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## APPENDICES

### Appendix A FTIR Spectra of Shell Layer Polymer

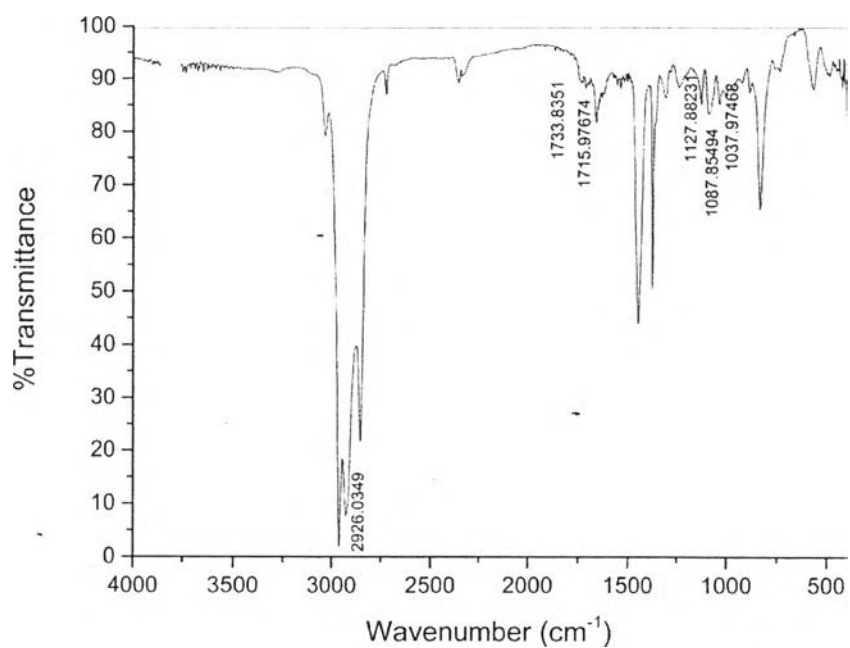


Figure A1 FTIR spectra of 307005.

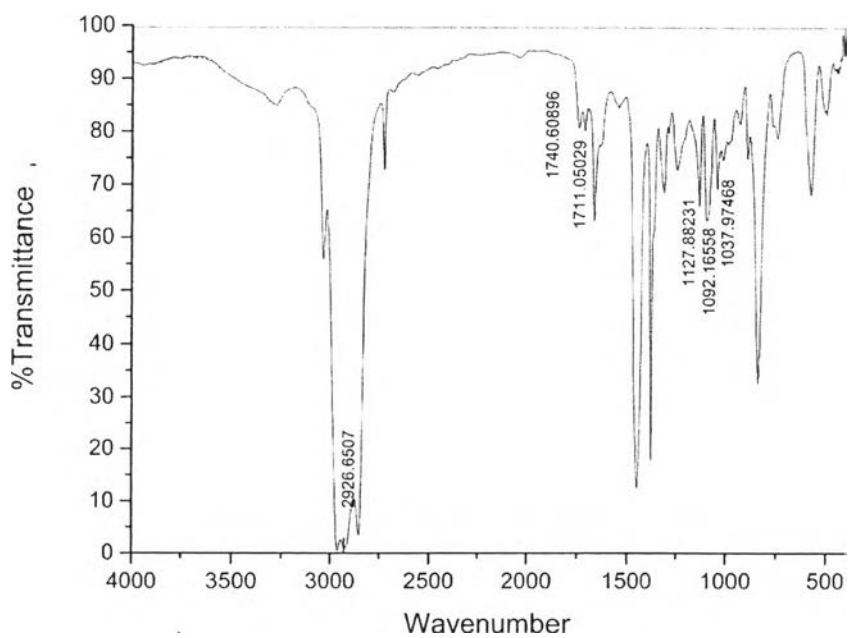


Figure A2 FTIR spectra of 406005.

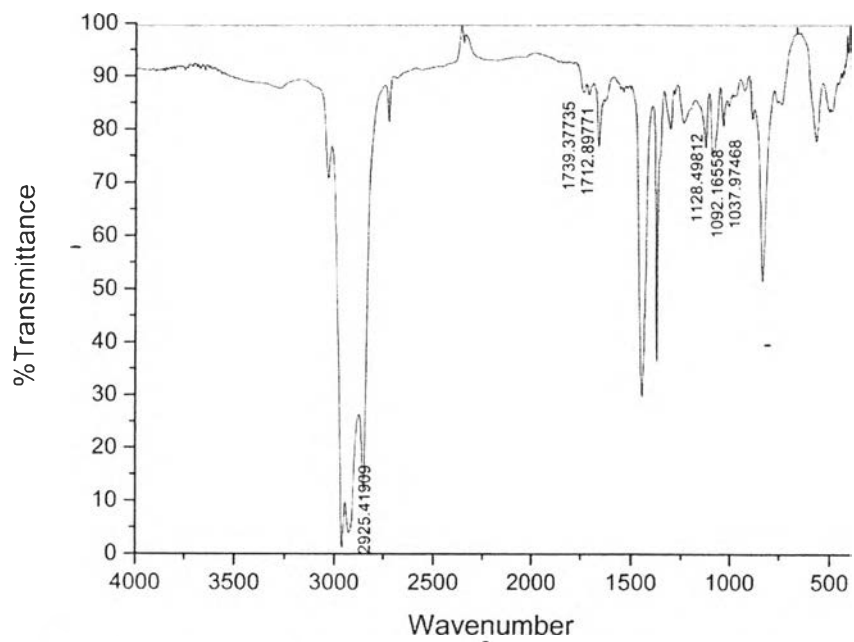


Figure A3 FTIR spectra of 505005.

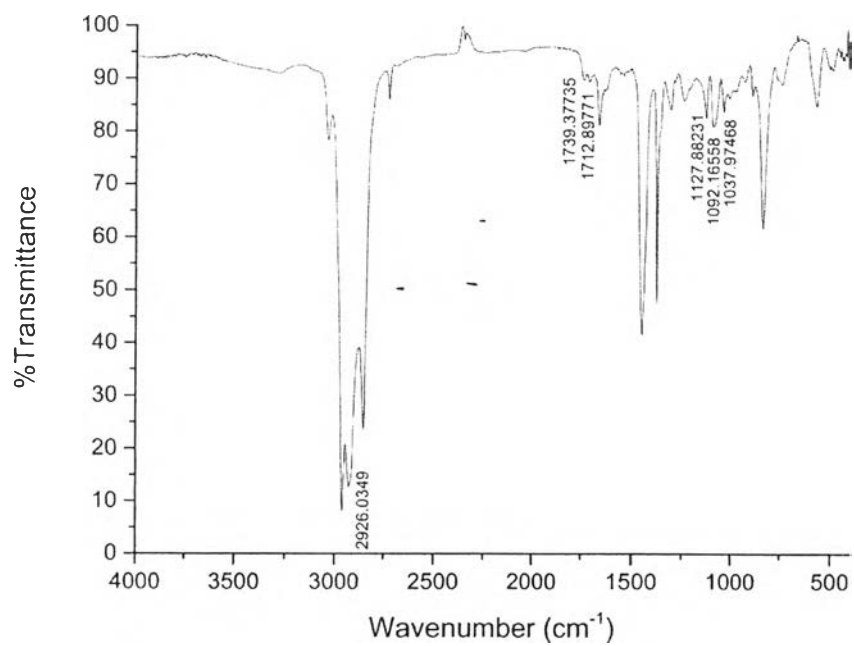


Figure A4 FTIR spectra of 505010.

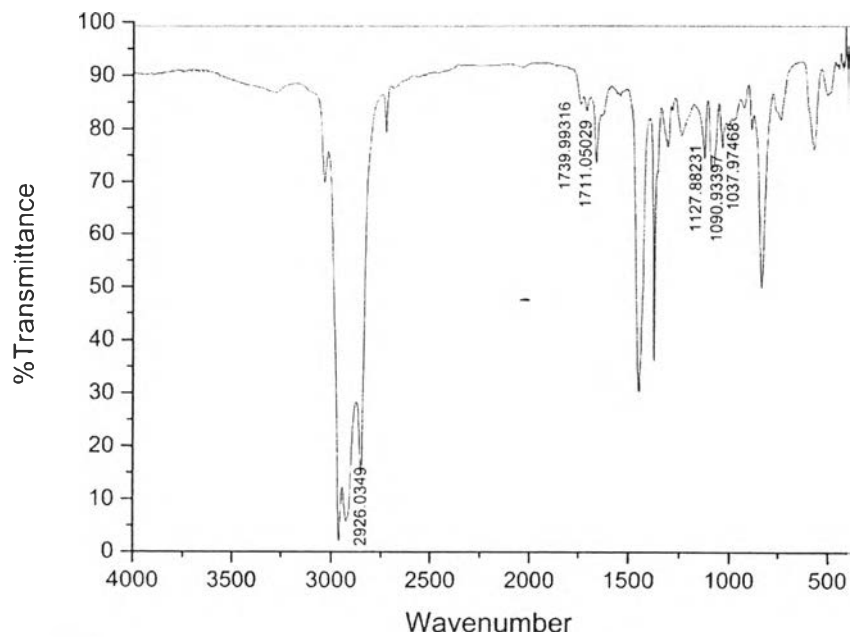


Figure A5 FTIR spectra of 505015.

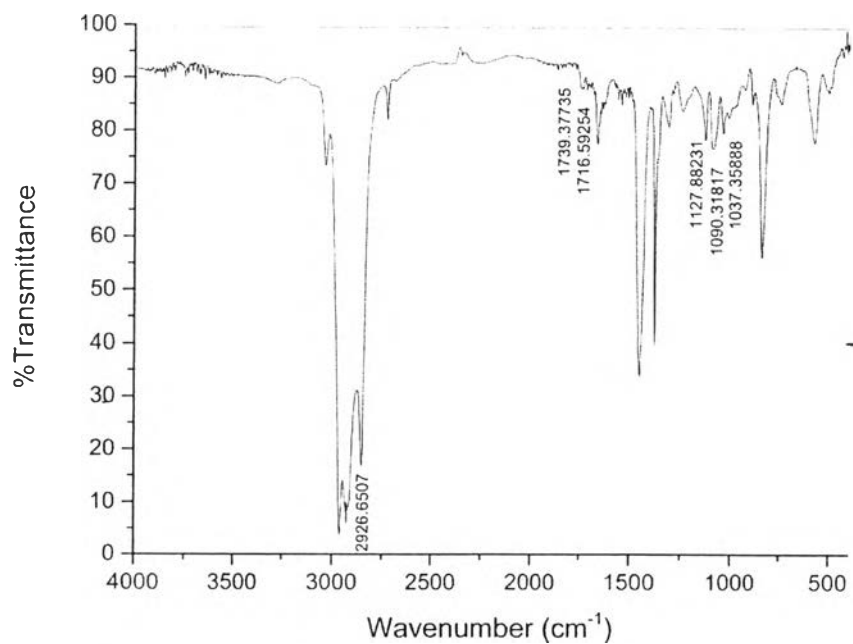


Figure A6 FTIR spectra of 505020.

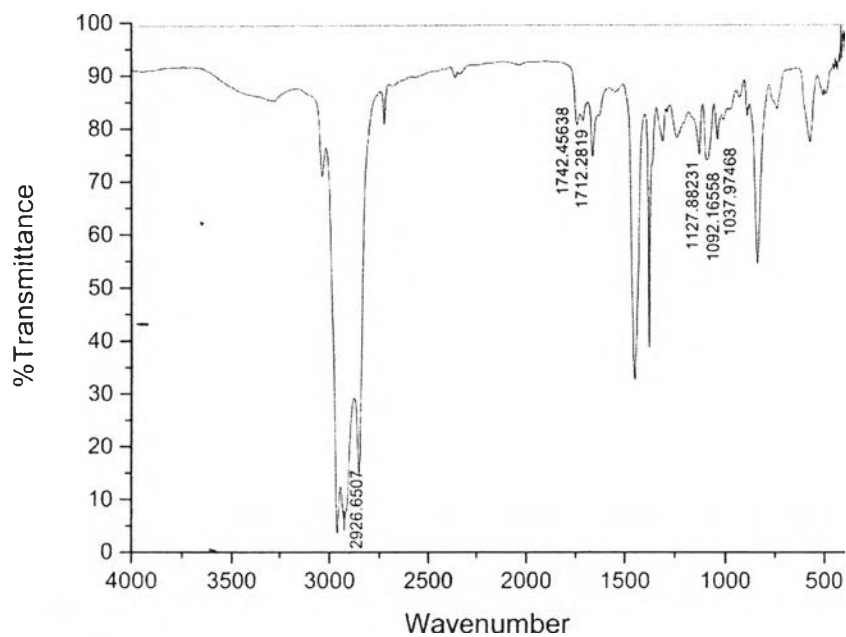


Figure A7 FTIR spectra of 604005.

