




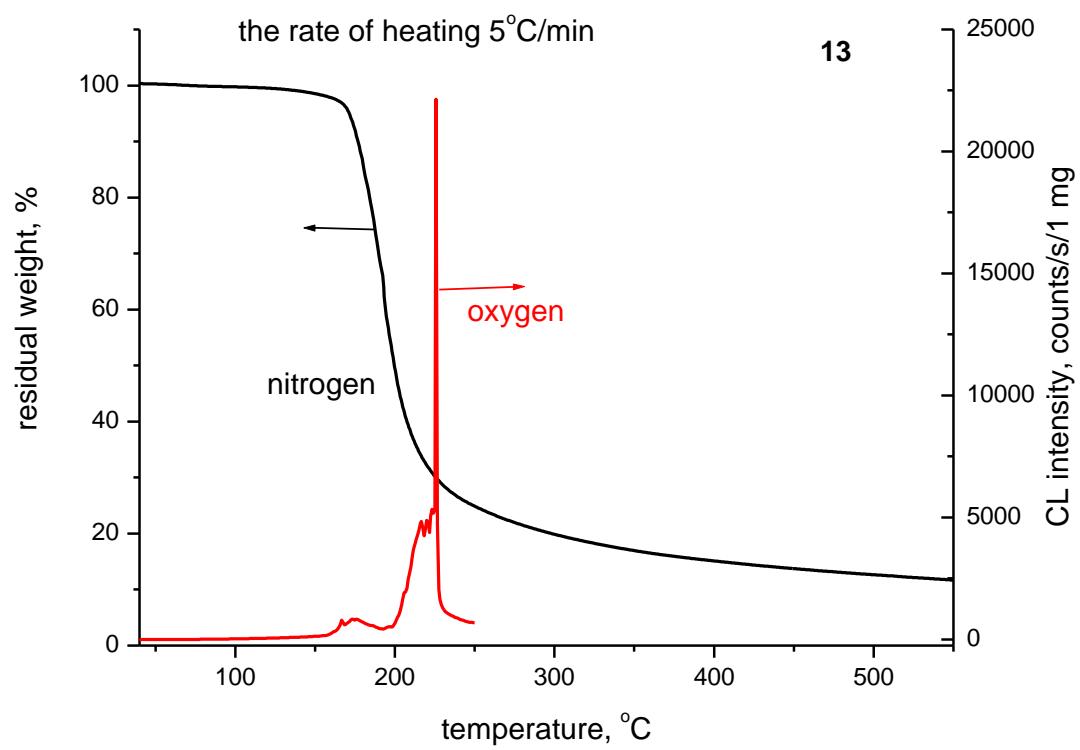


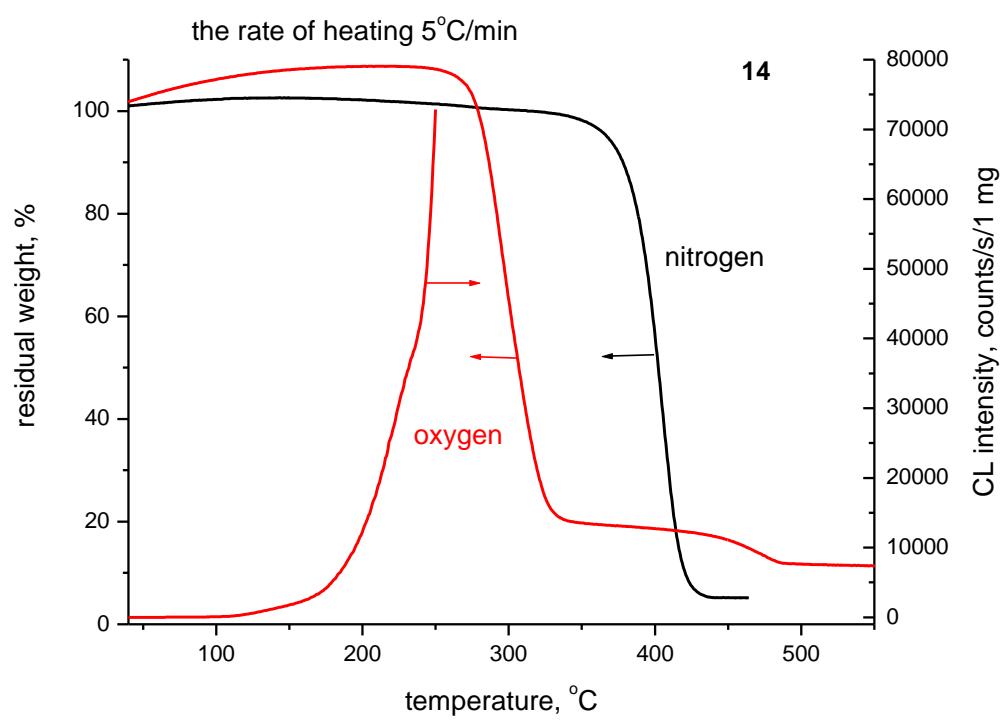




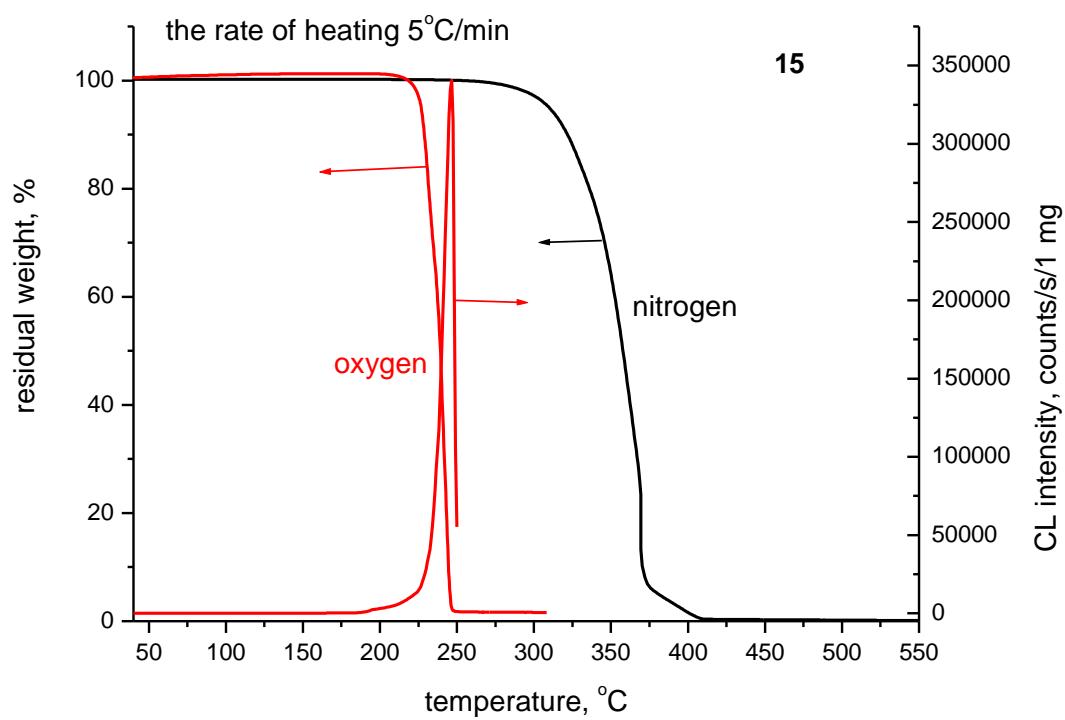


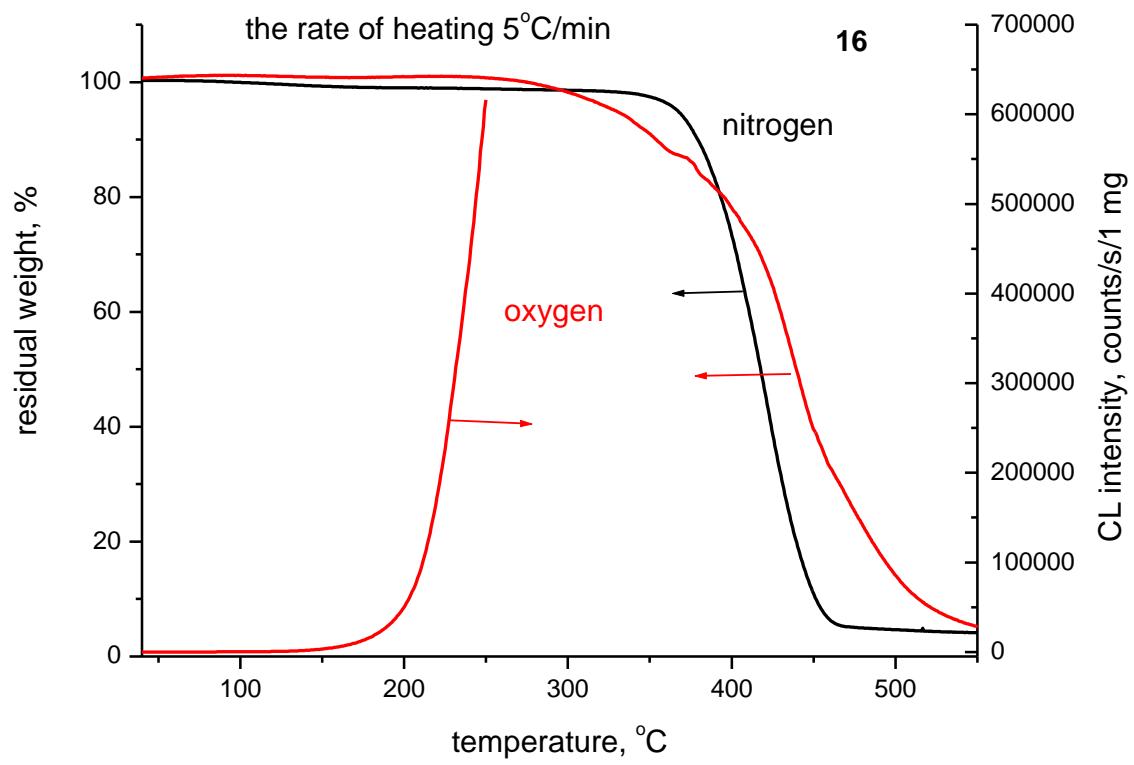
