Electronic Supplementary Material (ESI) for RSC Advances.

Aging behavior of the silicone dielectric elastomers in simulated marine environment

Adrian Bele, George Stiubianu, Stelian Vlad, Codrin Tugui, Cristian-Dragos Varganici, Lavinia Matricala, Daniela Ionita, Daniel Timpu, Maria Cazacu

"Petru Poni" Institute of Macromolecular Chemistry, Aleea Gr. Ghica Voda 41A, 700487 Iasi, Romania

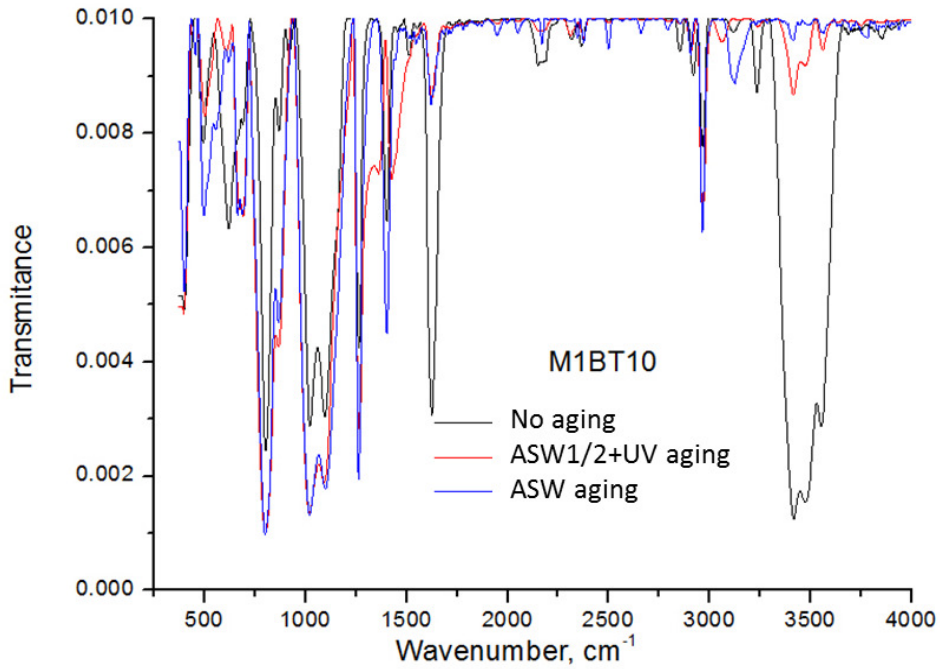


Figure 1S. Comparative FTIR spectra of the sample M1BT10, original and aging by protocols ASW1/2 + UV and ASW.