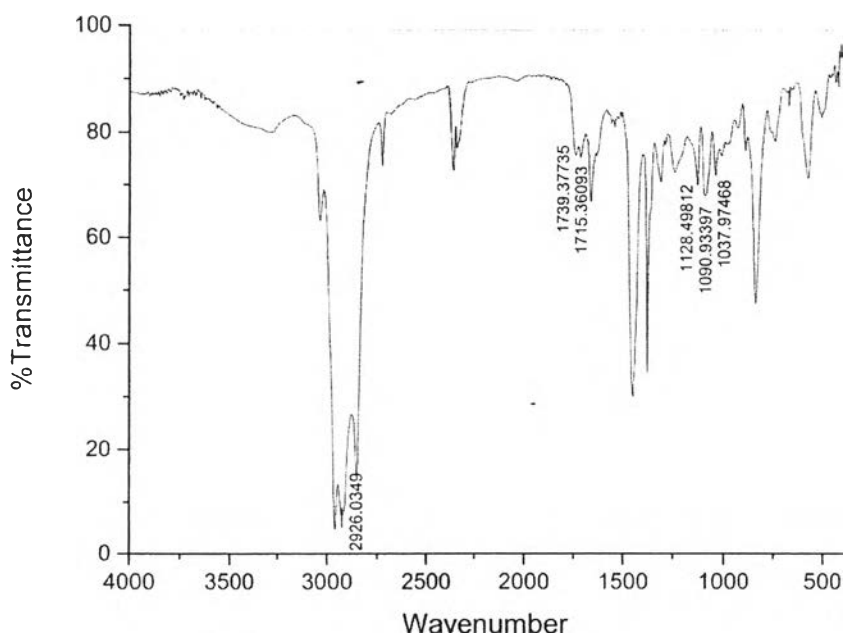
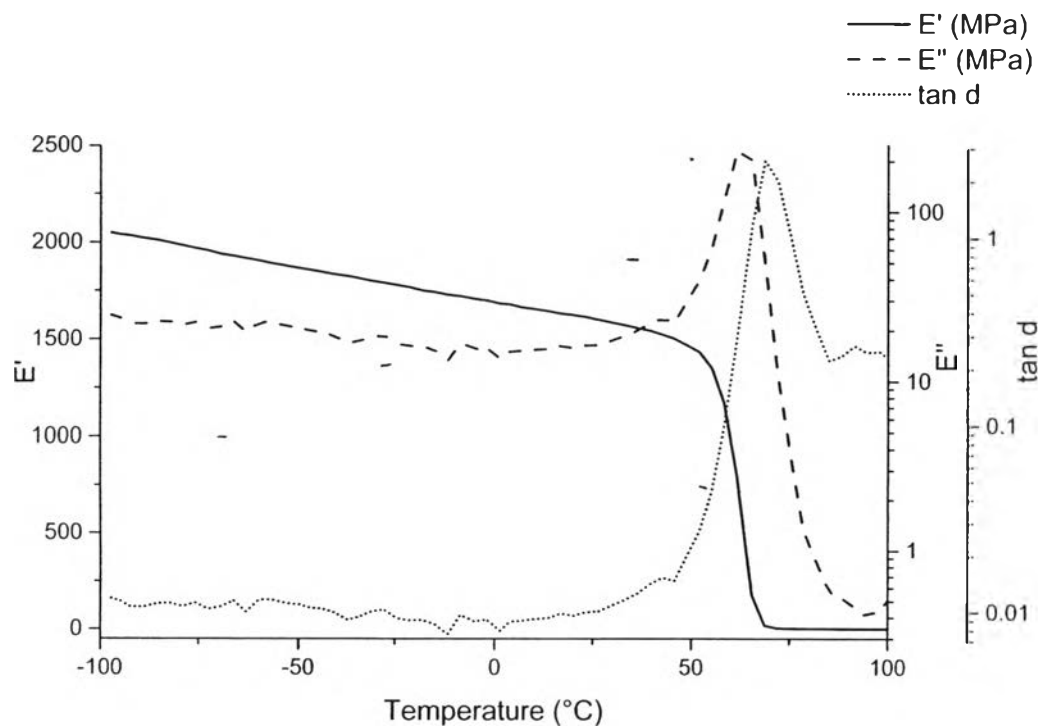


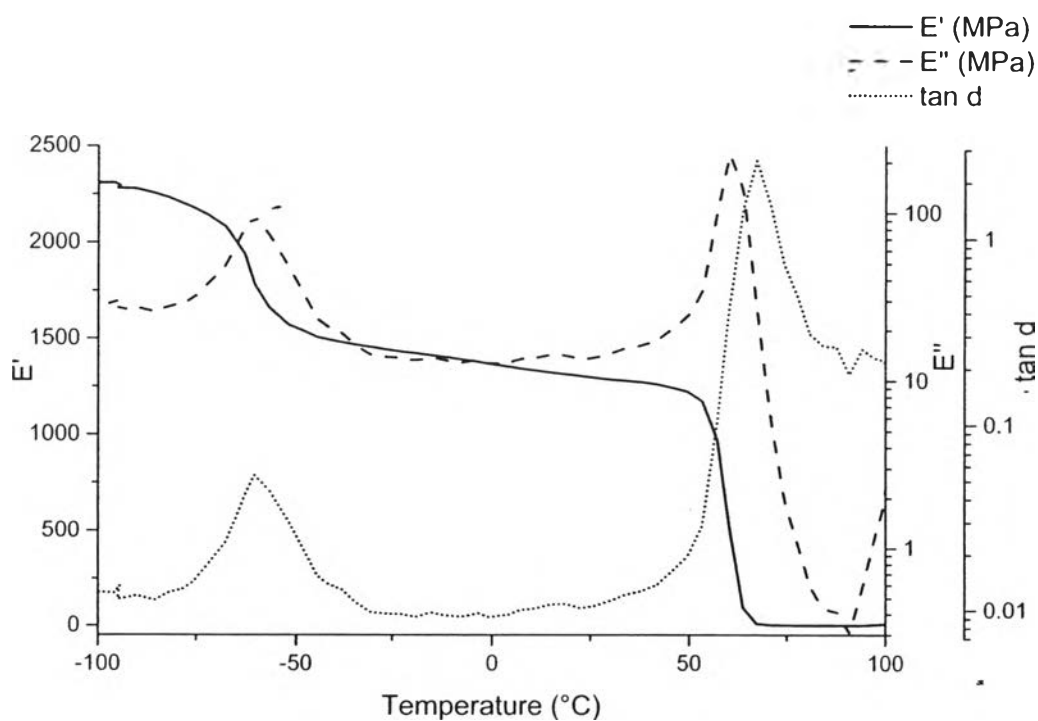
Figure A8 FTIR spectra of 703005.



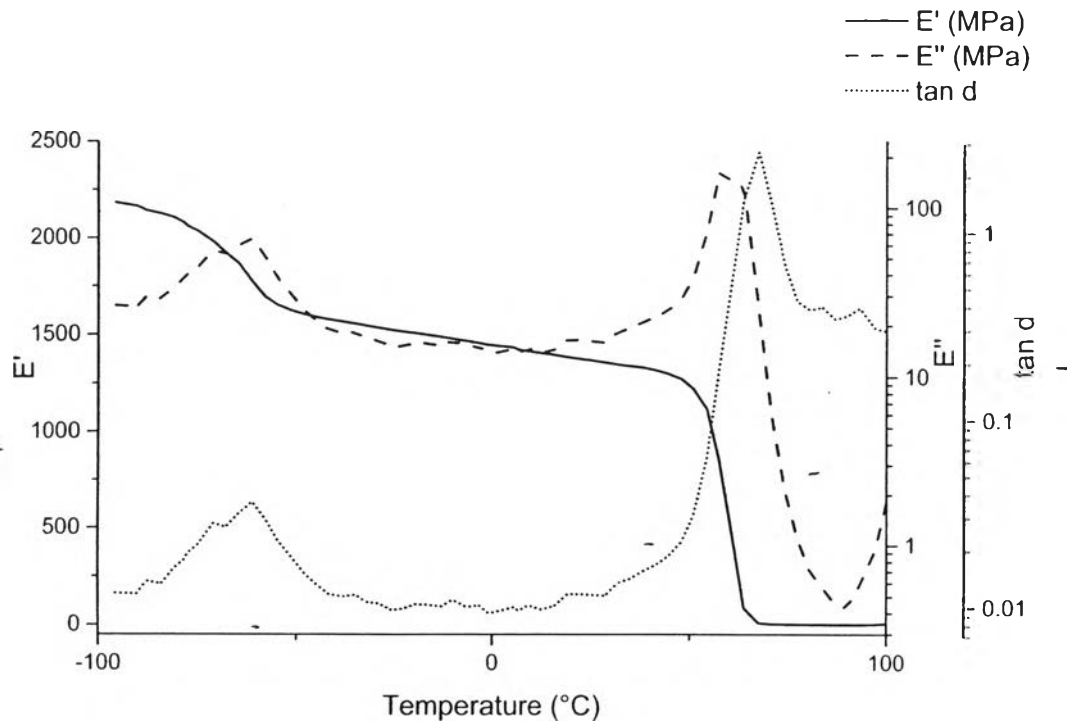
## Appendix B DMA Results of PLA/admicelled Rubber and PLA/admicelled Nanocomposites



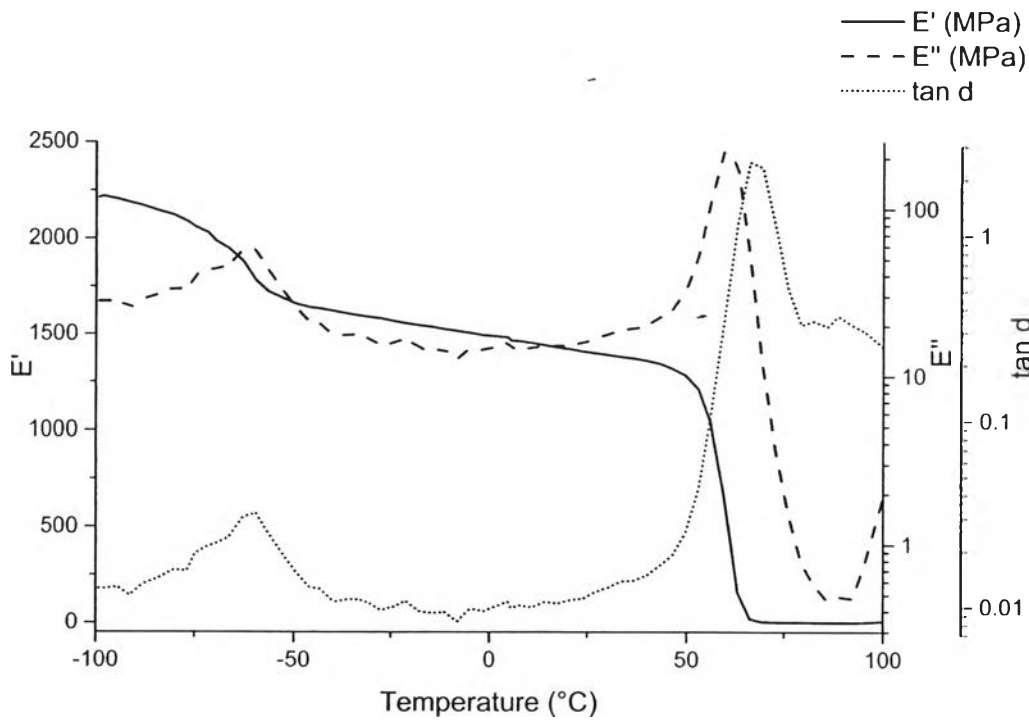
**Figure B1** DMA thermogram of neat PLA.



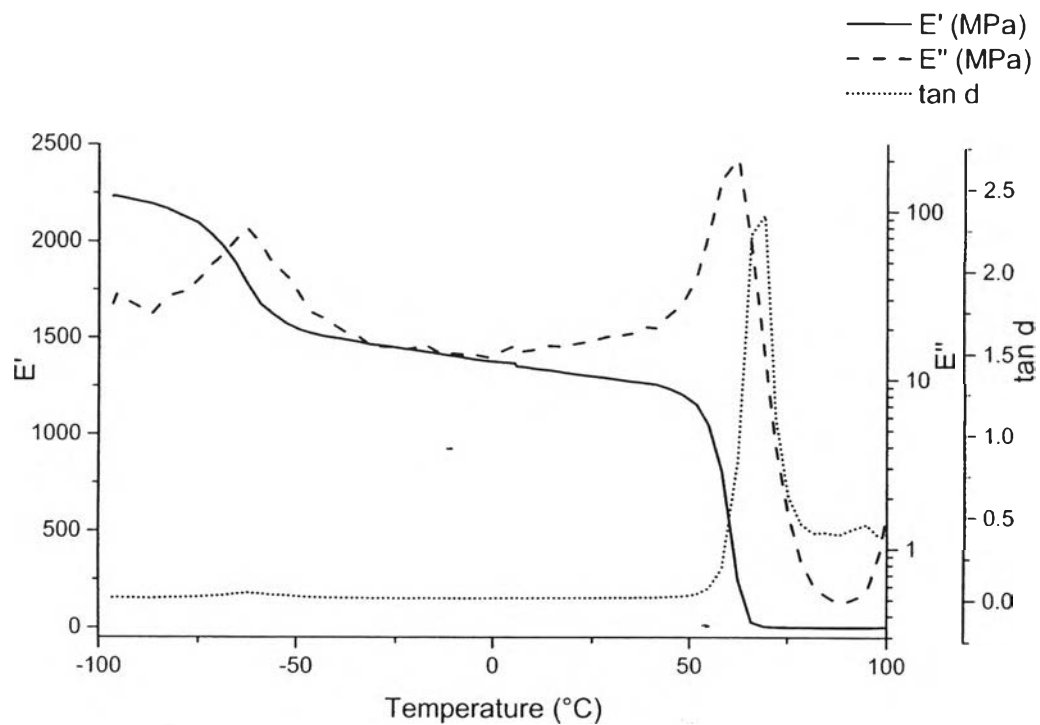
**Figure B2** DMA thermogram of PLA/NR blend with 10%wt NR.



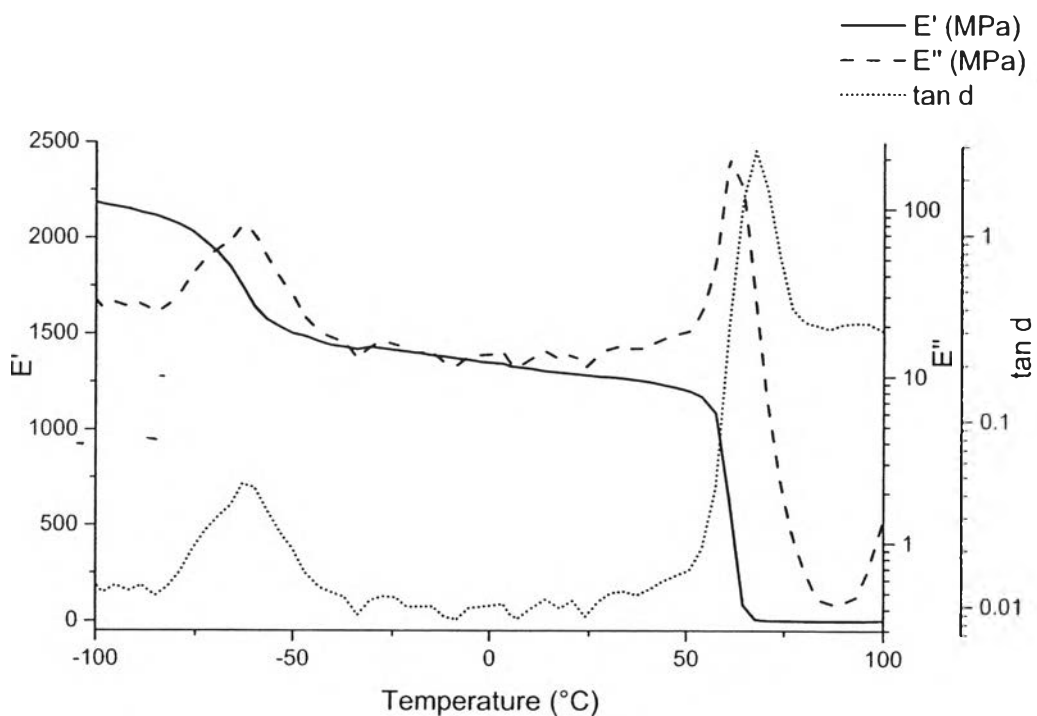
**Figure B3** DMA thermogram of PLA/307005 blend.