13



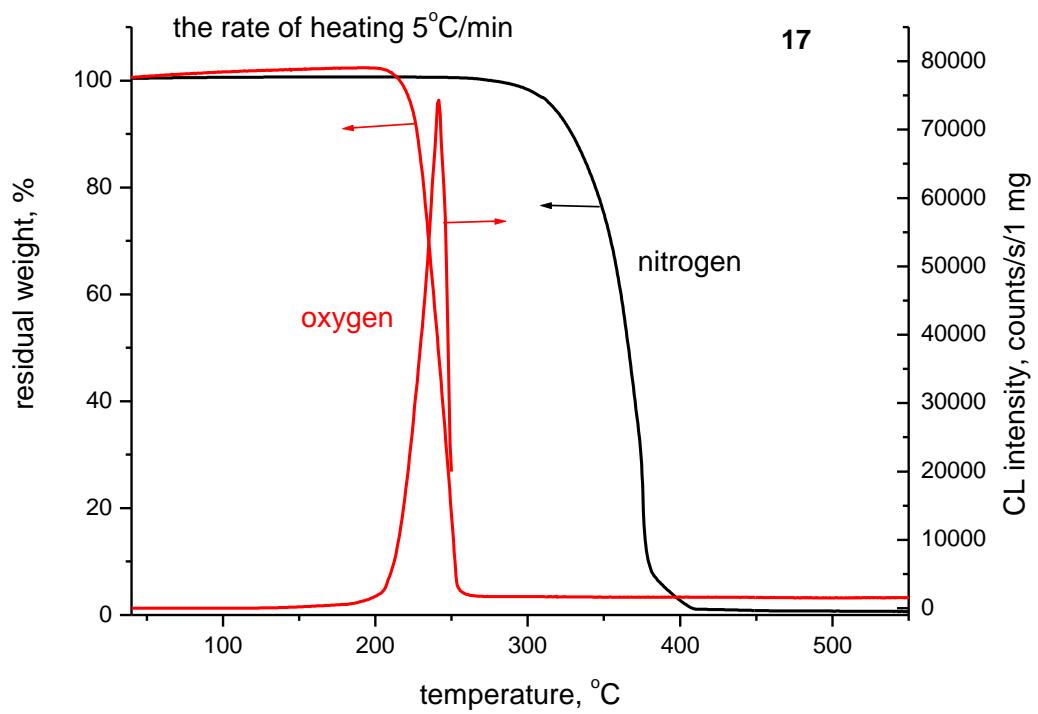


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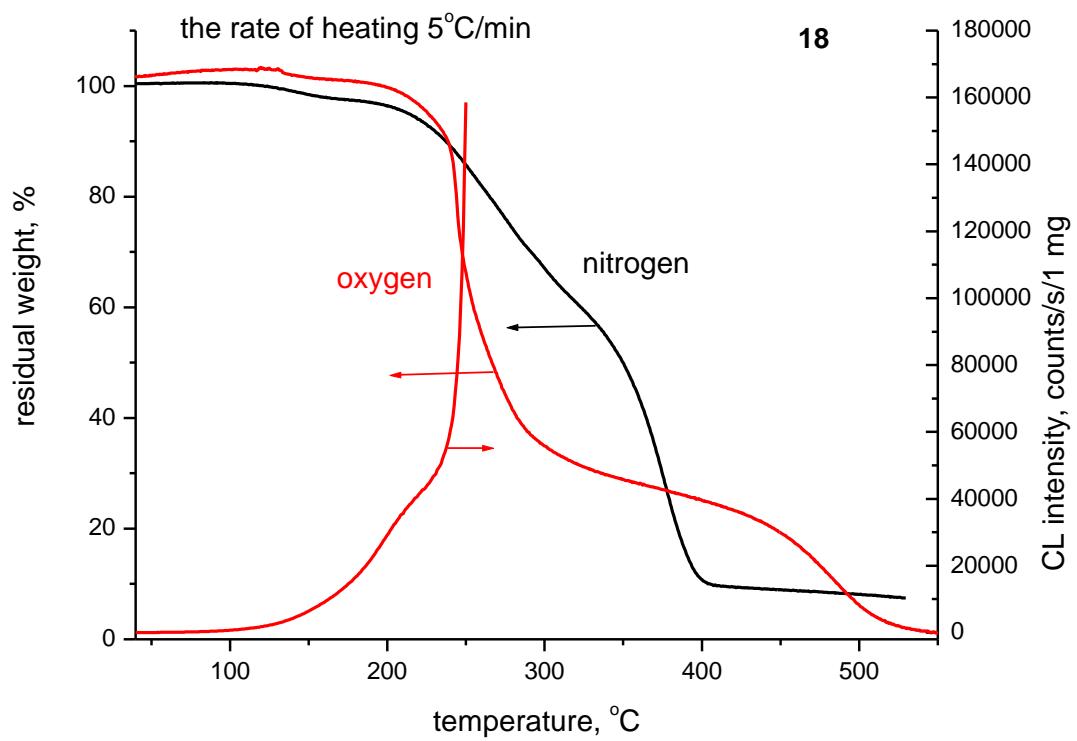