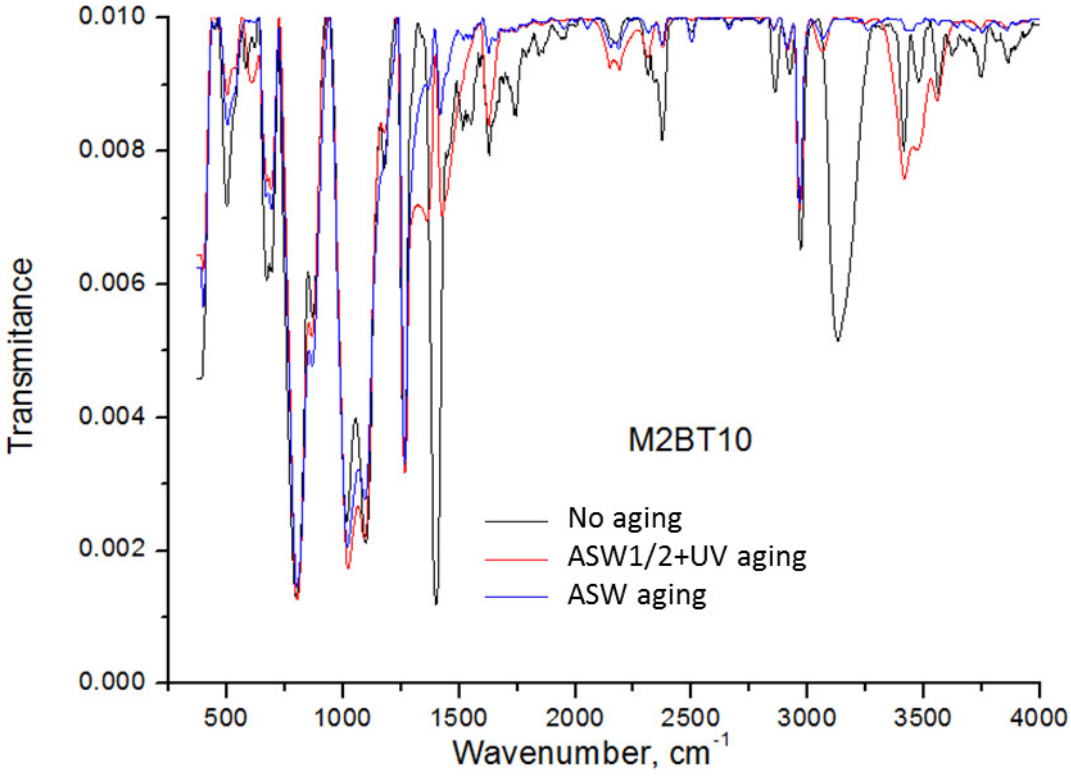


Figure 2S. Comparative FTIR spectra of the sample M2BT10, original and aging by protocols ASW1/2 + UV and ASW.

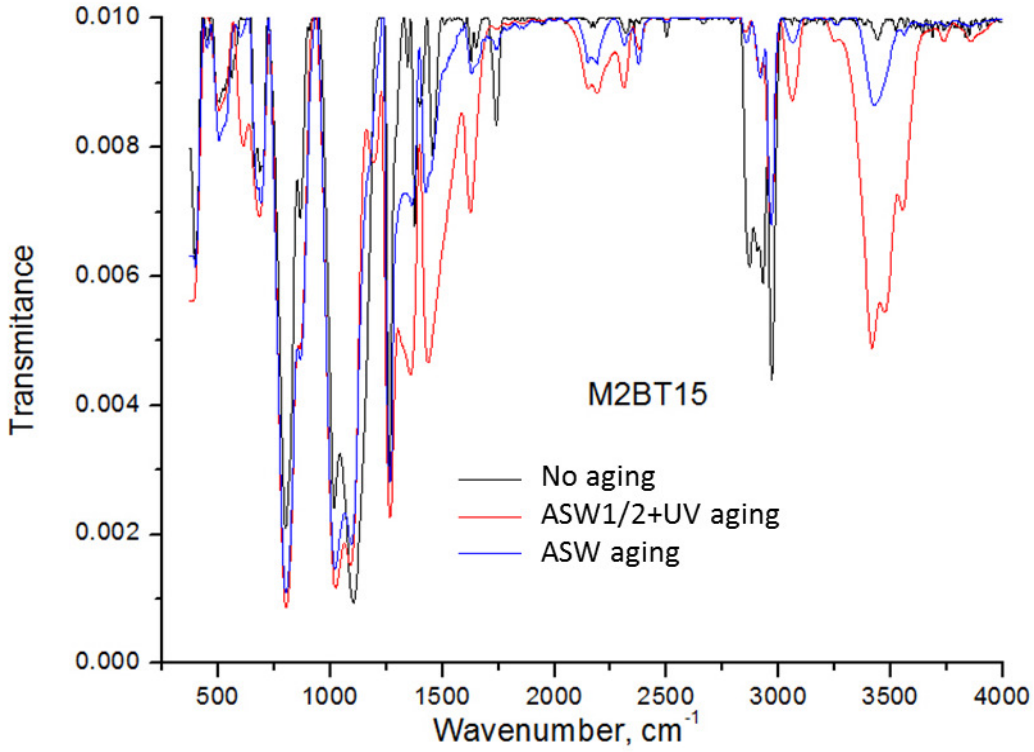


Figure 3S. Comparative FTIR spectra of the sample M2BT15, original and aging by protocols ASW1/2 + UV and ASW.