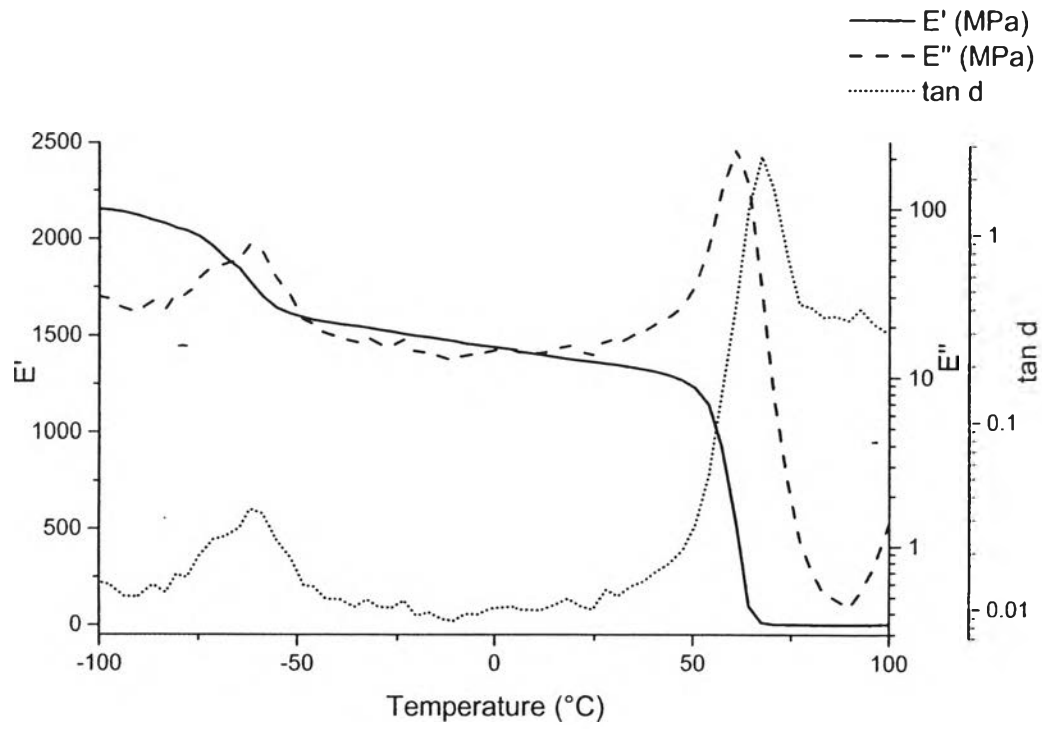
**Figure B4** DMA thermogram of PLA/406005 blend.



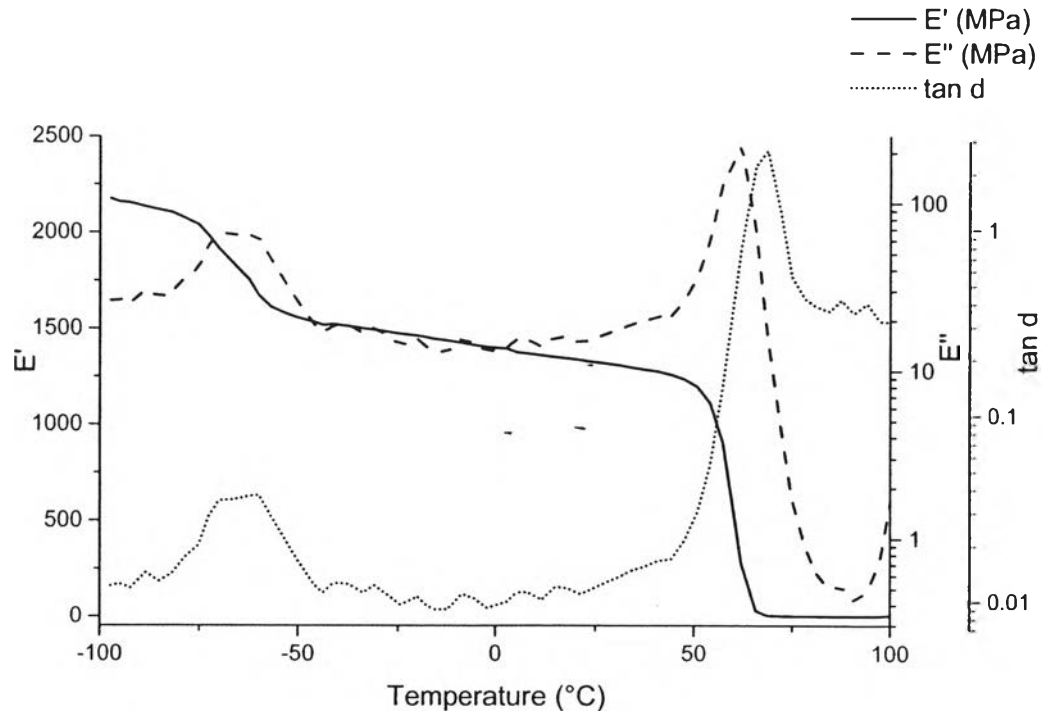
**Figure B5** DMA thermogram of PLA/505005 blend.



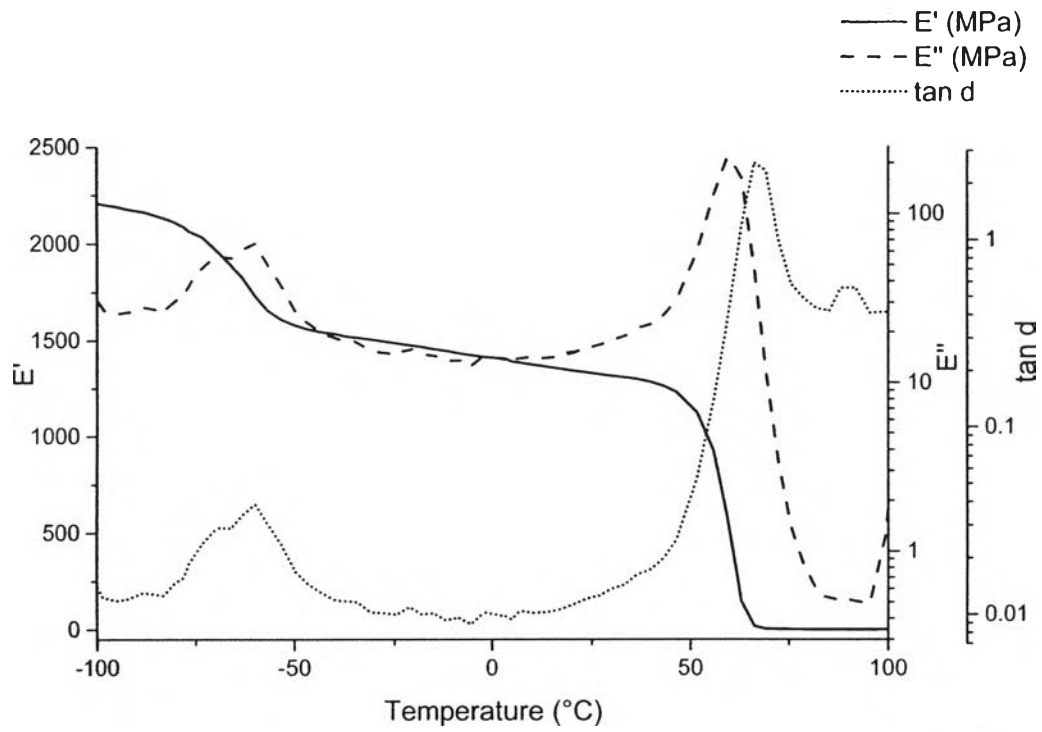
**Figure B6** DMA thermogram of PLA/505010 blend.



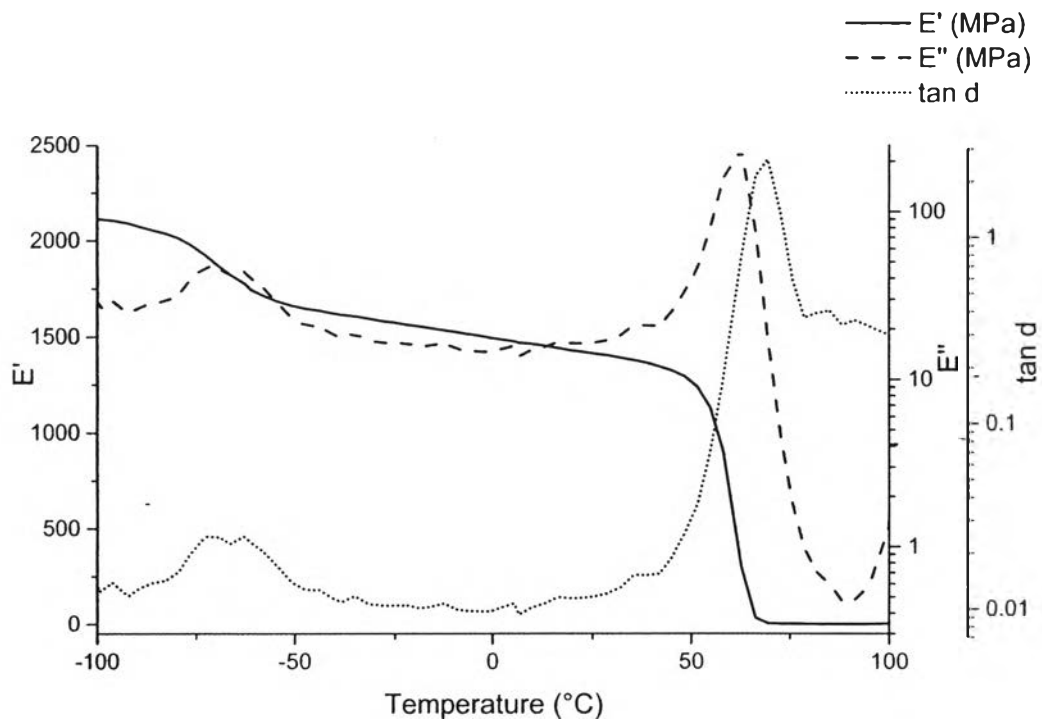
**Figure B7** DMA thermogram of PLA/505015 blend.



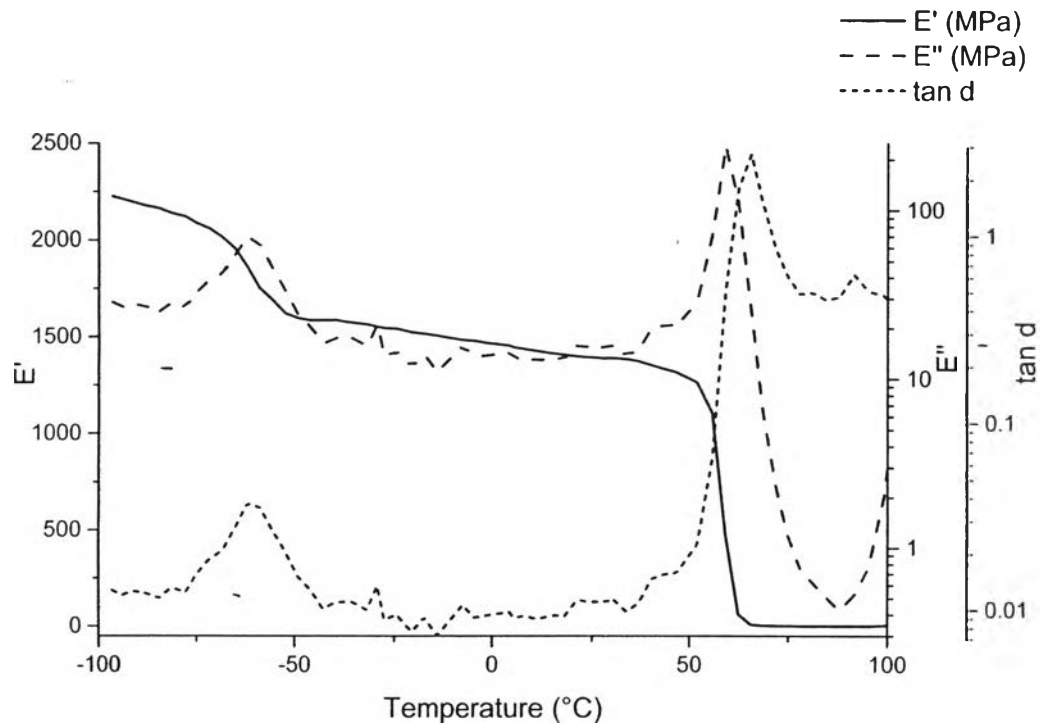
**Figure B8** DMA thermogram of PLA/505020 blend.