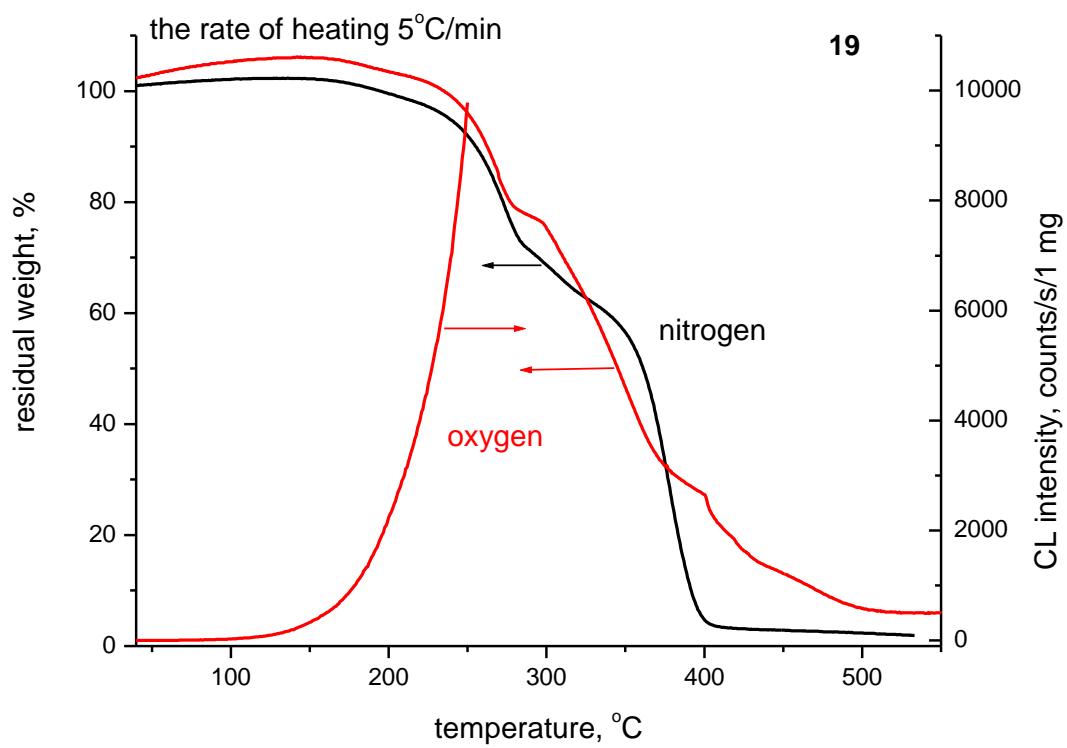
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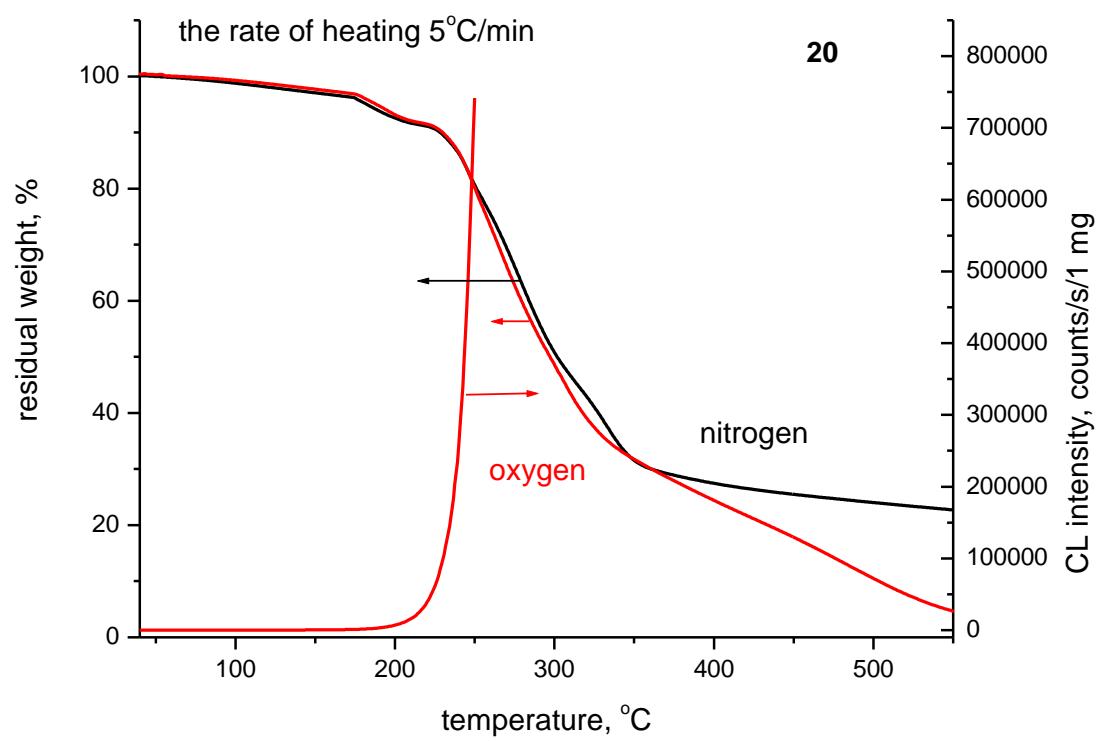


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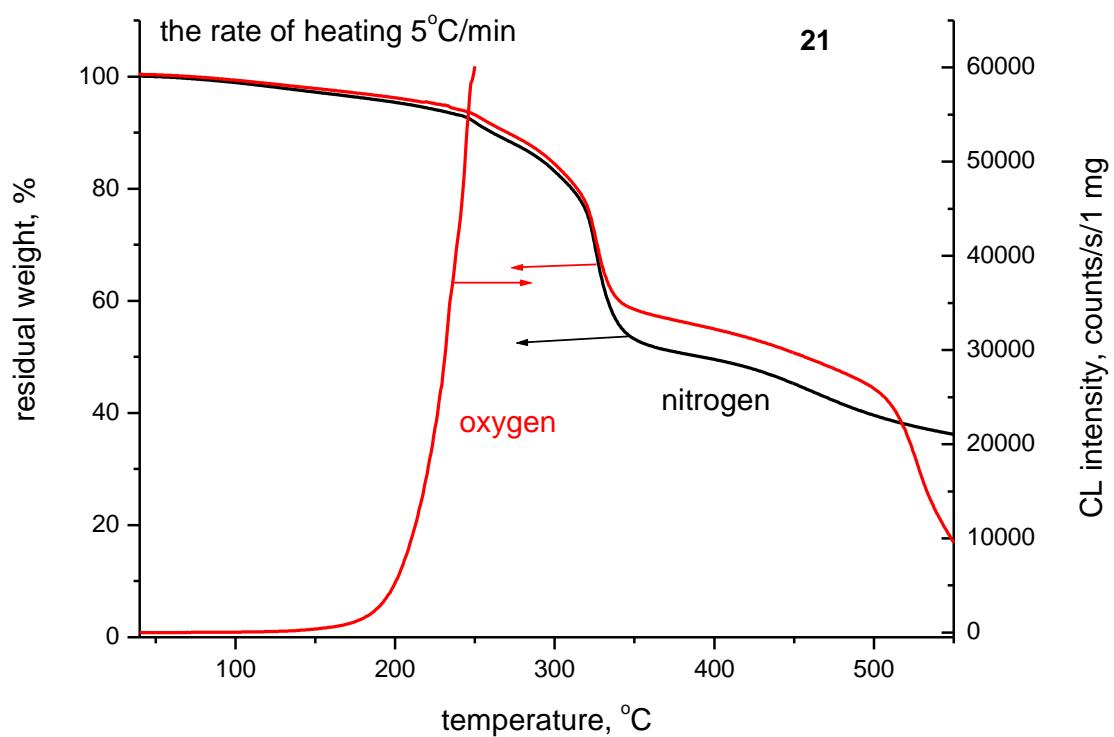