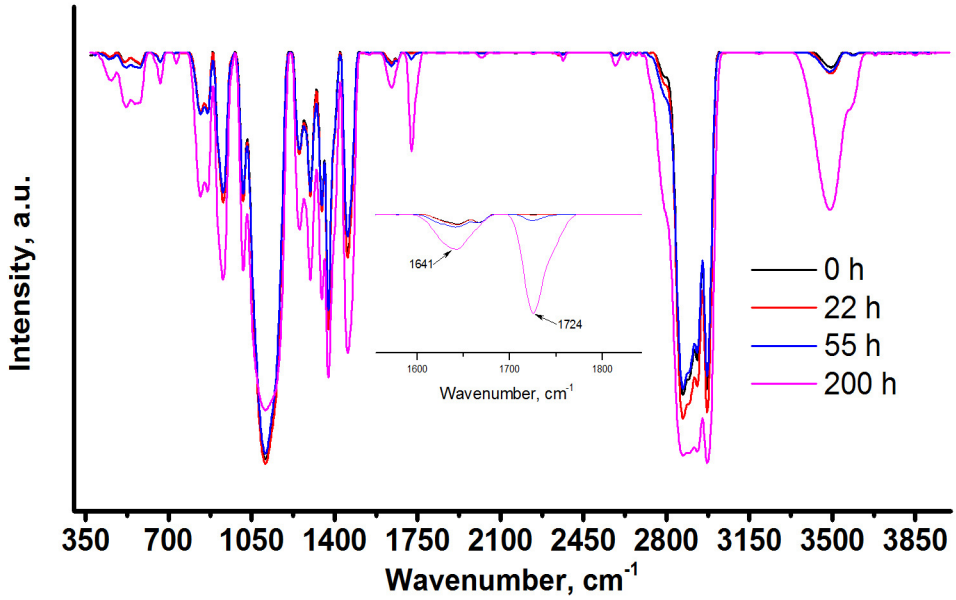
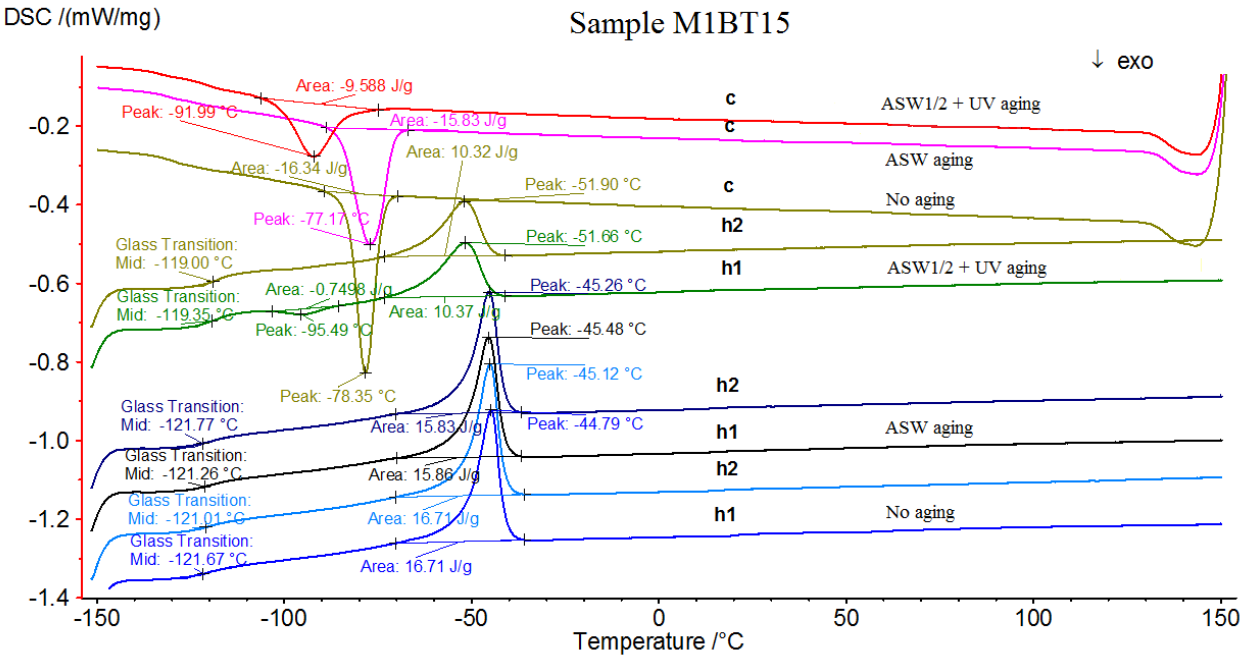
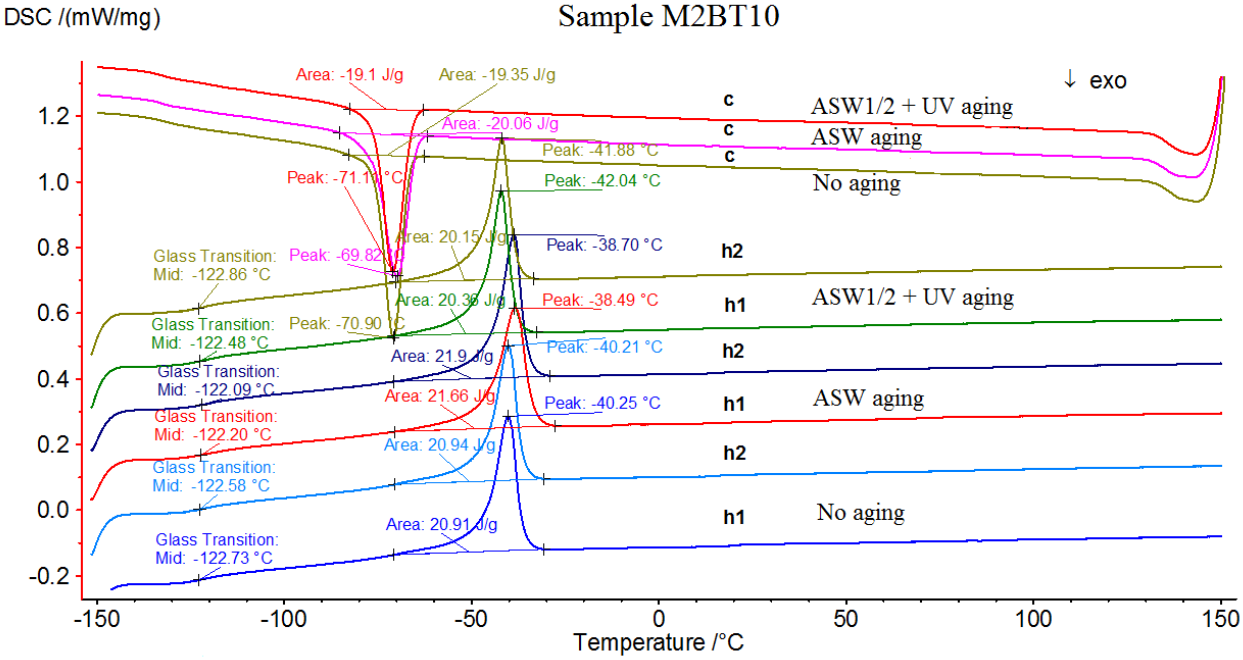