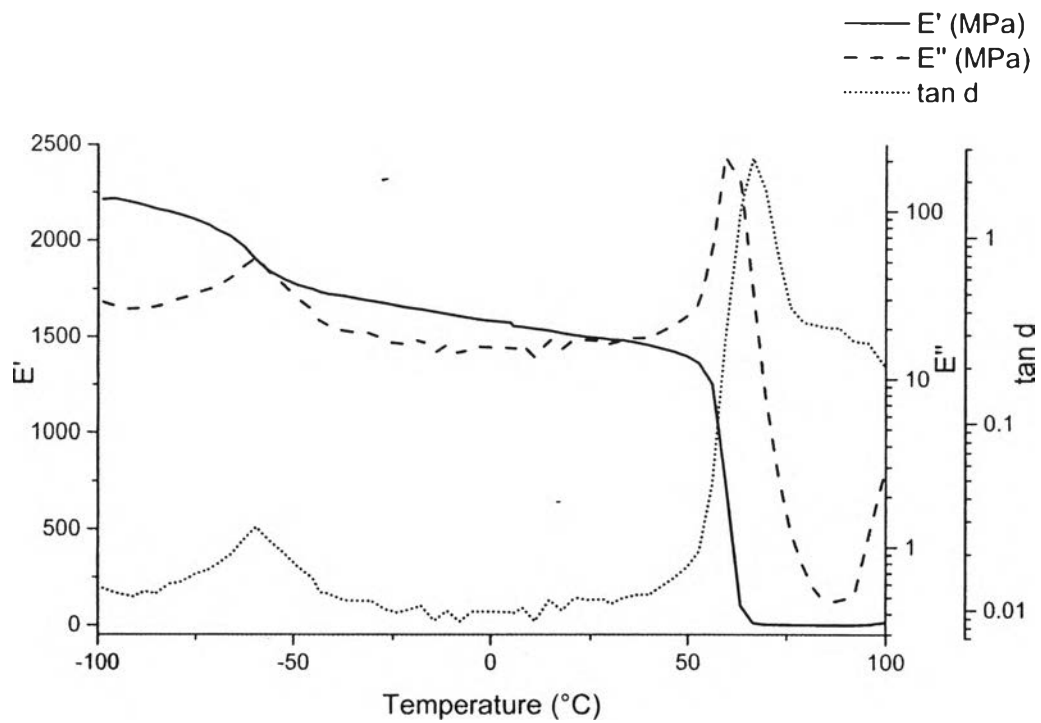
**Figure B9** DMA thermogram of PLA/604005 blend.



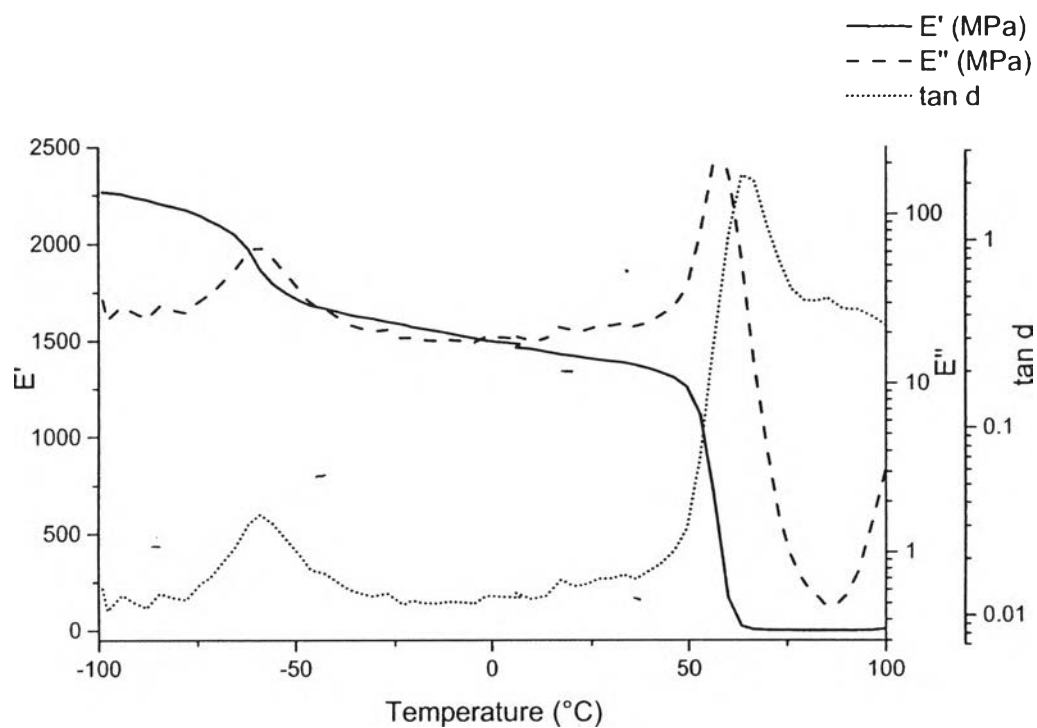
**Figure B10** DMA thermogram of PLA/703005 blend.



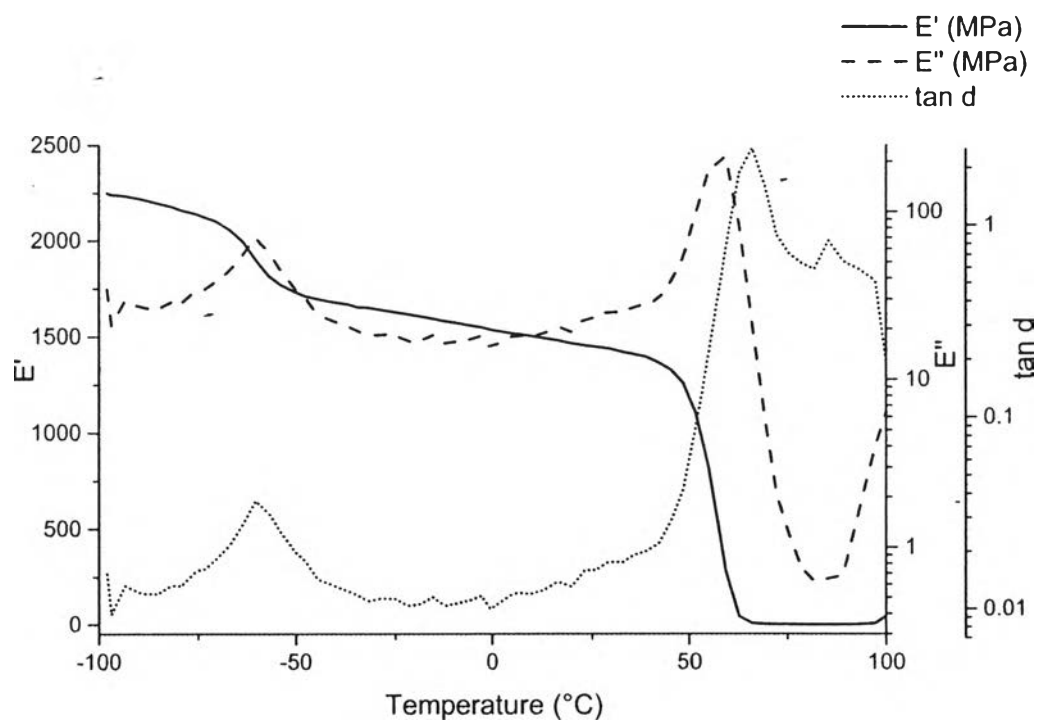
**Figure B11** DMA thermogram of PLA/505010 nanocomposites with 0.5% wt. clay.



**Figure B12** DMA thermogram of PLA/505010 nanocomposites with 1.0% wt. clay.



**Figure B13** DMA thermogram of PLA/505010 nanocomposites with 1.5% wt. clay.



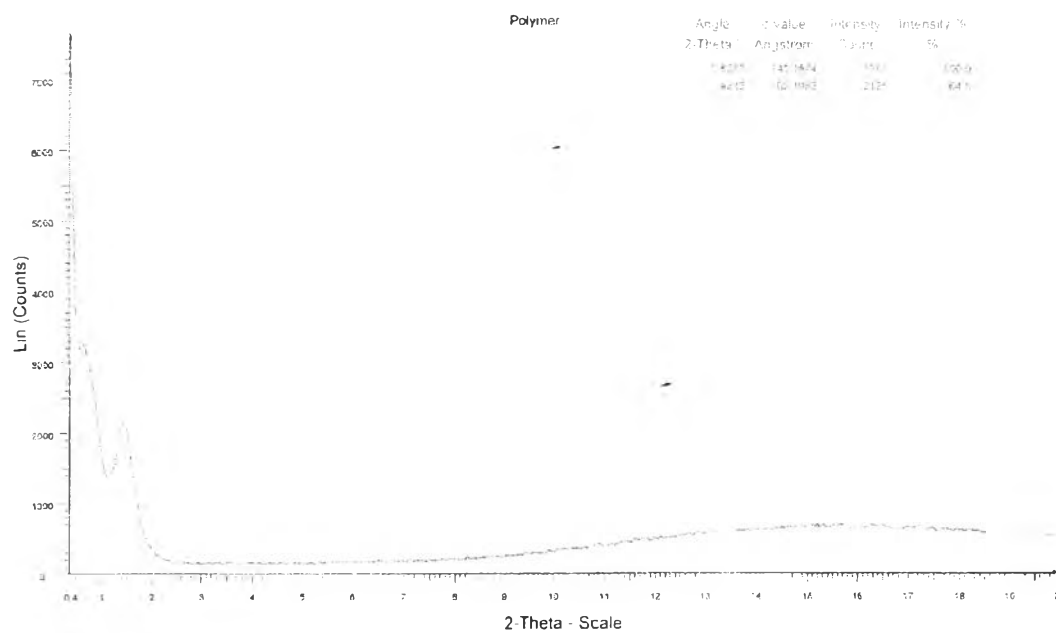
**Figure B14** DMA thermogram of PLA/505010 nanocomposites with 2.0% wt. clay.

## Appendix C XRD Result and Bragg's Law Calculation

Bragg's law equation	$n\lambda = 2d \sin \theta$
X-ray wavelngth	1.54 Angstrom

**Table C1** XRD data and calculated d-spacing.

Samples	2-Theta (°)	D-spacing (Angstrom)	Calculated D-spacing (Angstrom)
Bentonite	6.2841	14.0535	14.04811214
Modified Bentonite	2.2367	39.4667	39.45147023
PLA+505010+0.5	0.7871	112.1434	112.1029021
PLA+505010+1.0	0.6712	131.5149	131.4600789
PLA+505010+1.5	-	-	-
PLA+505010+2.0	0.4722	186.9226	186.8609703



**Figure C1** XRD pattern of neat PLA.



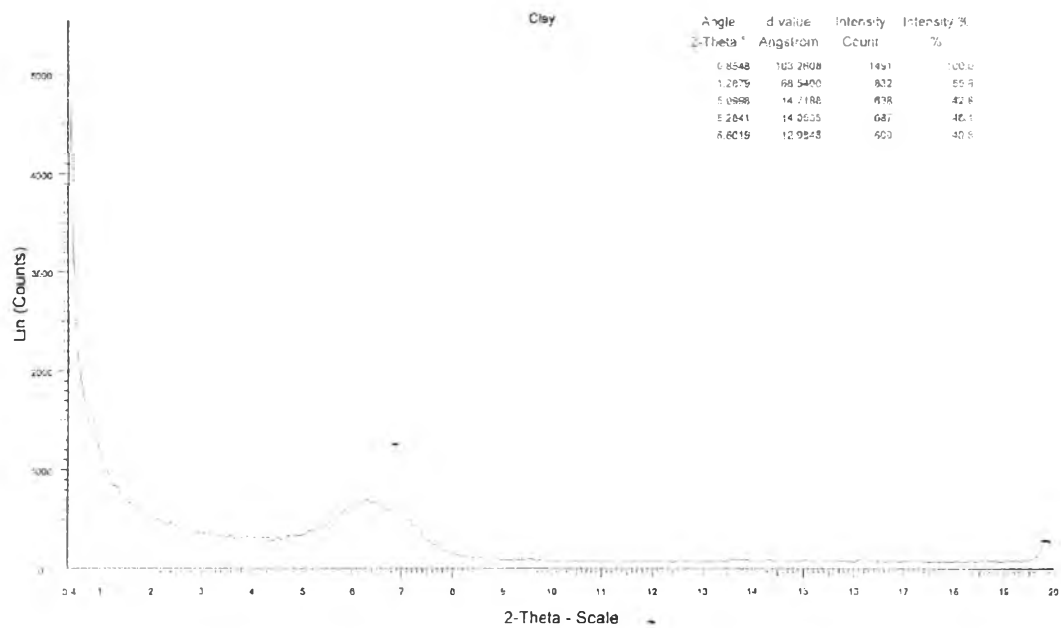


Figure C2 XRD pattern of bentonite.

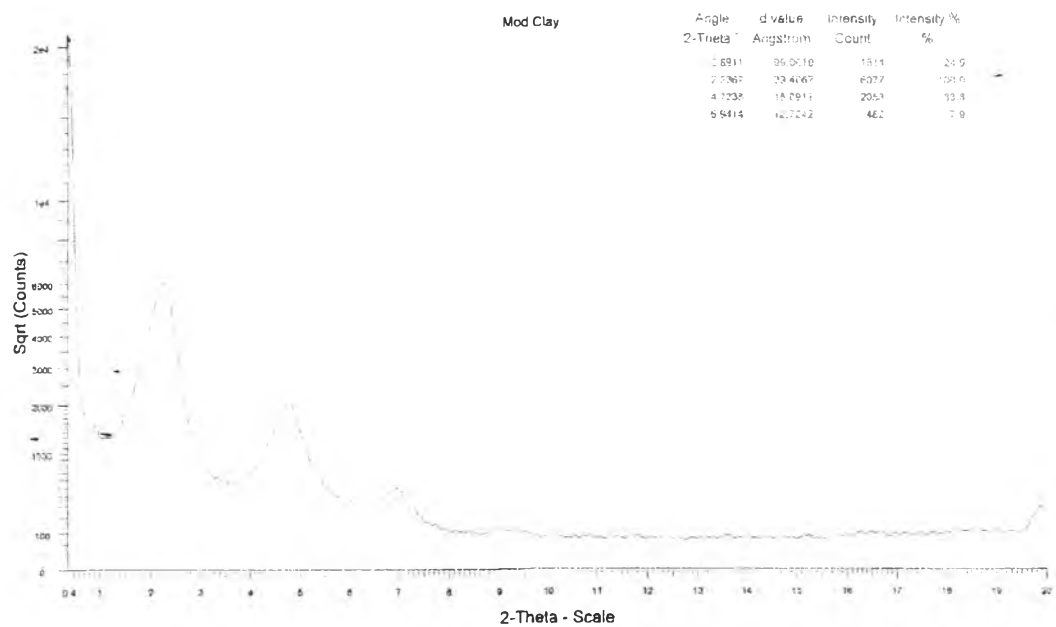


Figure C3 XRD pattern of modified bentonite.