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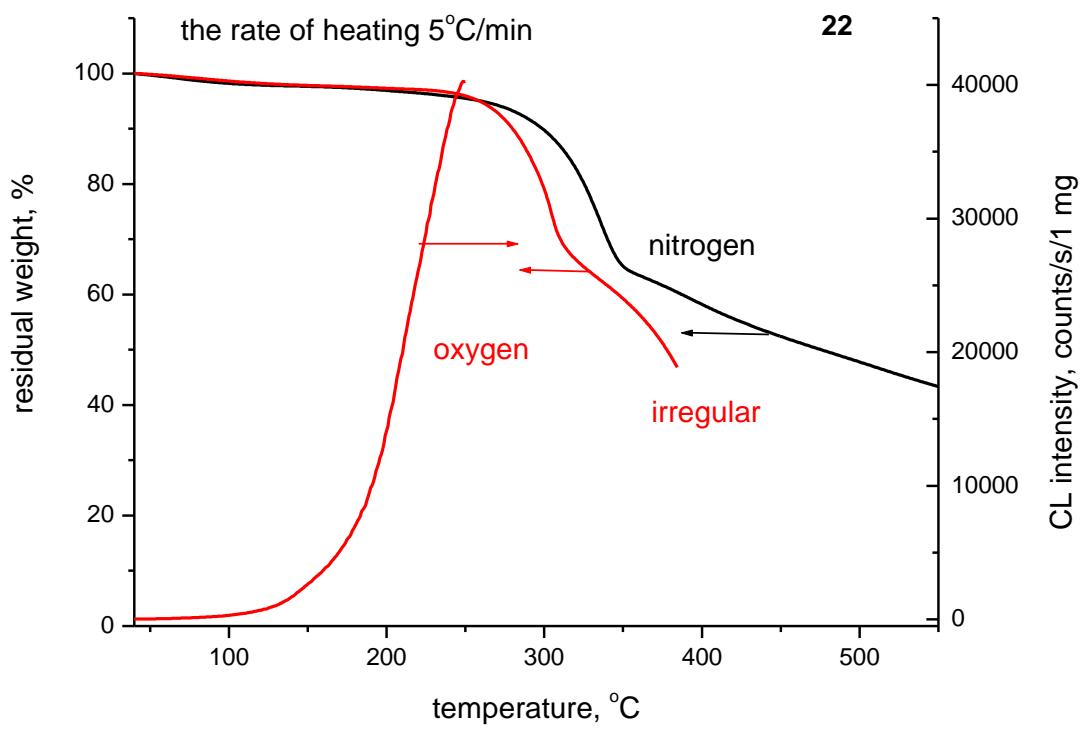


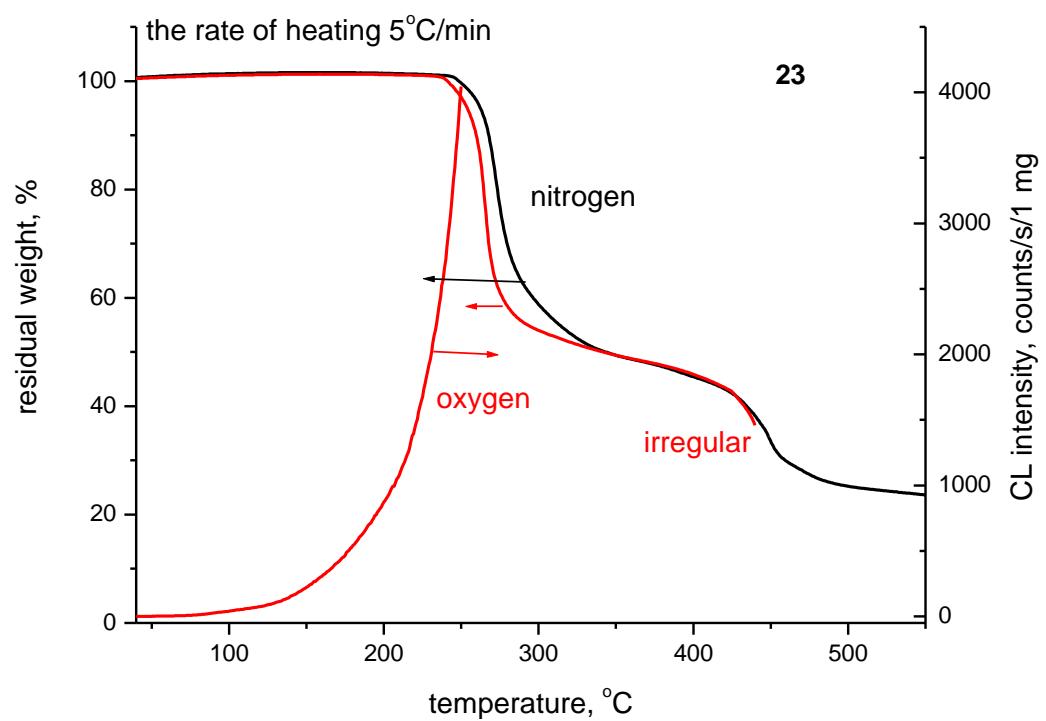


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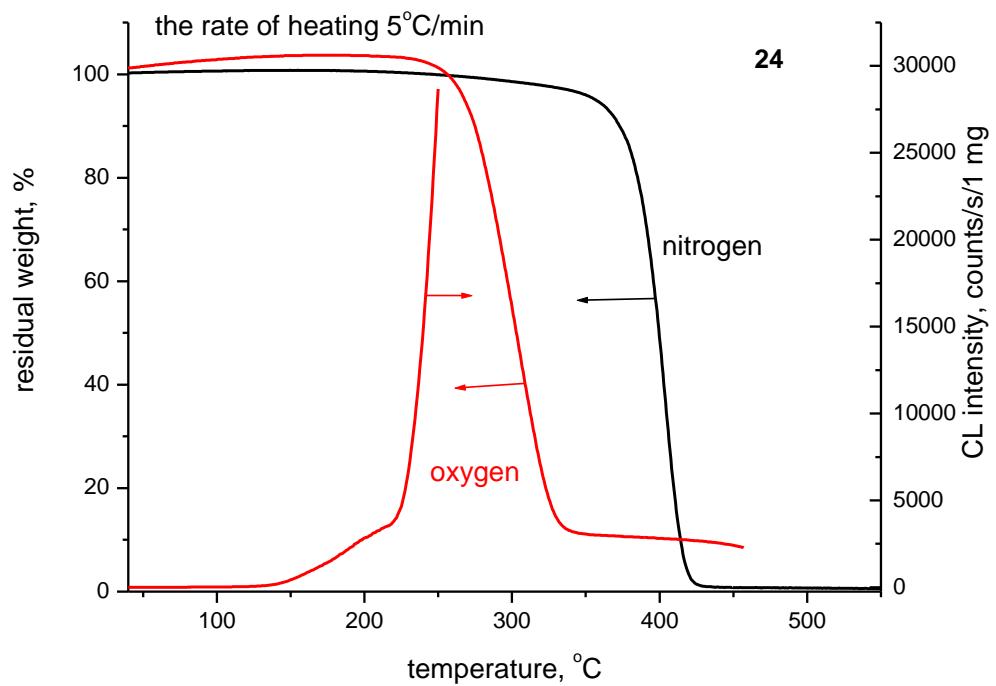