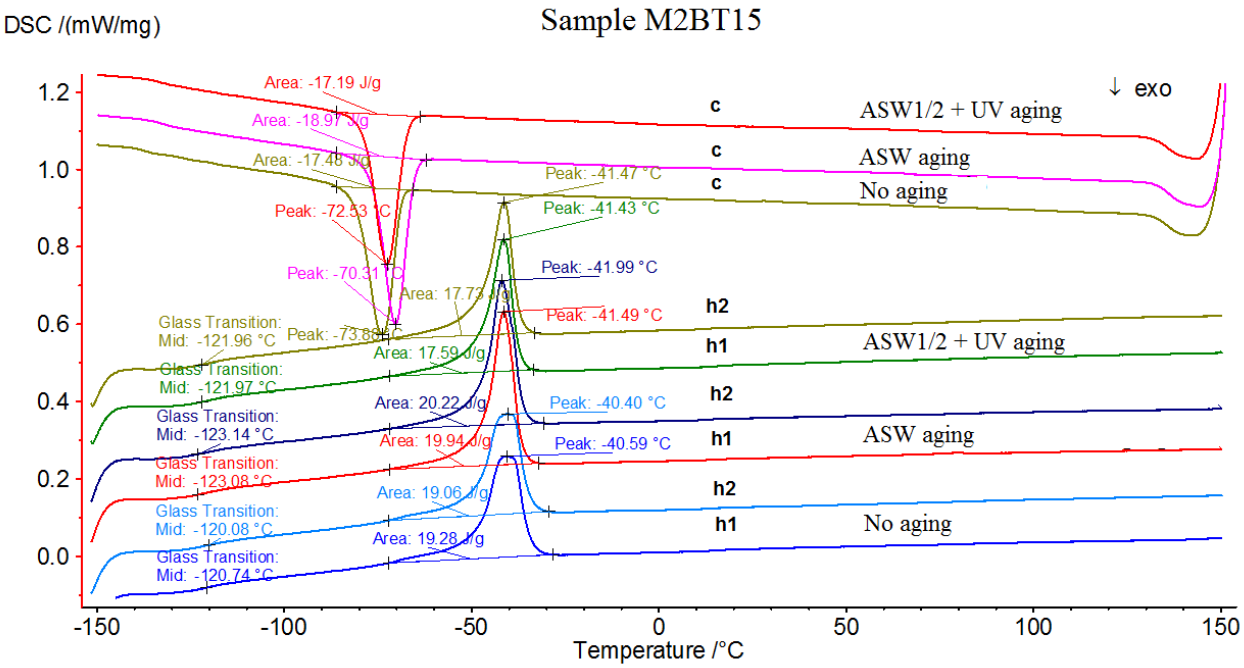
Figure 4S. FTIR spectra of the surfactant PLURONIC L-31, recorded after different UV irradiation (366 nm) times.