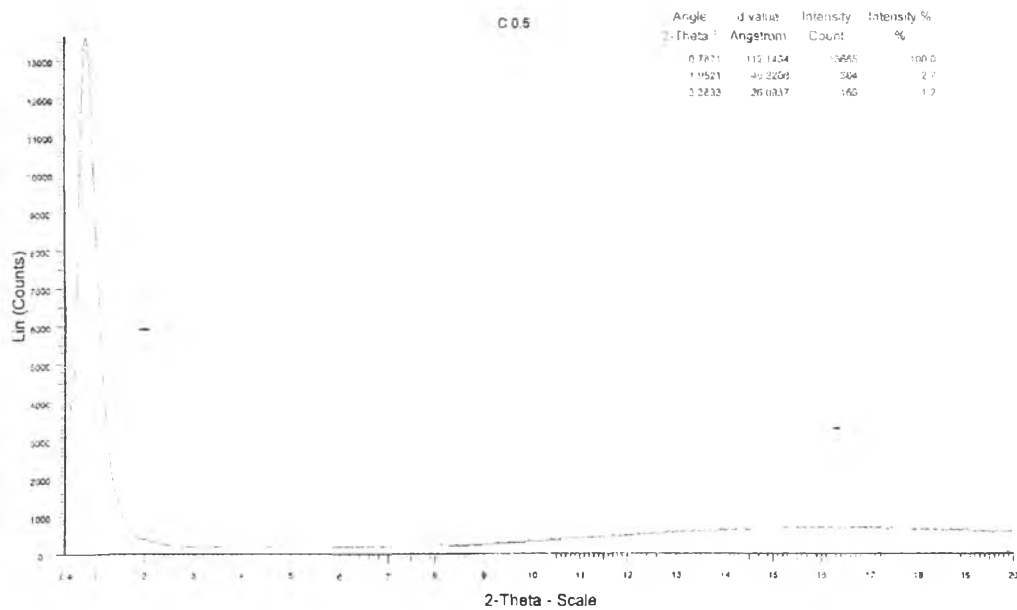


Figure C4 XRD pattern of PLA+505010 with clay 0.5%wt.

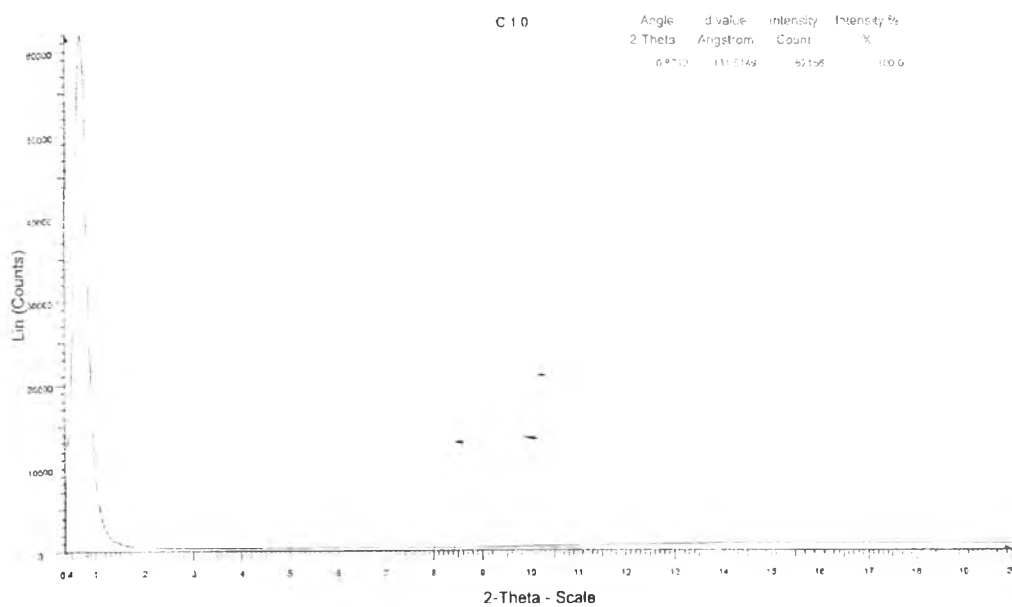


Figure C5 XRD pattern of PLA+505010 with clay 1.0%wt.

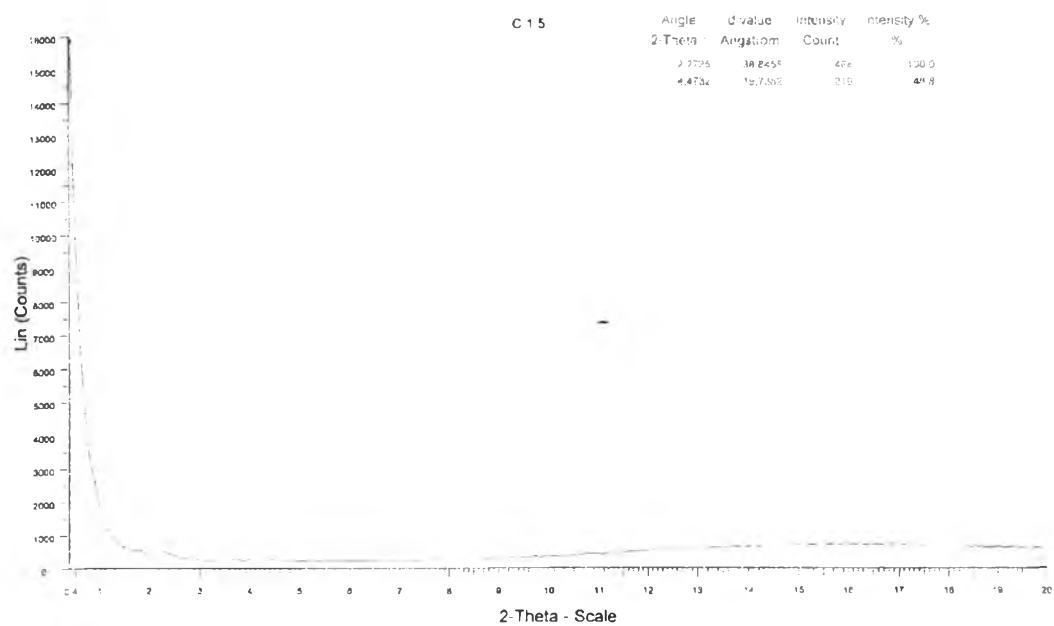


Figure C5 XRD pattern of PLA+505010 with clay 1.5%wt.

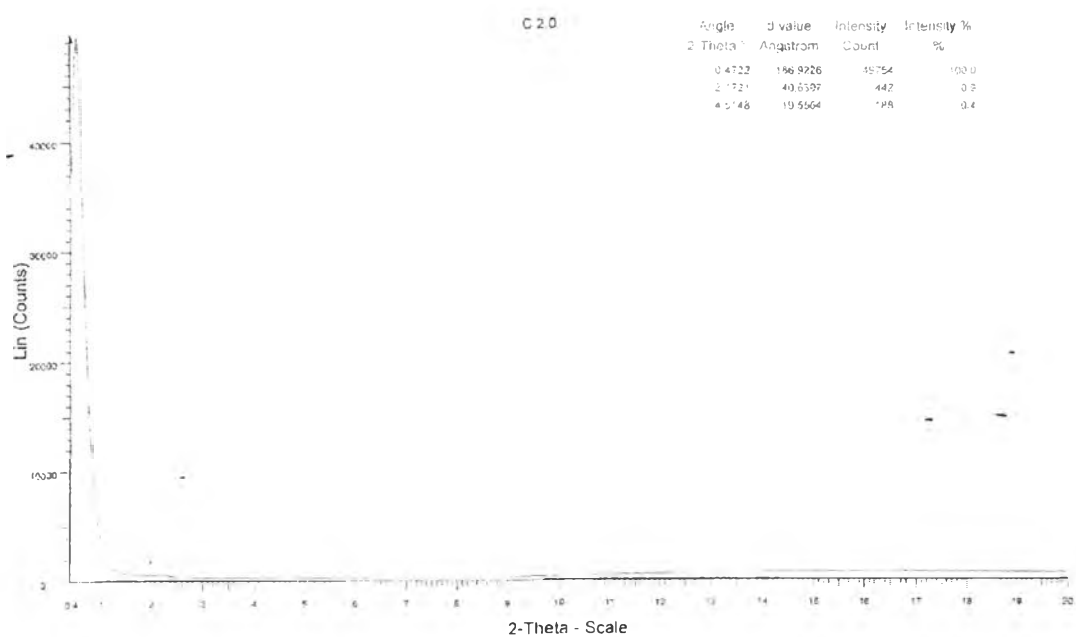


Figure C5 XRD pattern of PLA+505010 with clay 2.0%wt.

## Appendix D Impact Testing Results

**Table D1** Impact strength from testing and standard deviations.

Specimens	Impact force (J/m)					Average	SD
	1	2	3	4	5		
Neat PLA	58.7	59.1	60.8	59.1	58.5	59.24	0.909945
PLA+307005	62	61.2	61.6	61.6	61.6	61.6	0.282843
PLA+406005	60.5	61.6	61.2	61.6	62.7	61.52	0.798123
PLA+505005	61.6	61.8	61.8	61.6	61.8	61.72	0.109545
PLA+505010	61	61.6	60.8	61.4	61.6	61.28	0.363318
PLA+505010+0.5	44.5	44.8	44.8	44.8	45.2	44.82	0.248998
PLA+505010+1.0	44.6	44.3	44.8	44.8	44.6	44.62	0.204939
PLA+505010+1.5	44.6	44.5	44.5	44.5	44.3	44.48	0.109545
PLA+505010+2.0	43.9	44.2	44.2	44.3	44.2	44.16	0.151658
PLA+505015	77.9	72.6	76.6	76.3	76.9	76.06	2.025586
PLA+505020	71.8	70.5	70	70	69.3	70.32	0.931128
PLA+604005	61.4	61.2	61.6	61.2	61.4	61.36	0.167332
PLA+703005	61.6	61.2	60.8	61.8	60.8	61.24	0.45607

## Appendix E DSC Results

**Table E1** 1<sup>st</sup> heating results with 3°C/min heating rate.

Sample	Weight mg	T <sub>g</sub> °C	T <sub>c</sub> °C	ΔH <sub>c</sub> J/g	T <sub>m</sub> °C	ΔH <sub>m</sub> J/g	%Crystallinity
neat PLA	8.73	56.79	98.44	45.78	155.15	-46.13	0.0039
PLA/NR	8.31	56.15	91.62	42.01	154.3	-42.10	0.0010
PLA+307005	8.92	54.65	91.17	40.56	154.64	-40.75	0.0021
PLA+406005	7.57	53.4	88.7	41.70	153.69	-41.74	0.0005
PLA+505005	7.95	54.47	90.06	41.97	154.48	-42.04	0.0007
PLA+505010	8.66	54.76	87.89	40.24	154.13	-40.34	0.0011
PLA+505015	8.18	54.73	87.22	44.26	154.06	-44.55	0.0032
PLA+505020	7.65	54.78	86.68	41.67	155.43	-43.57	0.0208
PLA+604005	7.36	54.26	86.4	44.20	154.76	-44.38	0.0019
PLA+703005	8.96	54.95	87.29	46.03	153.62	-46.47	0.0048
PLA+505010+0.5clay	7.92	50.41	85.93	51.71	152.67	-53.75	0.0224
PLA+505010+1.0clay	8.57	52.25	89.12	42.49	155.99	-45.56	0.0338
PLA+505010+1.5clay	9.04	49.27	84.48	51.17	153.4	-51.32	0.0017
PLA+505010+2.0clay	7.78	51.02	86.54	57.41	153.75	-57.55	0.0016

**Table E2** 2<sup>nd</sup> heating results with 3°C/min heating rate.

Sample	Weight mg	T <sub>g</sub> °C	T <sub>c</sub> °C	ΔH <sub>c</sub> J/g	T <sub>m</sub> °C	ΔH <sub>m</sub> J/g	%Crystallinity
neat PLA	8.73	56.67	101.82	52.85	155.94	-52.96	0.0012
PLA/NR	8.31	52.34	93.61	54.81	154.39	-55.00	0.0021
PLA+307005	8.92	48.37	95.58	47.98	152.49	-58.01	0.1102
PLA+406005	7.57	46.55	95.75	51.97	153.35	-56.62	0.0511
PLA+505005	7.95	54.96	106.42	48.23	155.08	-48.31	0.0009
PLA+505010	8.66	46.6	91.88	52.53	150.77	-54.23	0.0187
PLA+505015	8.18	48.64	93.59	46.36	150.48	-57.35	0.1207
PLA+505020	7.65	53.4	102.48	51.58	154.98	-53.39	0.0199
PLA+604005	7.36	43.64	86.33	18.99	147.7	-60.05	0.4512
PLA+703005	8.96	49.93	93.88	58.24	152.56	-65.66	0.0815
PLA+505010+0.5clay	7.92	49.01	98.51	58.10	150.33	-59.53	0.0157
PLA+505010+1.0clay	8.57	53.66	108.03	52.05	155.09	-52.21	0.0018
PLA+505010+1.5clay	9.04	42.66	90.66	25.73	145.72	-54.17	0.3126
PLA+505010+2.0clay	7.78	44.61	90.89	16.46	147.79	-65.55	0.5395