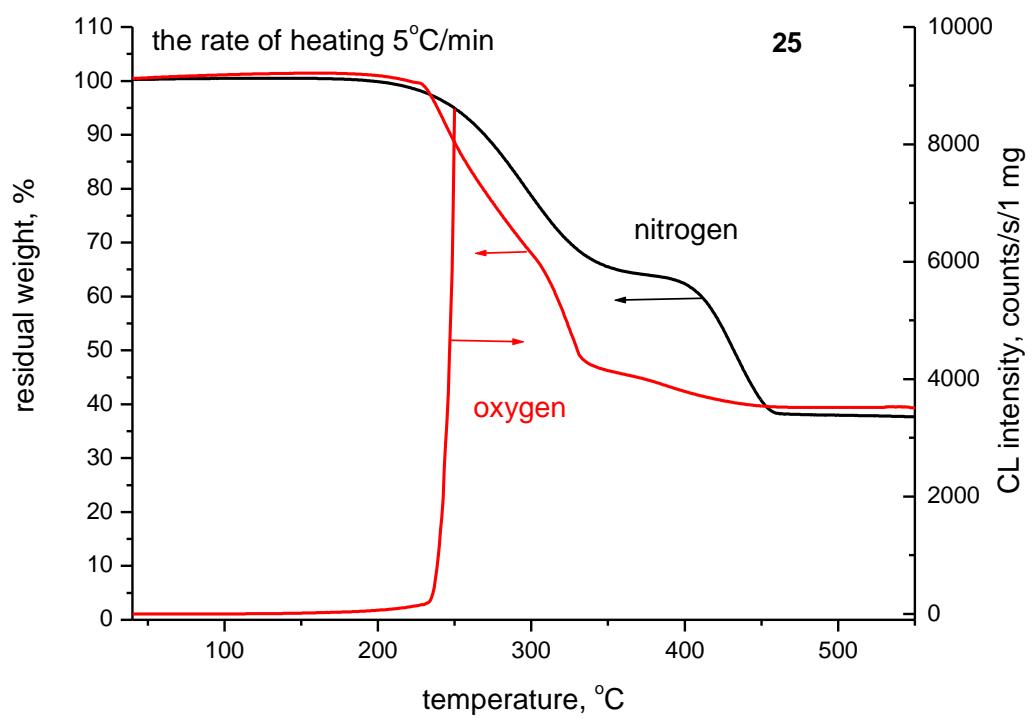
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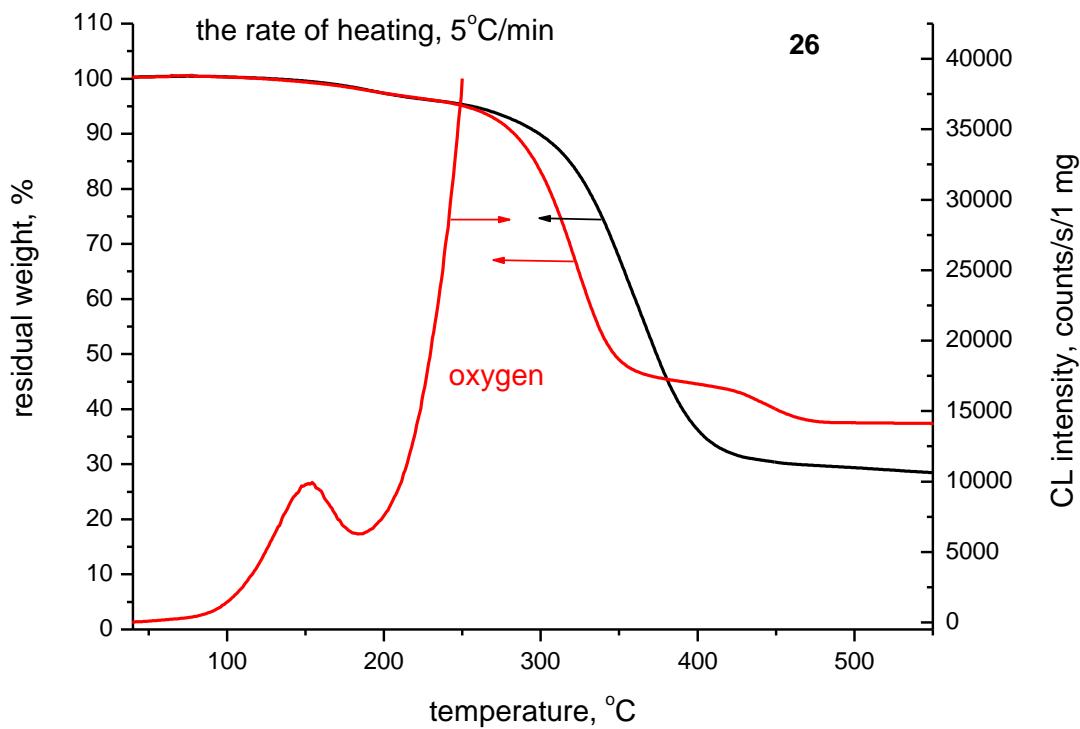