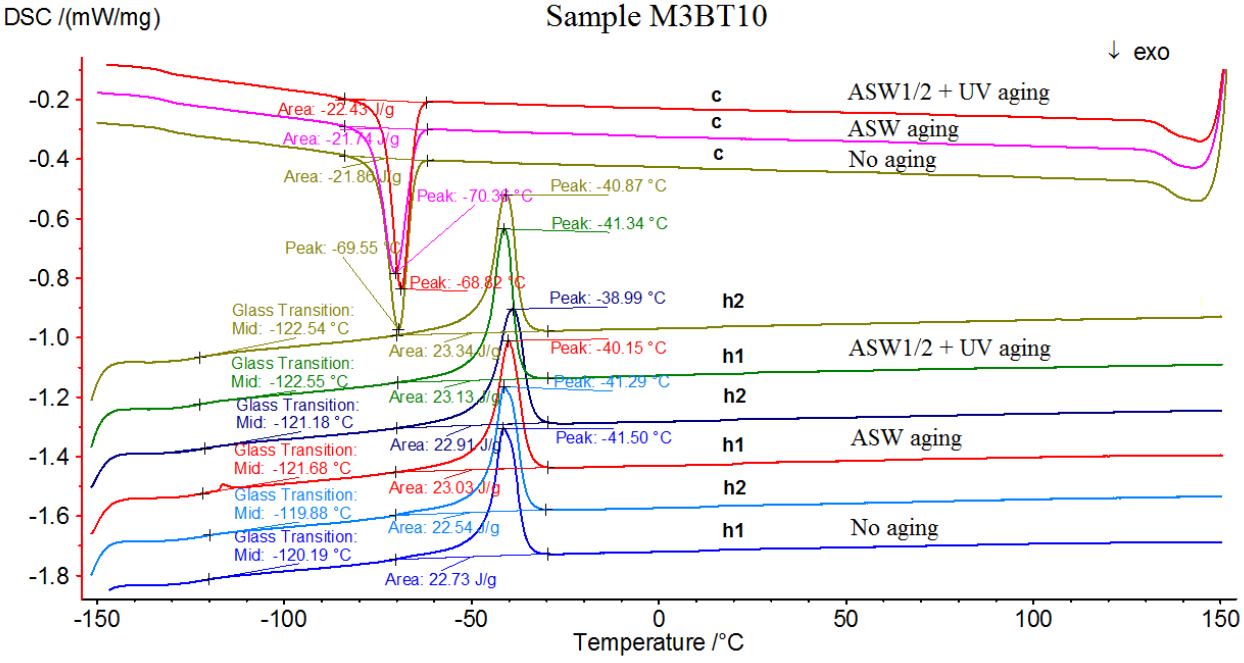
Table 1S. The main values of the diffractograms for the sample M2BT10 in the three stages as compared with those for barium titanate.

BaO_3Ti		Sample M2BT10					
		No aged		ASW1/2 + UV		ASW	
Angle, 2-Theta °	d value, Angstrom	Angle, 2-Theta °	d value, Angstrom	Angle, 2-Theta °	d value, Angstrom	Angle, 2-Theta °	d value, Angstrom
22.23	3.996	22.28	3.988	22.33	3.979	22.25	3.992
31.62	2.827	31.63	2.827	31.70	2.820	31.62	2.827
38.96	2.310	38.99	2.308	39.05	2.305	38.97	2.309
45.29	2.001	45.32	2.000	45.42	1.995	45.33	1.999
50.98	1.790	51.11	1.786	51.03	1.788	50.99	1.789
56.24	1.634	56.28	1.633	56.33	1.632	56.27	1.634
65.89	1.416	65.97	1.415	66.03	1.414	65.96	1.415


DSC /(mW/mg)
Sample M1BT15
↓ exo
Area: -9.588 J/g
Peak: -91.99 °C
Area: -15.83 J/g
Area: 10.32 J/g
Area: -16.34 J/g
Peak: -51.90 °C
Peak: -77.17 °C
Peak: -51.66 °C
Glass Transition: Mid: -119.00 °C
Peak: -45.26 °C
Glass Transition: Mid: -119.35 °C
Area: -0.7498 J/g
Area: 10.37 J/g
Peak: -95.49 °C
Peak: -45.48 °C
Peak: -45.12 °C
Peak: -78.35 °C
Glass Transition: Mid: -121.77 °C
Area: 15.83 J/g
Peak: -44.79 °C
Glass Transition: Mid: -121.26 °C
Area: 15.86 J/g
Glass Transition: Mid: -121.01 °C
Area: 16.71 J/g
Glass Transition: Mid: -121.67 °C
Area: 16.71 J/g
c
c
c
h2
h1
h2
h1
h2
h1
ASW1/2 + UV aging
ASW aging
No aging
ASW1/2 + UV aging
ASW aging
No aging
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-150
-100
-50
0
50
100
150
Temperature /°C