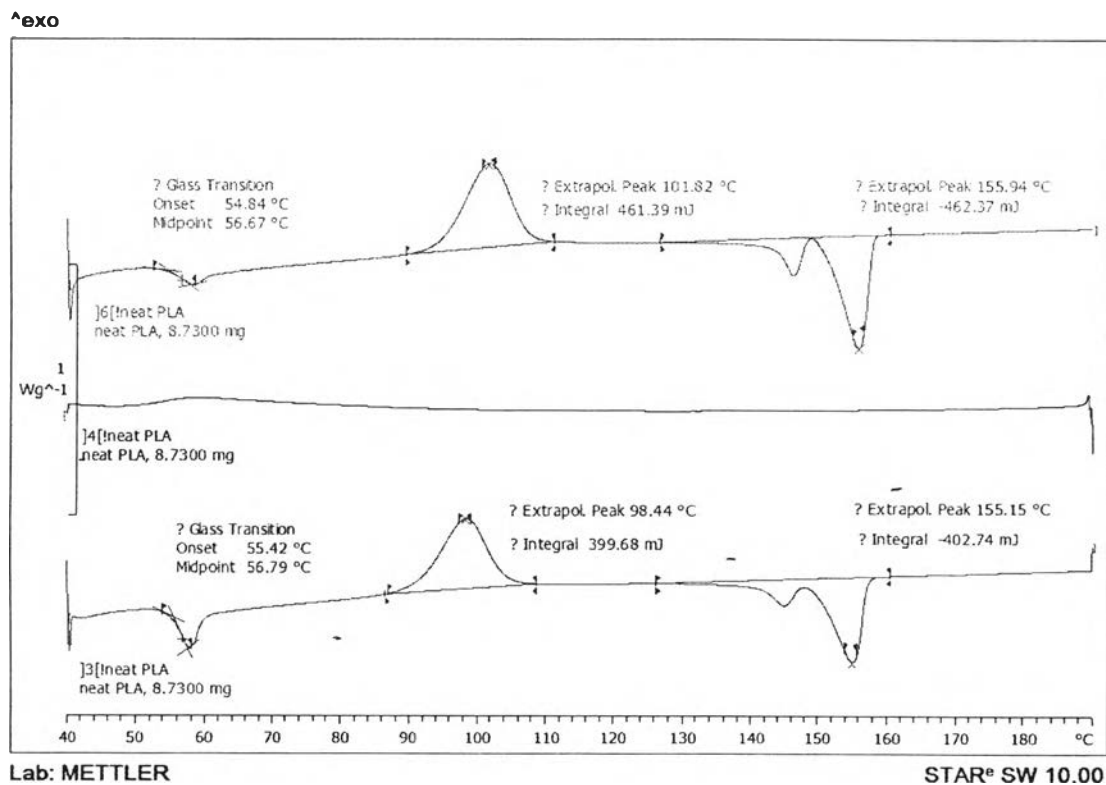


Figure E1 DCS Thermogram of neat PLA

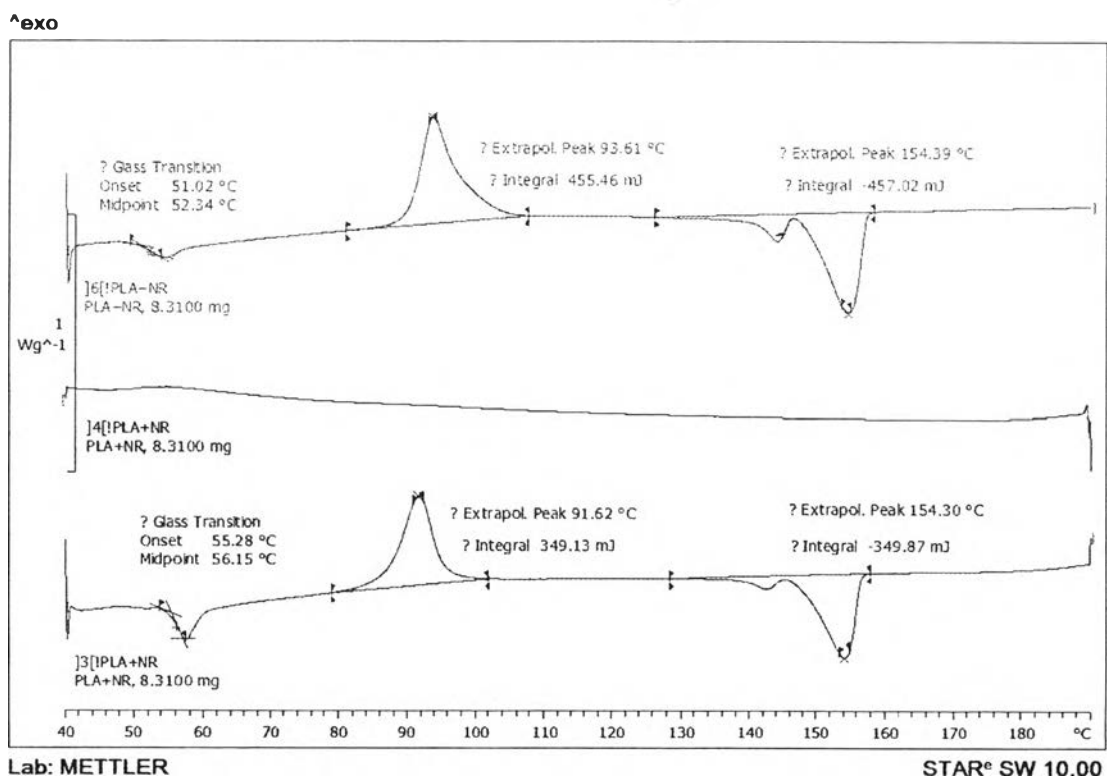


Figure E2 DCS Thermogram of PLA/NR blends with 10%wt NR

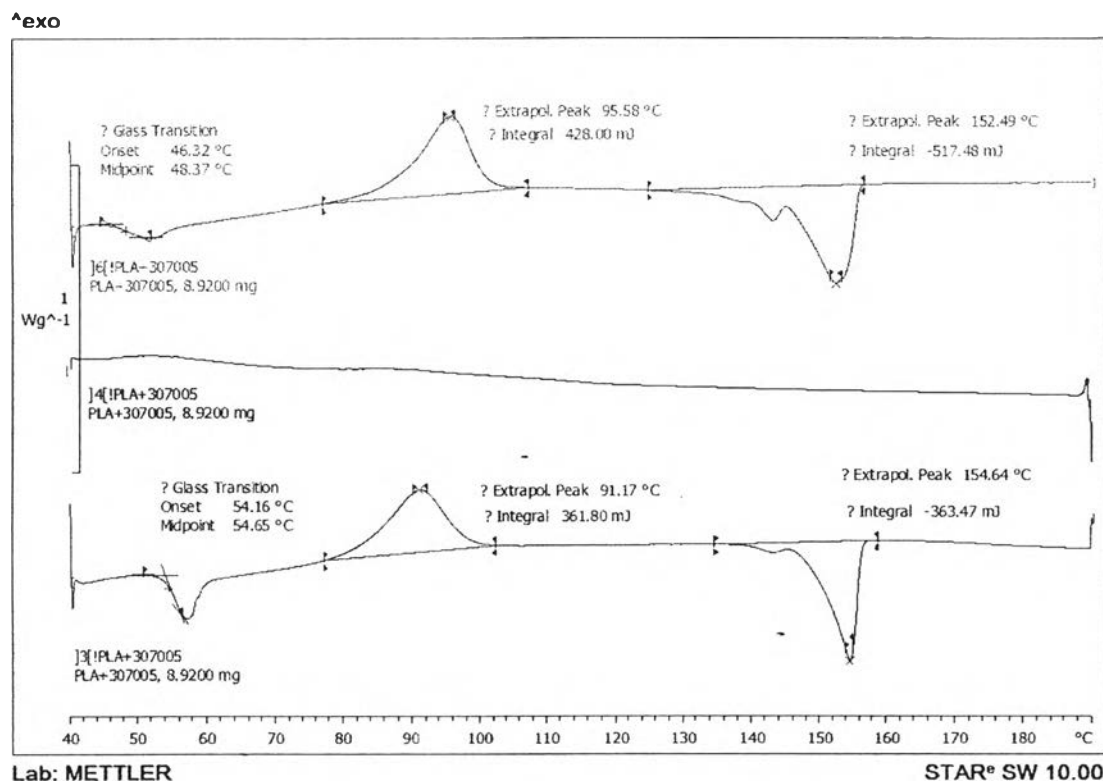


Figure E3 DCS Thermogram of PLA/307005 blend.

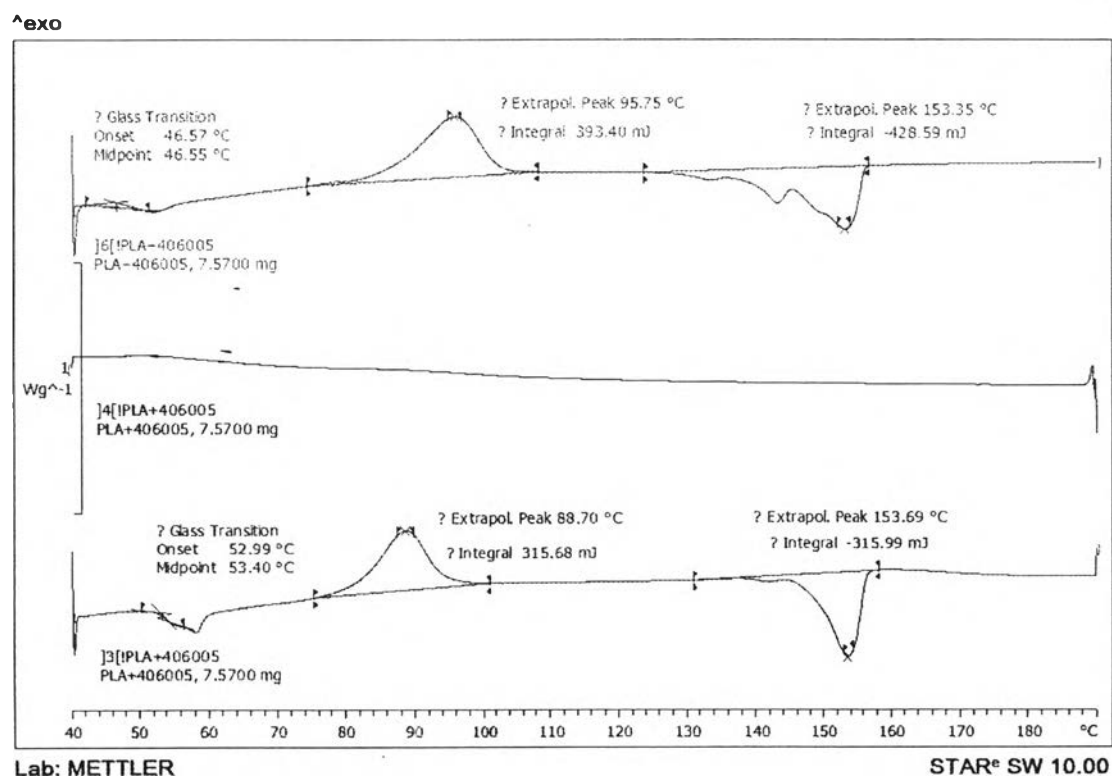


Figure E4 DCS Thermogram of PLA/406005 blend.

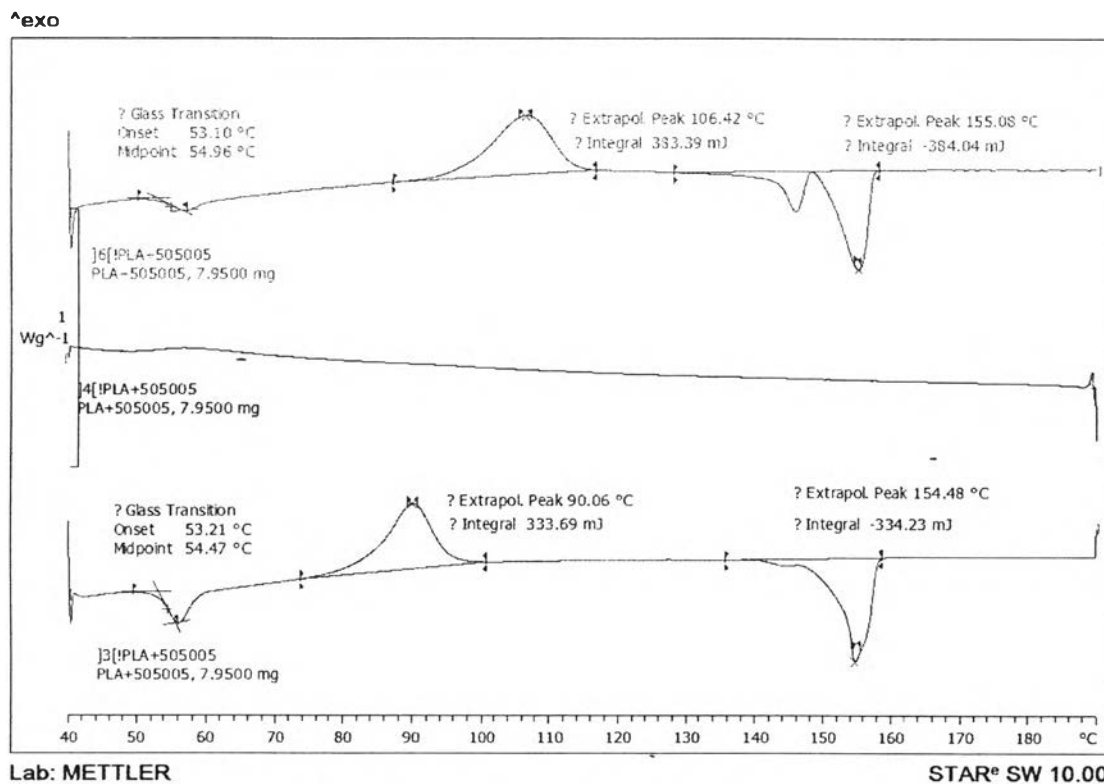


Figure E5 DCS Thermogram of PLA/505005 blend.