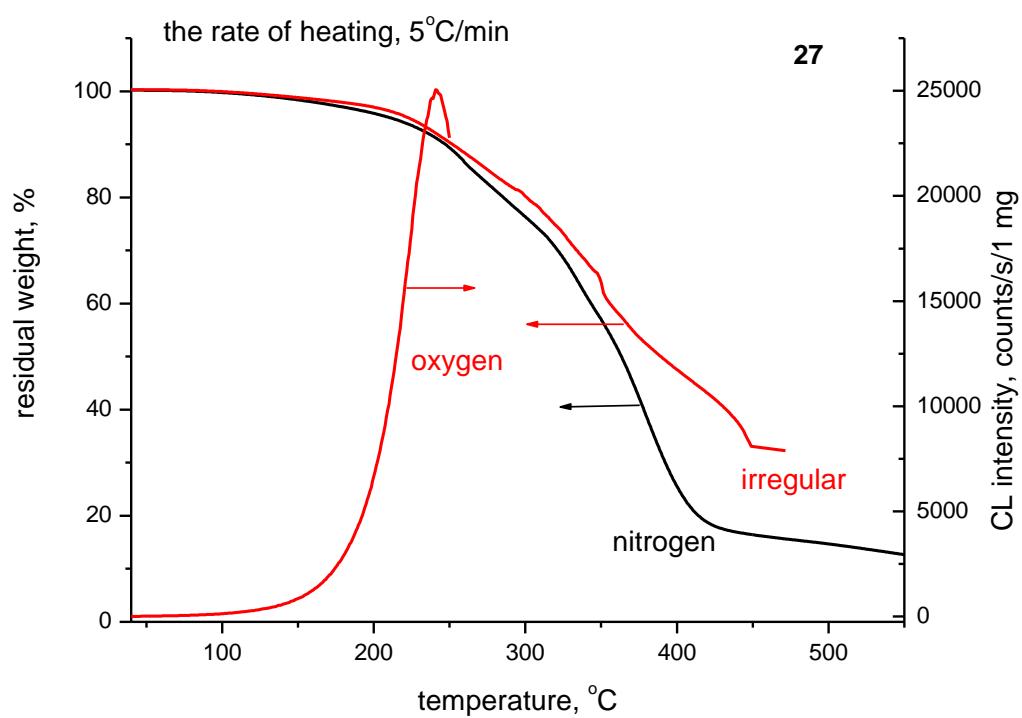
24



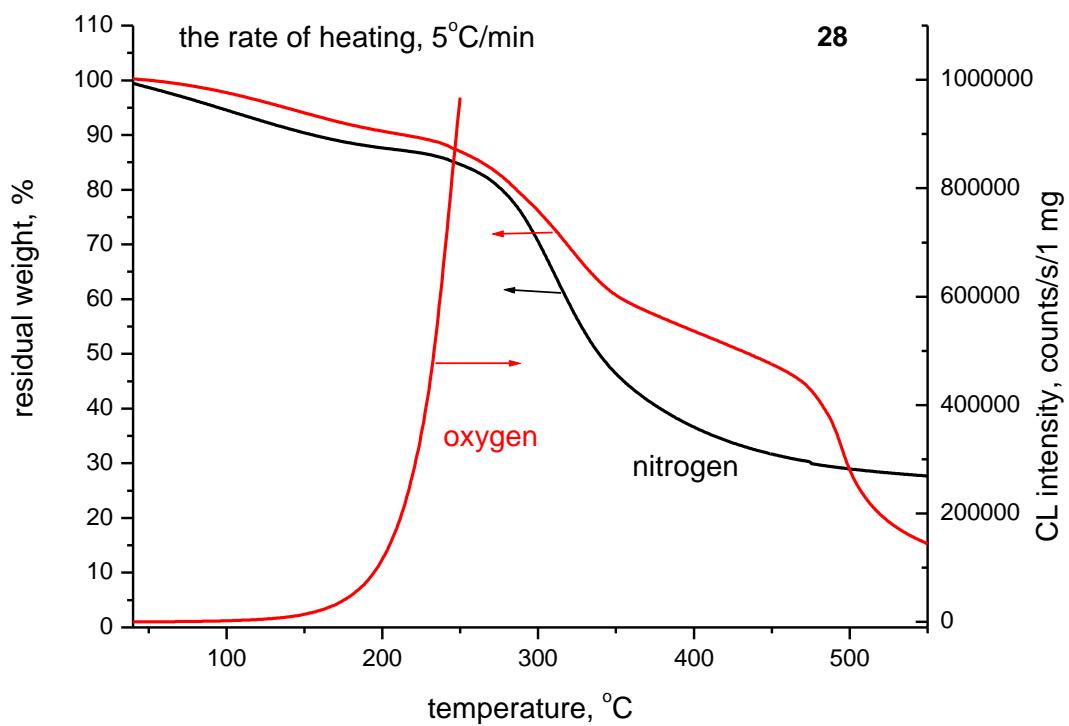


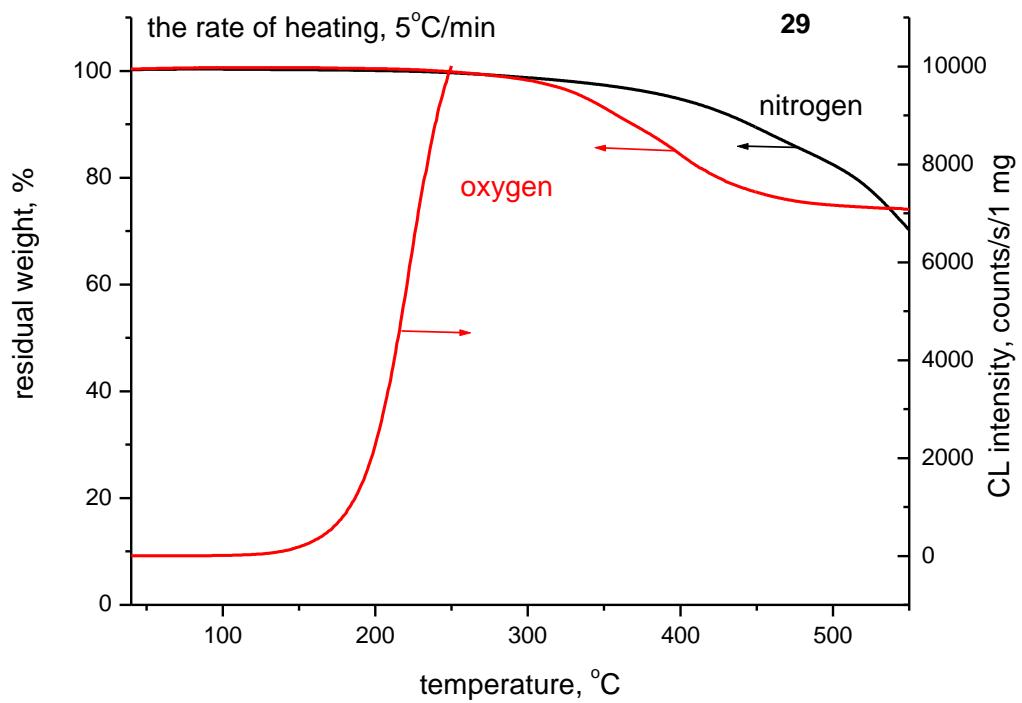
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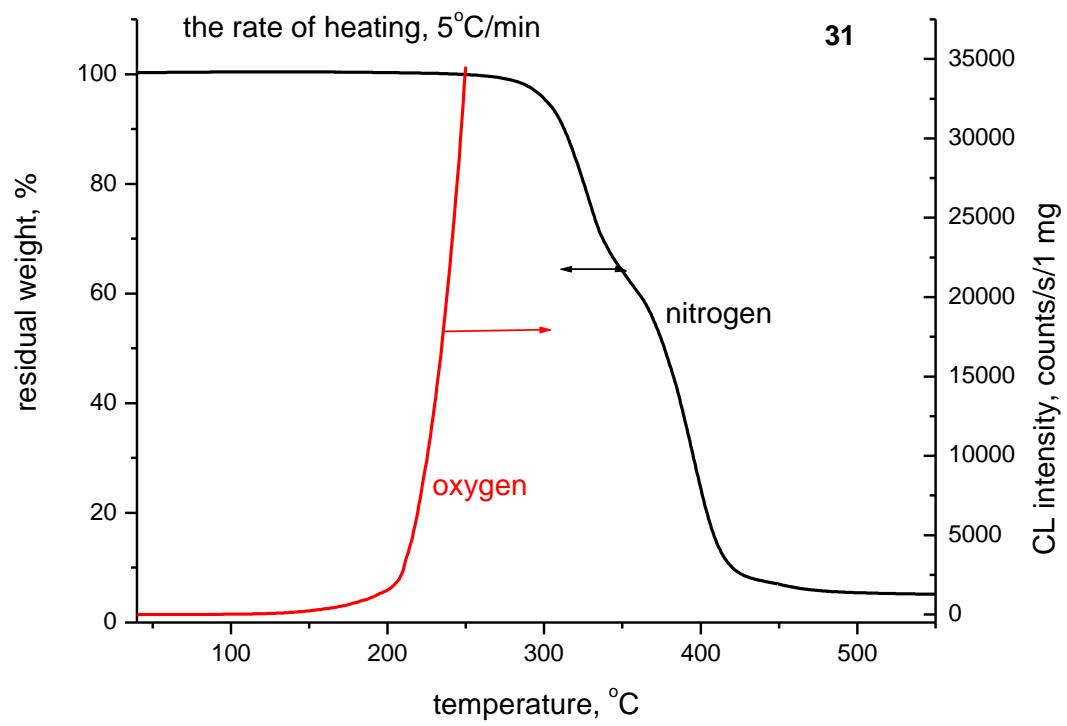


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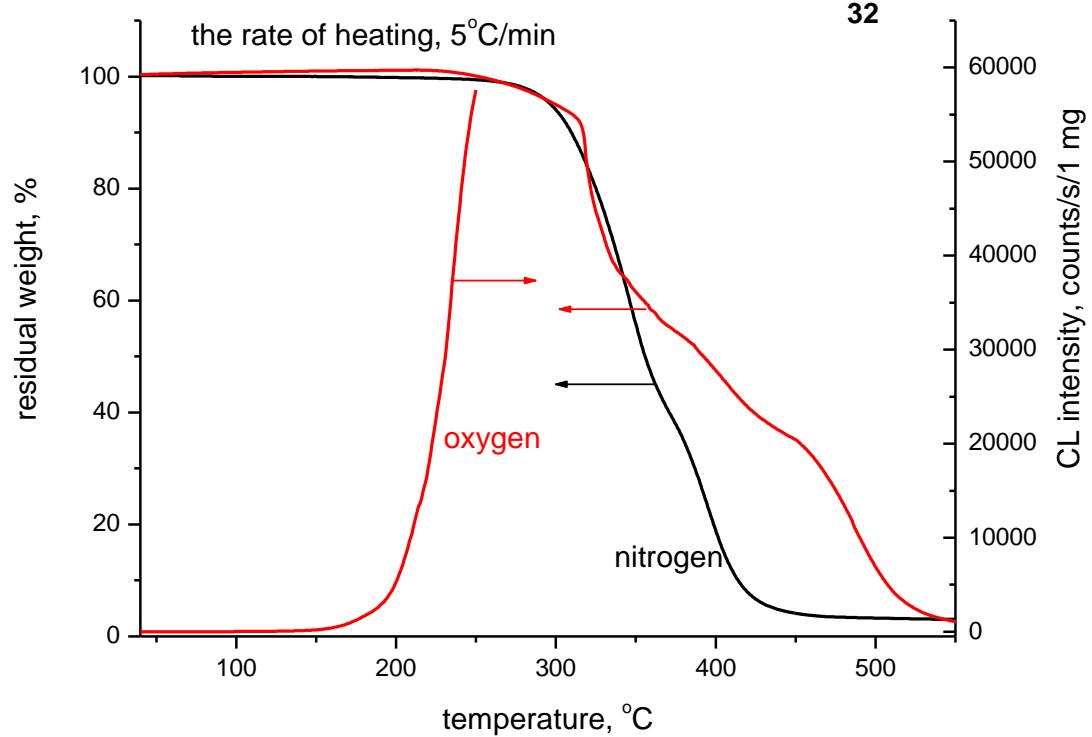