DSC /(mW/mg)
Sample M2BT10
↓ exo
Area: -19.1 J/g
Area: -19.35 J/g
Area: -20.06 J/g
Peak: -41.88 °C
Peak: -71.19 °C
Peak: -42.04 °C
Area: 20.15 J/g
Peak: -38.70 °C
Glass Transition: Mid: -122.86 °C
Peak: -69.82 °C
Area: 20.36 J/g
Peak: -38.49 °C
Glass Transition: Mid: -122.48 °C
Peak: -70.90 °C
Area: 21.9 J/g
Peak: -40.21 °C
Glass Transition: Mid: -122.09 °C
Area: 21.66 J/g
Peak: -40.25 °C
Glass Transition: Mid: -122.20 °C
Area: 20.94 J/g
Glass Transition: Mid: -122.58 °C
Area: 20.91 J/g
Glass Transition: Mid: -122.73 °C
c
c
c
h2
h1
h2
h1
h2
h1
ASW1/2 + UV aging
ASW aging
No aging
ASW1/2 + UV aging
ASW aging
No aging
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-150
-100
-50
0
50
100
150
Temperature /°C


DSC /(mW/mg)
Sample M2BT15
↓ exo
ASW1/2 + UV aging
ASW aging
No aging
Area: -17.19 J/g
Area: -18.97 J/g
Area: -17.48 J/g
Peak: -72.53 °C
Peak: -70.31 °C
Peak: -41.47 °C
Peak: -41.43 °C
Peak: -41.99 °C
Peak: -41.49 °C
Peak: -73.85 °C
Area: 17.59 J/g
Area: 20.22 J/g
Area: 19.94 J/g
Peak: -40.40 °C
Peak: -40.59 °C
Area: 19.06 J/g
Area: 19.28 J/g
Glass Transition: Mid: -121.96 °C
Glass Transition: Mid: -121.97 °C
Glass Transition: Mid: -123.14 °C
Glass Transition: Mid: -123.08 °C
Glass Transition: Mid: -120.08 °C
Glass Transition: Mid: -120.74 °C
c
h2
h1
Temperature /°C


DSC /(mW/mg)
Sample M3BT10
↓ exo
ASW1/2 + UV aging
ASW aging
No aging
Area: -22.43 J/g
Area: -21.74 J/g
Area: -21.86 J/g
Peak: -70.34 °C
Peak: -69.55 °C
Peak: -68.82 °C
Peak: -40.87 °C
Peak: -41.34 °C
Peak: -38.99 °C
Peak: -40.15 °C
Peak: -41.29 °C
Peak: -41.50 °C
Area: 23.34 J/g
Area: 23.13 J/g
Area: 22.91 J/g
Area: 23.03 J/g
Area: 22.54 J/g
Area: 22.73 J/g
Glass Transition: Mid: -122.54 °C
Glass Transition: Mid: -122.55 °C
Glass Transition: Mid: -121.18 °C
Glass Transition: Mid: -121.68 °C
Glass Transition: Mid: -119.88 °C
Glass Transition: Mid: -120.19 °C
c
h2
h1
Temperature /°C