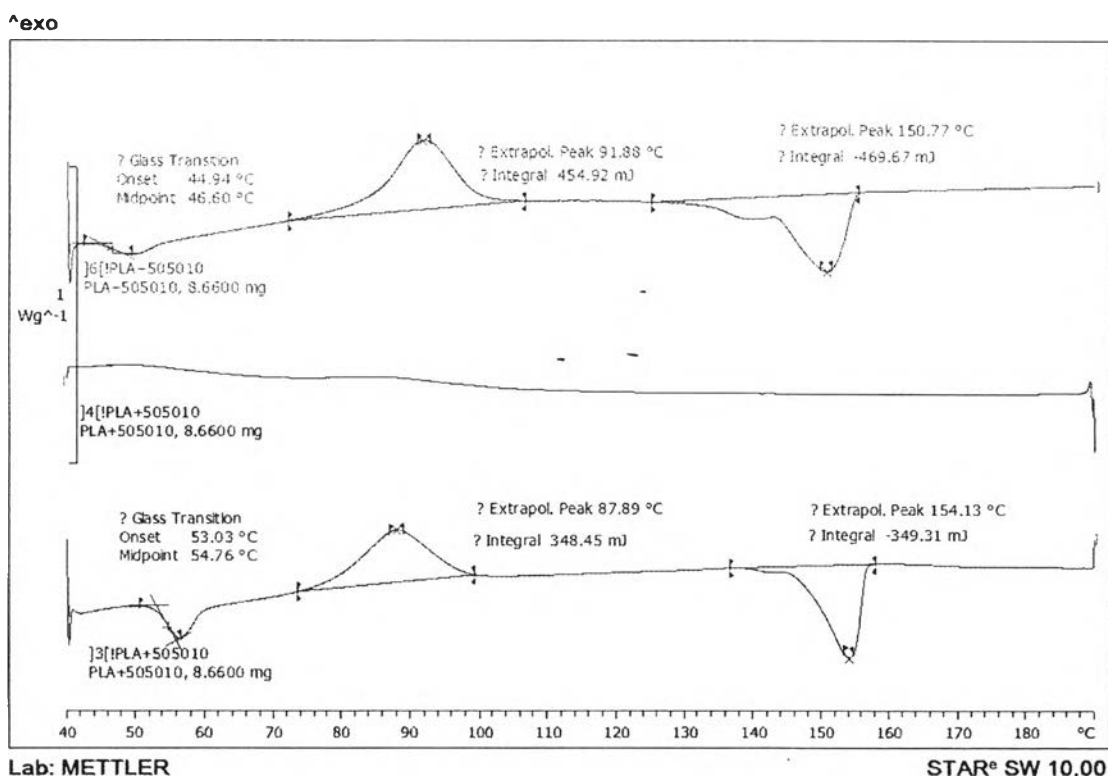


Figure E6 DCS Thermogram of PLA/505010 blend.



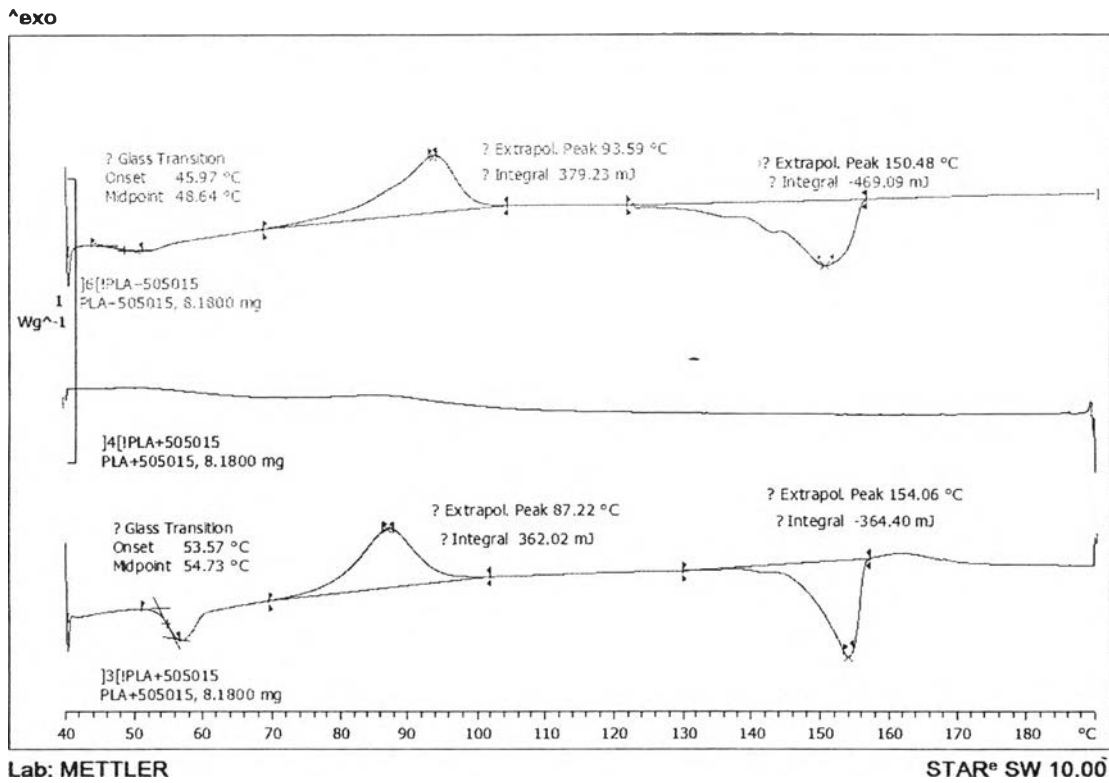


Figure E7 DCS Thermogram of PLA/505015 blend.

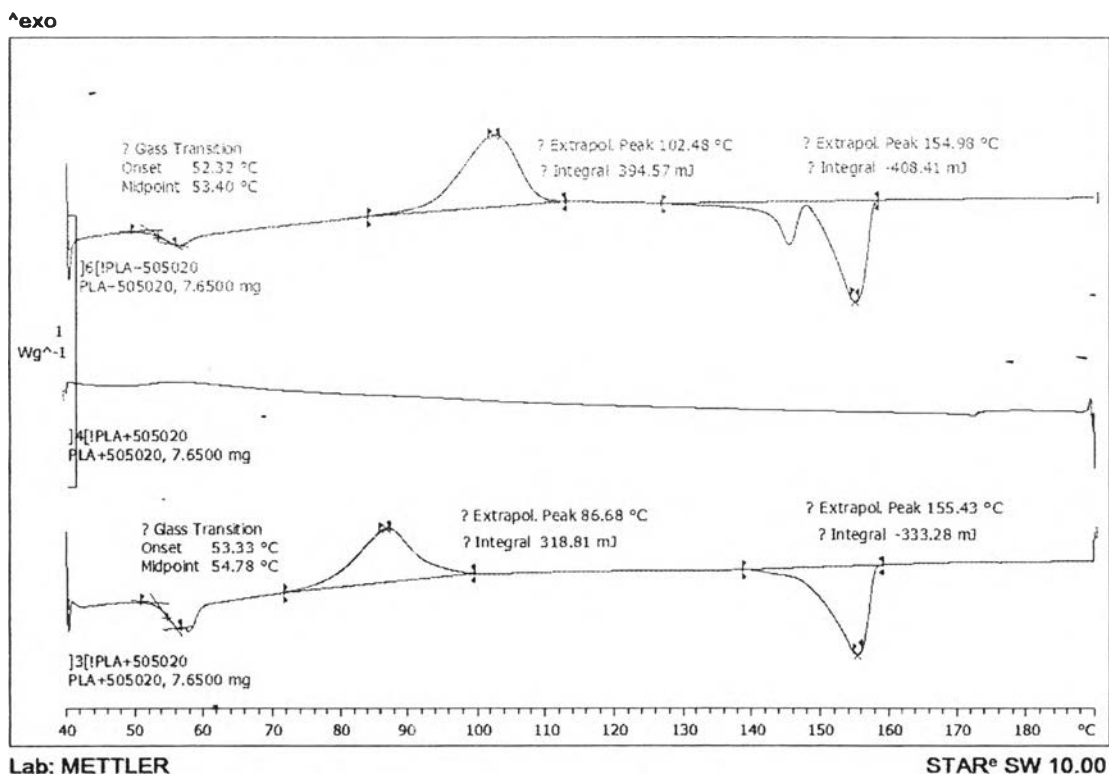


Figure E8 DCS Thermogram of PLA/505020 blend.

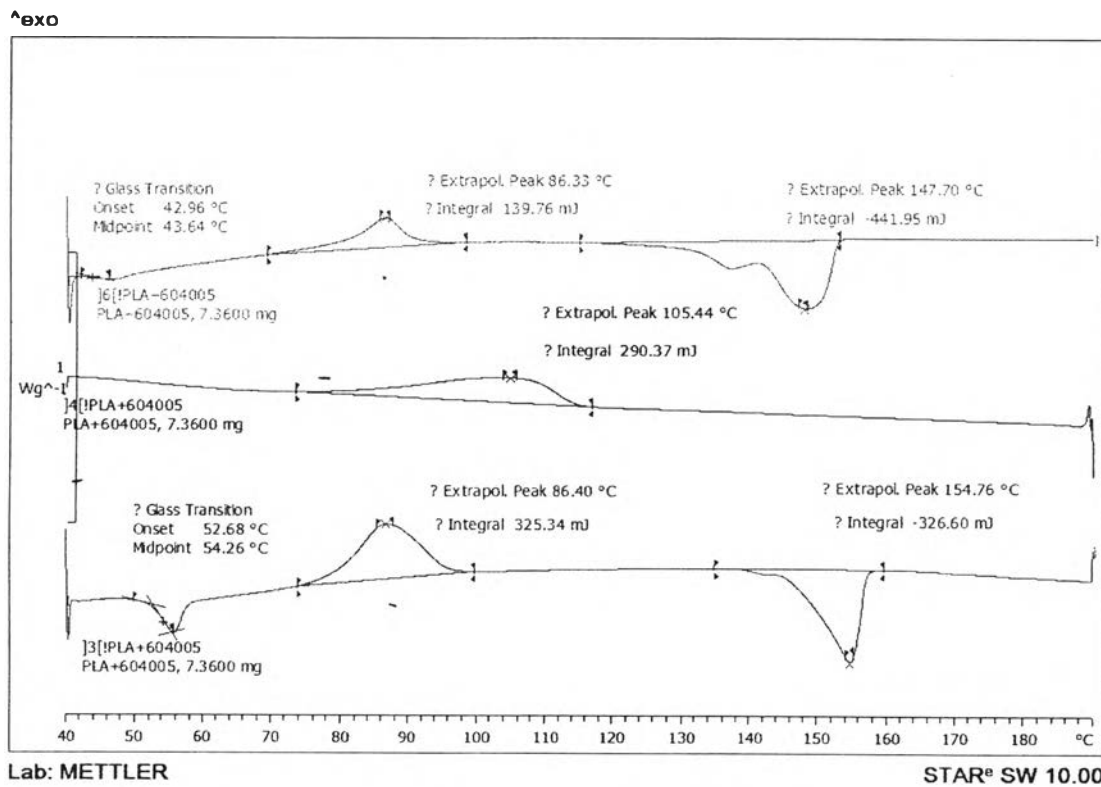


Figure E9 DCS Thermogram of PLA/604005 blend.

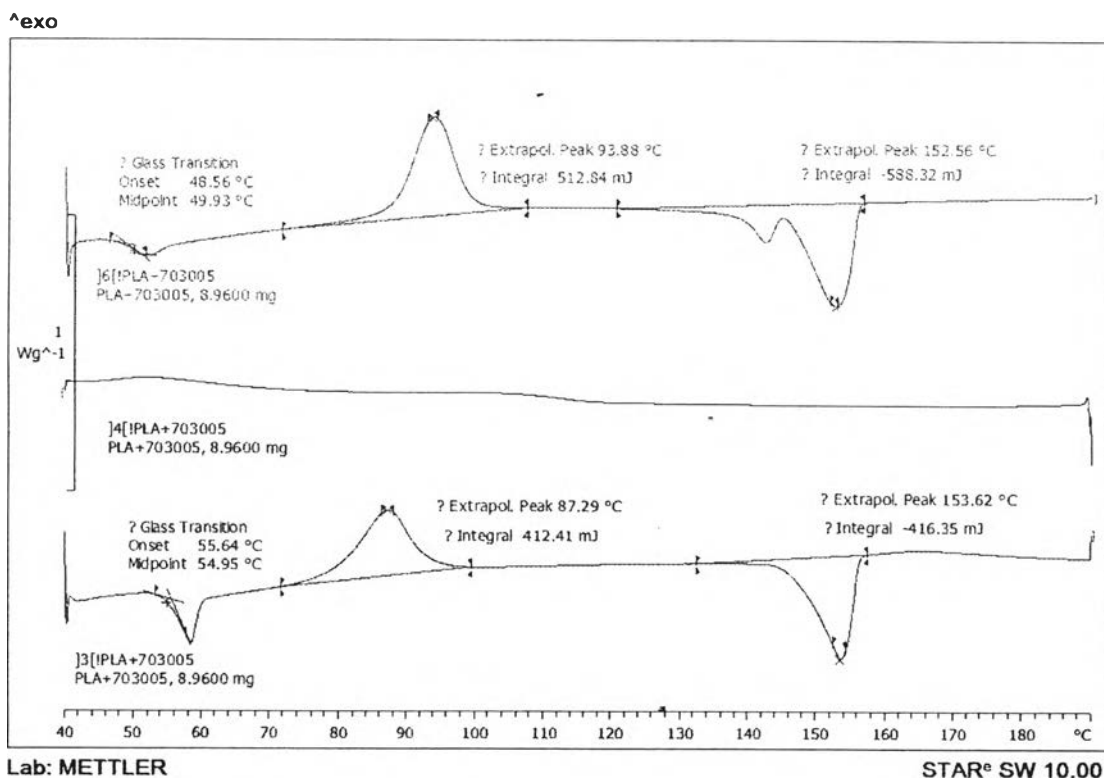


Figure E10 DCS Thermogram of PLA/703005 blend.