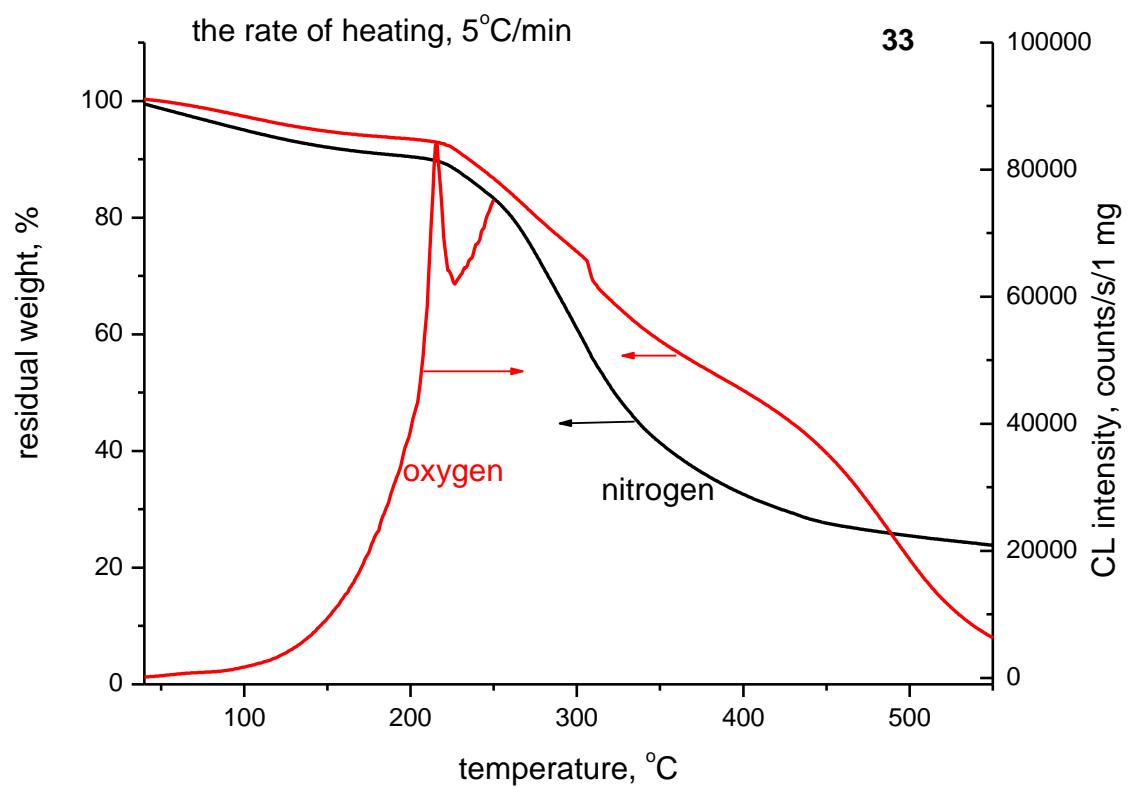
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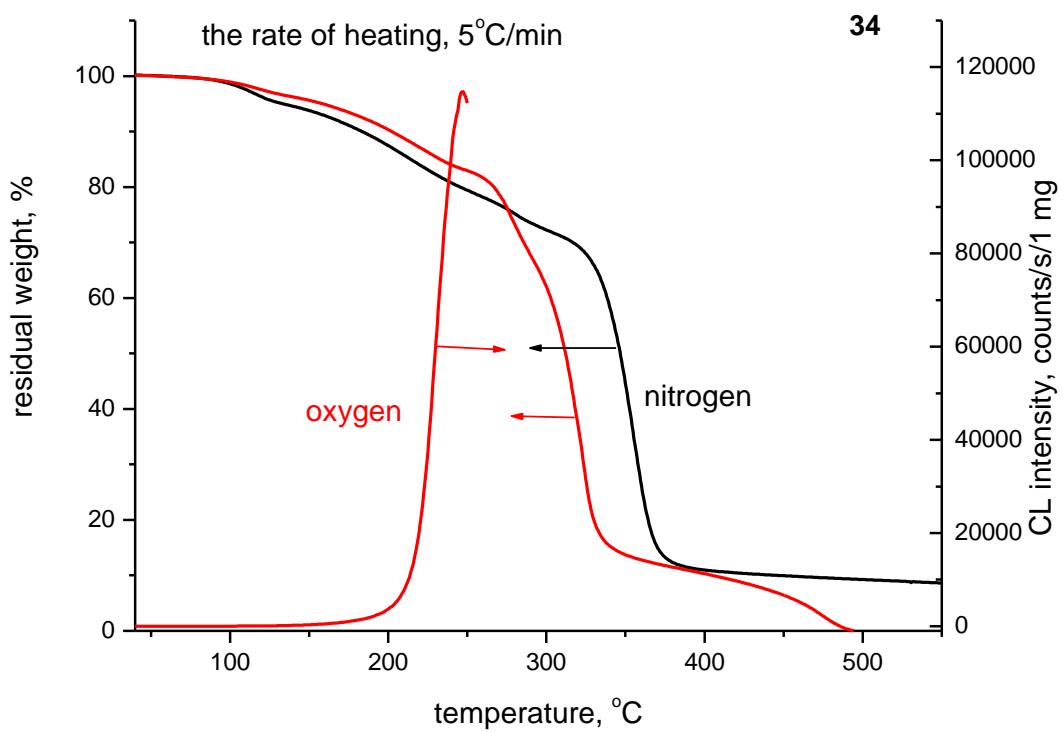
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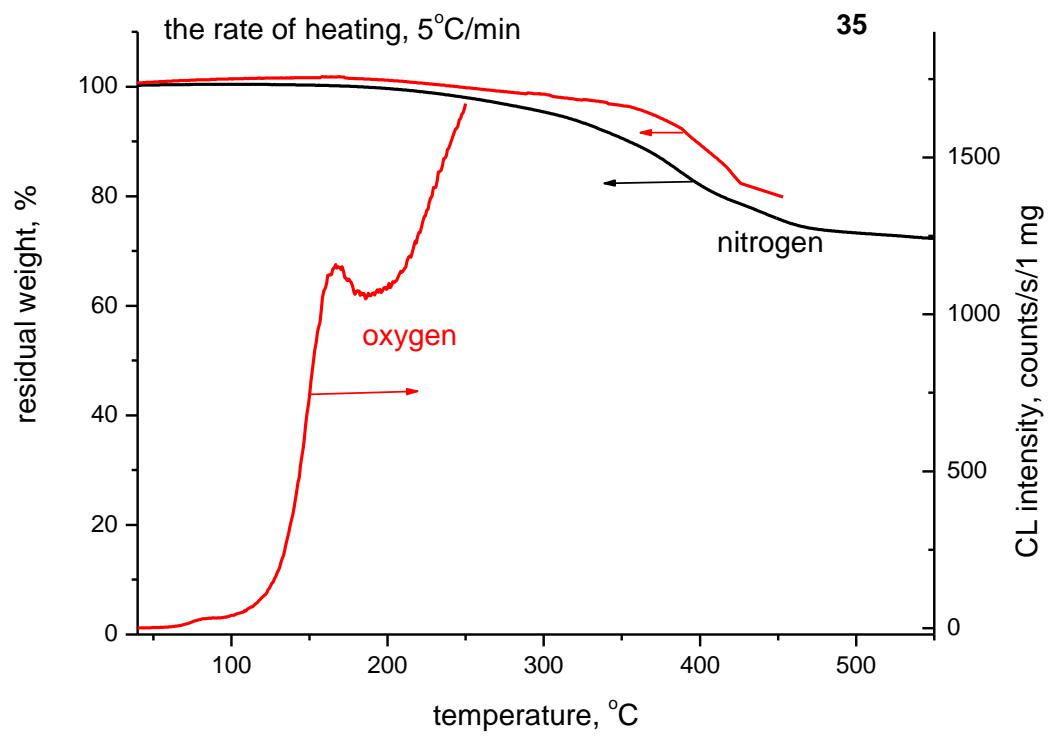