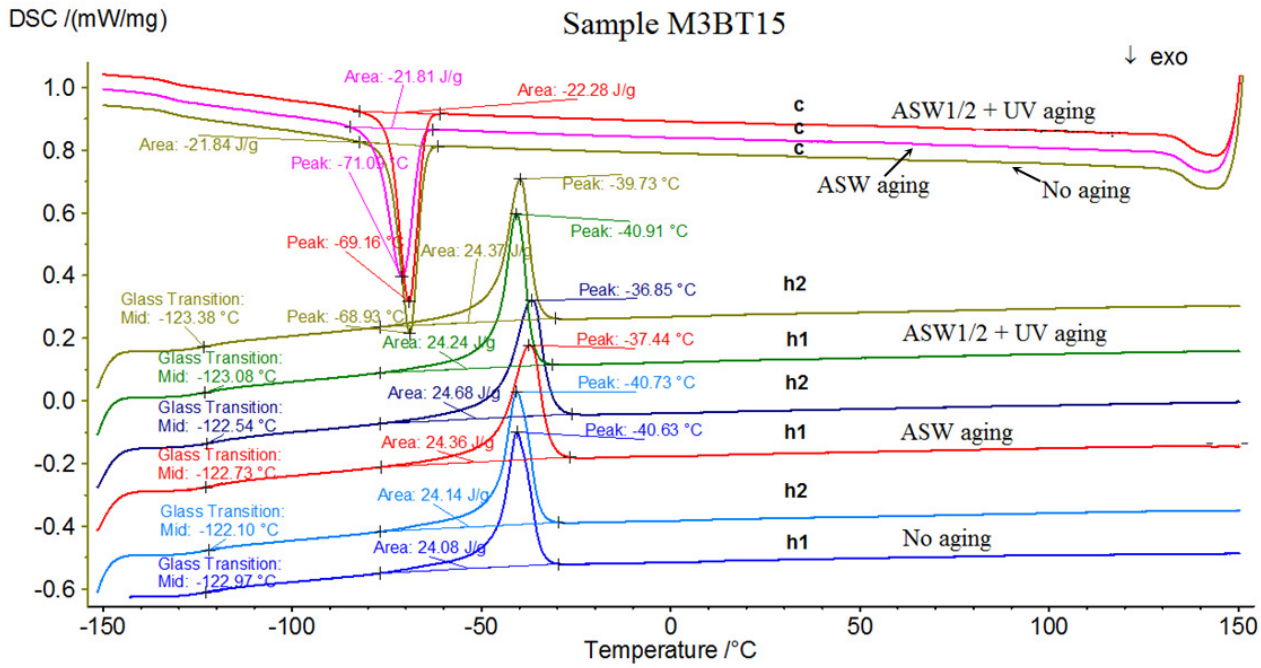


Fig. 5S. DSC curves for all samples in different aging stages.

Table 2S. Thermal characteristics extracted from DSC data.

Aging conditions	Sample code	T_{g1} (°C)	T_{g2} (°C)	T_{t1} (°C)	ΔHt_1 (J/g)	T_{t2} (°C)	ΔHt_2 (J/g)	T_{cr} (°C)	ΔH_{cr} (J/g)	χ_c (%)
No aging	**M3BT10**	–120.2	–119.9	–41.5	22.73	–41.3	22.54	–69.6	–21.86	36.77
	M3BT15	–123	–122.1	–40.6	24.08	–40.7	24.14	–68.9	–21.84	39.38
	M2BT10	–122.7	–122.6	–40.3	20.91	–40.2	20.94	–70.9	–41.88	34.16
	M2BT15	–120.7	–120	–40.6	19.28	–40.4	19.06	–73.9	–17.5	31.09
	M1BT10	–120.2	–121	–49	16.13	–49	15.98	–87.6	–14.8	26.07
	M1BT15	–121.7	–121	–44.8	16.71	–45.1	16.71	–78.4	–16.34	27.26
ASW1/2+UV	**M3BT10**	–121.7	–121.2	–40.2	23.03	–39	22.91	–70.4	–21.74	37.4
	M3BT15	–122.7	–122.5	–37.4	24.36	–36.9	24.68	–71.09	–21.81	40.26
	M2BT10	–122.2	–122.1	–38.5	21.66	–38.7	21.9	–69.8	–20.06	35.73
	M2BT15	–123	–123.1	–41.5	19.94	–42	20.22	–70.3	–18.97	32.99
	M1BT10	–120.1	–120.2	–45.1	15.39	–45	15.42	–81.3	–15.3	25.16
	M1BT15	–121.2	–121.8	–45.5	15.86	–45.3	15.83	–77.2	–15.83	25.82
ASW	**M3BT10**	–122.6	–122.6	–41.3	23.13	–40.9	23.34	–68.8	–22.4	38.07
	M3BT15	–123.1	–123.4	–40.9	24.24	–39.7	24.37	–69.2	–22.3	39.76
	M2BT10	–122.5	–122.9	–42	20.36	–41.9	20.15	–71.1	–19.1	32.87
	M2BT15	–122	–122	–41.4	17.59	–41.5	17.73	–72.5	–17.19	28.92
	M1BT10	–117.8	–118.5	–47.6	12.87	–47.7	12.62	–83.7	–11.89	20.59
	M1BT15	–119.4	–119	–51.7	10.37	–51.9	10.32	–92	–9.59	16.84

T_{g1} – glass transition temperature corresponding to the first heating run;

T_{g2} – glass transition temperature corresponding to the second heating run;

T_{t1} – melting temperature corresponding to the first heating run (h1);

T_{t2} – melting temperature corresponding to the second heating run (h2);

ΔHt_1 – enthalpy of the melting profile corresponding to the first heating run;

ΔHt_2 – enthalpy of the melting profile corresponding to the second heating run;

T_{cr} – crystallization temperature corresponding to the cooling run (c);

ΔH_{cr} – enthalpy of the crystallization profile;

χ_c – degree of cristalnity.