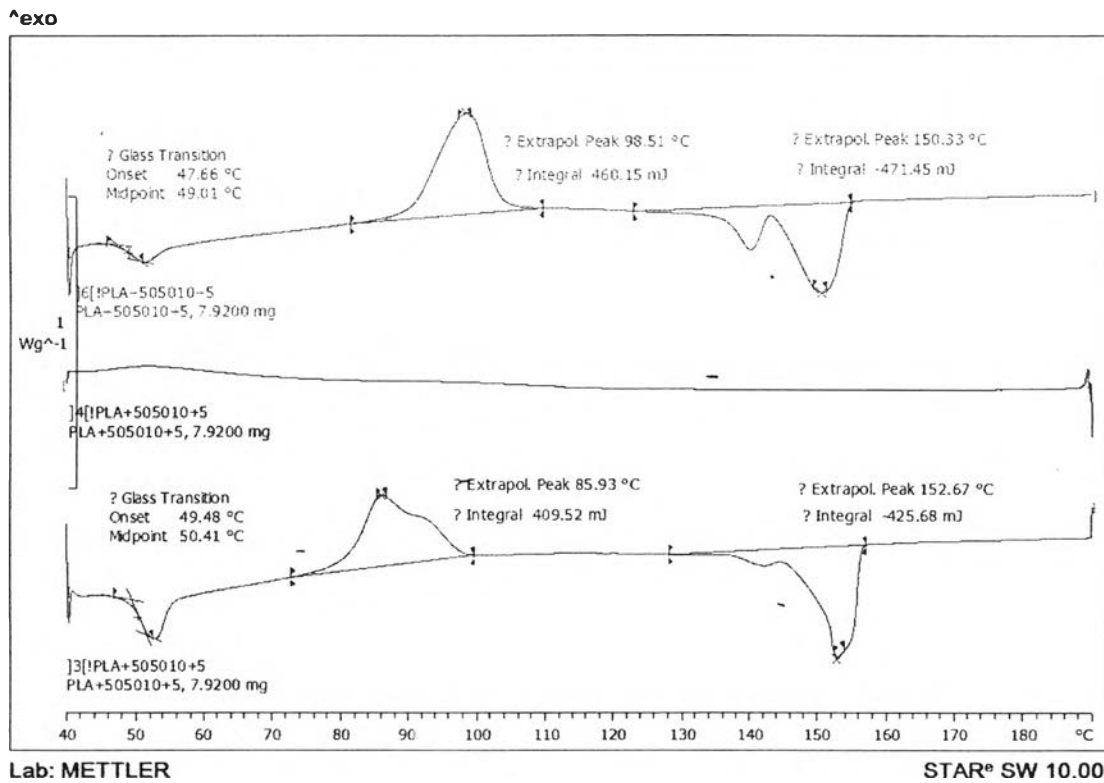


Figure E11 DCS Thermogram of PLA/505010 nanocomposites with 0.5% wt. clay.

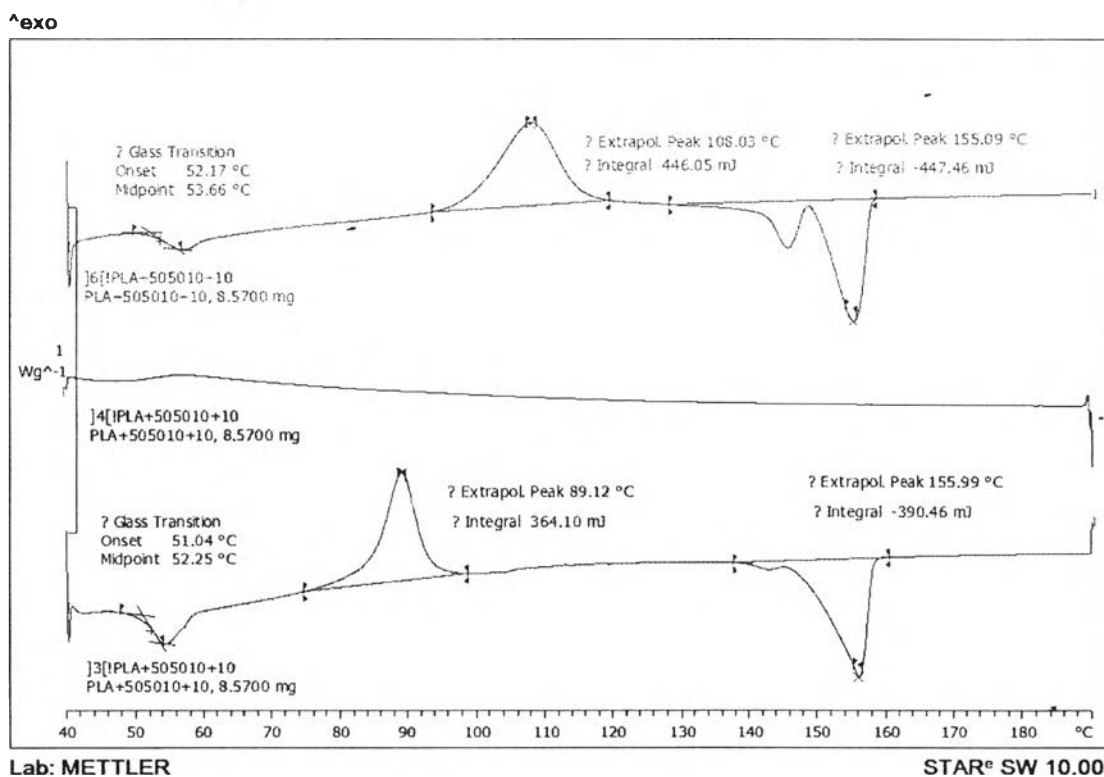


Figure E12 DCS Thermogram of PLA/505010 nanocomposites with 1.0% wt. clay.

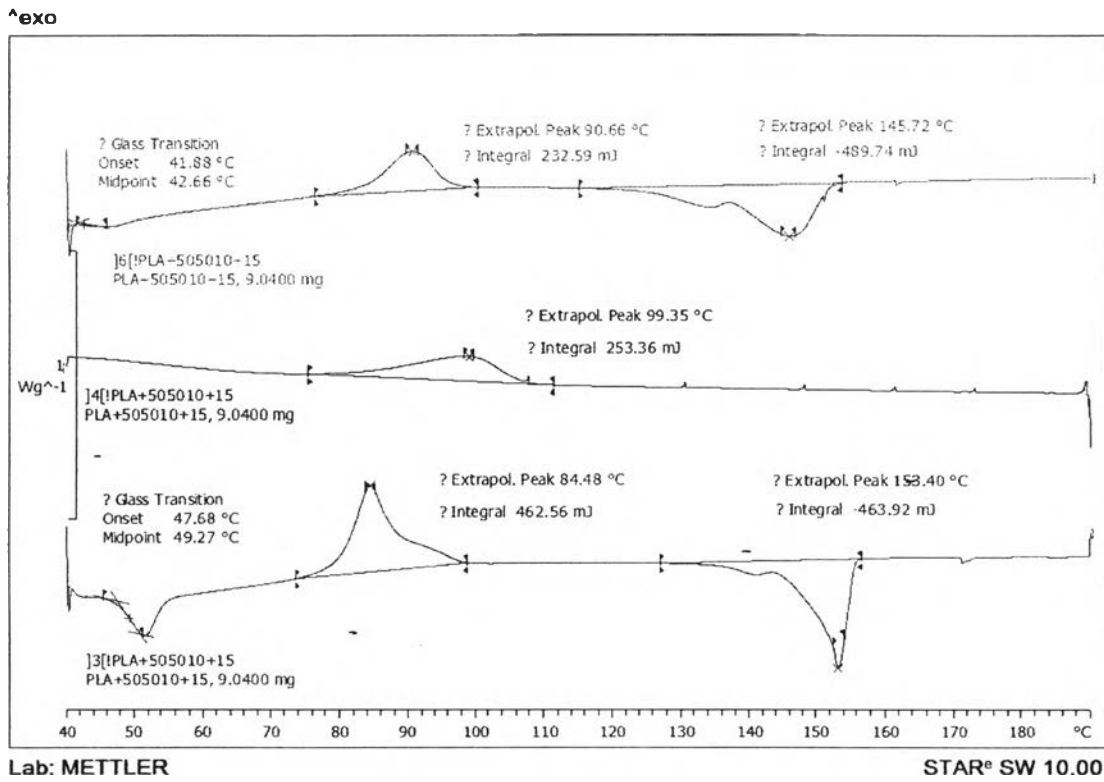


Figure E13 DCS Thermogram of PLA/505010 nanocomposites with 1.5% wt. clay.

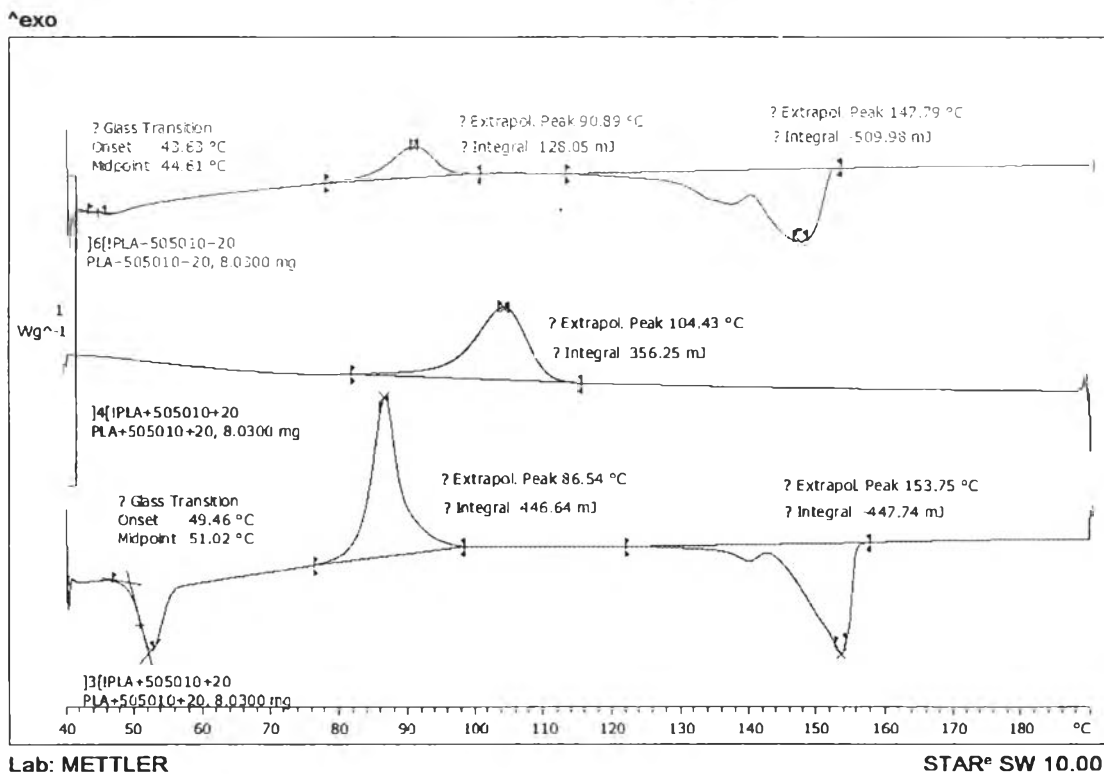


Figure E14 DCS Thermogram of PLA/505010 nanocomposites with 2.0% wt. clay.

## Appendix F Tensile Testing Results

**Table F1** Average Specimens Dimension.

specimens	Width [mm]		Thickness [mm]	
	value	SD	value	SD
neat PLA	14.14	0.81	4.04	0.03
PLA+NR	14.04	0.73	4.11	0.07
PLA+307005	14.04	0.72	4.03	0.04
PLA+406005	14.06	0.77	4.02	0.02
PLA+505005	14.02	0.80	3.99	0.02
PLA+505010	13.64	1.04	4.04	0.07
PLA+505010+0.5	14.14	1.17	3.96	0.01
PLA+505010+1.0	13.16	0.27	3.99	0.02
PLA+505010+1.5	13.42	0.65	3.95	0.02
PLA+505010+2.0	14.17	1.19	3.97	0.02
PLA+505015	13.61	0.73	3.95	0.02
PLA+505020	13.11	0.32	3.99	0.07
PLA+604005	13.25	0.75	4.02	0.02
PLA+703005	12.97	0.35	4.00	0.05

**Table F2** Tensile testing results and standard deviation.

specimens	Modulus Young's [MPa]		Stress at Max Load [N/mm <sup>2</sup> ]		Strain at Break [mm/mm]		Energy at Break [J]	
	value	SD	value	SD	value	SD	value	SD
neat PLA	1304.74	28.36	59.52	0.11	0.08	0.006	8.72	0.17
PLA+NR	992.04	15.44	34.18	0.64	0.05	0.006	3.44	0.38
PLA+307005	1050.45	23.23	39.12	0.90	0.05	8.5E-18	3.27	0.13
PLA+406005	1087.65	9.82	42.00	0.26	0.06	0	4.24	0.27
PLA+505005	1081.02	15.40	40.98	0.42	0.05	8.5E-18	3.68	0.12
PLA+505010	1064.69	28.78	37.37	0.95	0.05	8.5E-18	2.73	0.31
PLA+505010+0.5	1224.89	32.63	22.71	0.65	0.02	0	0.67	0.04
PLA+505010+1.0	1242.92	23.93	40.72	0.29	0.04	0	2.31	0.05
PLA+505010+1.5	1187.94	33.45	15.42	0.52	0.02	0	0.33	0.04
PLA+505010+2.0	1293.20	48.95	12.01	0.44	0.01	0	0.19	0.01
PLA+505015	1080.59	26.92	41.11	0.10	0.06	0.006	3.97	0.55
PLA+505020	1101.05	7.86	42.49	0.44	0.07	0	5.05	0.08
PLA+604005	1083.63	28.70	36.00	0.88	0.04	0	2.02	0.16
PLA+703005	1161.19	23.71	43.21	0.94	0.05	8.5E-18	2.95	0.09

## **Appendix G Standard of Specimens Dimension**

ASTM-D256: Impact testing

Rectangular shape specimens with dimension 64 x 12.7 x 3.2 mm

ASTM-D638 type I: Tensile testing

Dog bone shape specimens with gauge length dimension 57 x 13 x 3.2 mm with overall length at 165 mm and width at 19 mm.

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**Proceedings:**

1. Wongphonchai, W.; and Magaraphan, R. (2014, April 22) Toughening of Polylactide with Admicelled Natural Rubber Particles and Its Nanocomposite. Proceedings of the 5<sup>th</sup> Research Symposium on Petrochemical and Materials Technology and the 20<sup>th</sup> PPC Symposium on Petroleum, Petrochemicals and Polymers, Bangkok, Thailand.
2. Wongphonchai, W.; and Magaraphan, R. (2014, June 8-12) Admicellar polymerization of PCL-PLA on NR latex particles. Proceedings of the 30th International Conference of the Polymer Processing Society, Cleveland, Ohio, USA.

**Presentations:**

1. Wongphonchai, W.; and Magaraphan, R. (2014, April 22) Toughening of Polylactide with Admicelled Natural Rubber Particles and Its Nanocomposite. Paper presented at the 5<sup>th</sup> Research Symposium on Petrochemical and Materials Technology and the 20<sup>th</sup> PPC Symposium on Petroleum, Petrochemicals and Polymers, Bangkok, Thailand.