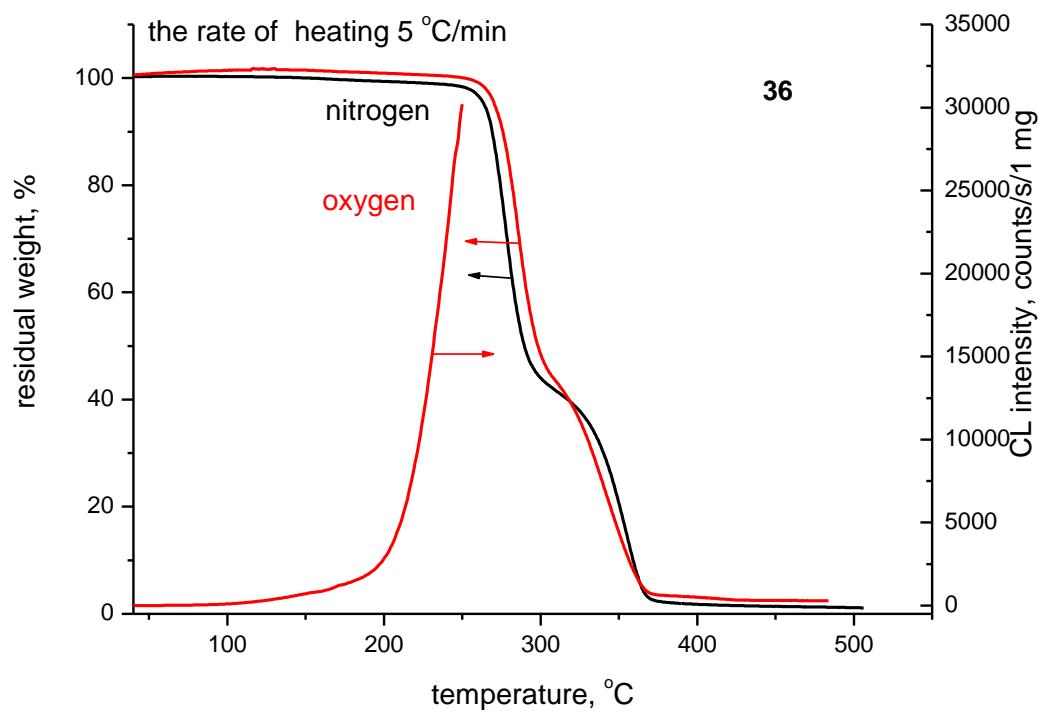
33



34







Overview of chemiluminescence, DSC and thermogravimetry data useful for identification of originally unknown polymers

Sample No.	Residue at 550 °C, nitrogen, %	Temperature of maximum release of volatiles, °C, nitrogen	Maximum rate of release of volatiles, nitrogen, rel.u./s	Heat of combustion, J/g	Temperature of DSC melting endotherm, °C	I_{max} of CL, counts/s/1mg	Temperature of I_{max} , °C
1 PE	0.4-	464.3	0.00251	47 426	132.2 133.6	135 783	>250
2 HIPS	4.3>	414.9	0.00251	41 325		1 075	>250
3 PMMA	0.7-	246.7 356.1	1.2e-4 0.00151	27 767		8 240	>250
4 PC	26.9>	508.3	0.00174	32085		708	>250
5 PBT	4.4>	386.9	0.00226	26 425	224.4	122 404	>250

6 CA	36.9>	231.9	7.8e-4	-		10 177	231.5
7 PP	1.5-	421.5	0.0016	49 160	164.2	1 043 728	>250
8 PET	10.6>	420.1	0.00164	24 891	249.8	1 934	>250
9 PBT	5.3>	388.1	0.00227	26 951	225.5	2 902	248.5
10 PA 6,6	3.8>	421.5	0.00128	32 432	263.7	1 383 507	232.8
11 PVC flexible	12.5-	266.7 448.4	0.00215 2.9e-4	26 003		11 276	216.4
12 NR	44.8-	364.1	7.3e-4	39 284		1 736	>250
13 CN	12.1-	193.3	0.00239	19 463		22 125	226.1
14 PS*	5.2-	405.5	0.00245	49 575*		72 735	>250
15 POM	0.04-	369.5	0.00375	17 472		335 511	246.0
16 PA 6,6	4.0->	421.5	0.00132	32 196 32 013	264.2	616 811	>250
17 POM homopolymer	0.7-	376.1	0.00332	18 437	177.9	74 462	241.6

18	7.6>	143.9 274.7 376.1	4.9e-5 3.4e-4 9.1e-4	38 343*		158 397	>250
19	2.0-	273.3 377.5	6.1e-4 0.00134	30 229*		9 773	>250
20	22.8>	181.3 246.7 278.7 332.1	1.2e-4 4.9e-4 5.8e-4 3.8e-4	16 197		741 318	>250
21	36.4>	249.3 326.7	1.7e-4 0.001197	16179		59 959	>250
22	43.2>	336.1	6.1e-4	26 455		40 499	250
23	23.8>-	272.1 449.5	0.0017 5.2e-4	20 629		4 035	>250
24	1.1-	404.1	0.00264	43 092		28 821	>250
25	37.8-	297.2 430.9	3.4e-4 4.9e-4	28 609		8 613	>250
26	28.6>	362.6	6.2e-4	21 237		9 895 38 665	152.1 >250
27	12.8>	260.1 336.1 380.1	2.8e-4 4.1e-4 6.3e-4	29 927		25 165	242.3
28	27.4>	312.1	4.9e-4	20 488		966 898	>250

29 SI	68.4>	456.3 545.7	1.2e-4 2.7e-4	11 936		9 954	>250
31 Thermoplastic PUR ether	5.3-	329.5 394.4	8.0e-4 0.00106	28 180		34 439	>250
32 Thermoplastic PUR ester	5.5-	346.7 394.9	9.6e-4 7.4e-4	32 199		57 439	>250
33 Hoof	24.0>	302.7	4.5e-4	21 347		380 865	>250
34 CA	9.1>	114.5 354.7	1.1e-4 0.00161	21 387		114 878	246.6
35 Shellac	72.3->	388.1 442.9 533.7	1.7e-4 1.0e-4 1.9e-5	11 577		1 151 1 667	167.2 >250
36 PHB	1.1-	278.7 354.7	0.00207 0.00103	25 000		29 925	>250

*foam, -, > steady, decreasing value at 550 °C

Samples were identified as:

Sample No.	Explanation of abbreviation according to J.A.Brydson, Plastic Materials, Seventh edition, Butcherworth, 2006
1 PE	Polyethylene
2 HIPS	High impact polystyrene

3 PMMA	Poly methyl methacrylate
4 PC	Polycarbonate
5 PBT	Polybutylene terephthalate
6 CA	Cellulose acetate
7 PP	Polypropylene
8 PET	Polyethylene terephthalate
9 PBT	Polybutylene terephthalate
10 PA 6,6	Polyamide 6,6
11 PVC flexible	Polyvinyl chloride flexible
12 NR	Natural rubber
13 CN	Cellulose nitrate
14 PS*	Polystyrene
15	Polyacetal

POM	
16 PA 6,6	Polyamide 6,6
17 POM homopolymer	Polyoxymethylene
18 PUR ether*	Polyurethane ether
19 PUR ester*	Polyurethane ester
20 UF	Urea formaldehyde resin
21 MF	Melamine formaldehyde resin
22 PF	Phenol formaldehyde resin
23 PVC rigid	Polyvinyl chloride rigid
24 PS	Polystyrene
25 SBS	Styrene-butadiene-styrene copolymer
26 UP	Unsaturated polyester
27 Vulcanite	Vulcanite, vulcanized rubber

28 CS resin	Casein resin
29 SI	Polysiloxane
31 Thermoplastic PUR ether	Thermoplastic polyurethane ether
32 Thermoplastic PUR ester	Thermoplastic polyurethane ester
33 Hoof	Hoof
34 CA	Cellulose acetate
35 Shellac	Shellac
36 PHB	Polyhydroxy butyrate

*foam

Acknowledgements

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