Table 3S. Relevant mechanical and dielectric characteristics for tested samples

Ageing Type	Characteristic	Sample					
		M3BT10	**M3BT15**	**M2BT10**	**M2BT15**	**M1BT10**	**M1BT15**
No ageing	σ, MPa	0.23	0.2	0.29	0.24	0.39	0.41
	ε, %	1150	374	594	455	113	151
	E, MPa	0.10	0.05	0.25	0.08	0.66	0.36
	ε' (at 10 Hz)	4.95	5.89	4.41	5.07	3.78	5.03
	ε'' (at 10 Hz)	0.036	0.017	0.068	0.075	0.160	0.038
	UTT,[a] KJ/m^3	17.46	5.35	9.88	6.79	2.78	3.90
ASW1/2 + UV ageing	σ, MPa	0.18	0.19	0.23	0.36	0.69	0.52
	ε, %	240	252	234	272	78	123
	E, MPa	0.23	0.22	0.25	0.31	0.9	0.58
	ε' (at 10 Hz)	3.57	4.23	3.72	3.9	3.57	3.76
	ε'' (at 10 Hz)	0.017	0.016	0.1	0.016	0.042	0.13
	UTT,[a] KJ/m^3	3.06	3.26	3.51	6.11	2.98	3.59
ASW ageing	σ, MPa	0.29	0.31	0.55	0.6	0.45	0.45
	ε, %	806	763	435	422	76	100
	E, MPa	0.025	0.16	0.40	0.40	0.60	0.72
	ε' (at 10 Hz)	10.55	5.61	13.07	4.87	3.26	4.37
	ε'' (at 10 Hz)	51.92	18.063	147.23	4.41	0.26	0.12
	UTT,[a] KJ/m^3	15.53	15.21	13.89	15.01	1.70	2.82

[a] Ultimate tensile toughness

Table 4S. Permanent set values for initial samples and after ageing

	Original samples		ASW1/2 + UV ageing		ASW ageing	
	Strain, %	E, MPa	Strain, %	E, MPa	Strain, %	E, MPa
M3BT10	24.0	0.178	23.1	0.244	19.4	0.232
M3BT15	25.0	0.248	22.4	0.242	19.0	0.200
M2BT10	15.0	0.247	22.8	0.266	22.5	0.357
M2BT15	23.5	0.165	23.4	0.358	22.7	0.378
M1BT10	12.3	0.658	23.6	1.070	26.5	0.566
M1BT15	19.7	0.491	25.1	0.626	26.0	0.673

Table 5S. Absorbed energy (kJ/m^3) by the original samples at 100% elongation for 5 stress-strain cycles

Cycles	**M3BT10**	**M3BT15**	**M2BT10**	**M2BT15**	**M1BT10**	**M1BT15**
1	0.45	0.85	0.71	0.74	2.06	2.18
2	0.43	0.73	0.67	0.66	1.89	1.95
3	0.43	0.71	0.66	0.64	1.88	1.92
4	0.42	0.70	0.65	0.64	1.88	1.91
5	0.42	0.70	0.65	0.63	1.87	1.90

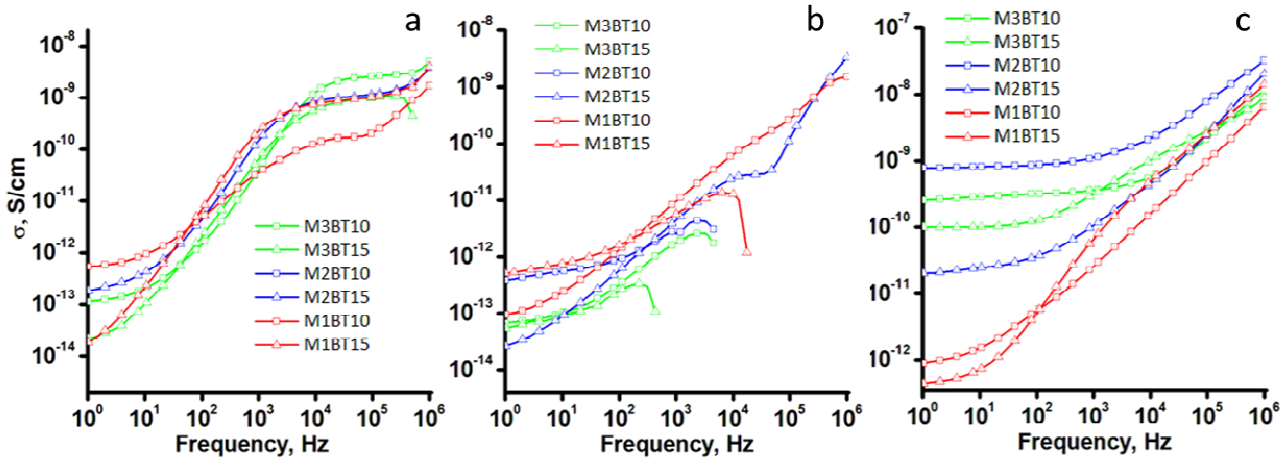


Fig. 6S. Conductivity curves for the samples: left - no ageing; middle - after ageing according to ASW1/2 + UV; right - after ageing according to ASW.