

Plastics App, lab test report – WO 401782

1. **Project:**

PA12-Graphene

2. **Objective:**

Evaluation of Graphene effect on PA12 properties

3. **Equipment:**

- 3.1. Twin screw extruder, Coperion, ZSK 18MegaLab, D=18mm, 48L/D
- 3.2. Injection molding machine, Boy 22A, 22 ton, D=24mm, 22L/D
- 3.3. Specific Gravity, Density Kit, Mettler Toledo
- 3.4. Testometric, M500-50CT
 - Flexural properties, full scale load cell 1kN, Span distance 64mm
- 3.5. Hot air circulation oven, 0.1°C Temperature readout
- 3.6. Heated Hydraulic 12Ton lab press, Carver
- 3.7. Desiccator

4. **Test methods:**

- 4.1. Compound preparation by twin screw extruder.
 - PA was pre-dried for >2 hours @ 100°C.
- 4.2. ISO 294, Injection molding of test specimens of thermoplastic materials
 - Tensile ISO 527 1A
 - Impact bars ASTM D256
 - Flexural bars ISO 178
 - Materials were dried for >2 hours @ 100°C prior to injection & pressing.
- 4.3. Samples were pressed @ 250°C & 10 Ton, into a 0.5X110X110 mm rectangular frame to produce flat panels.
 - Preheat ~7 minutes, ~0.5 minutes under load, ~2 minutes cooling.
- 4.4. Specific Gravity, ISO 1183 @ RT & Ethanol
- 4.5. Mechanical test methods:
 - 4.5.1. Determination of Flexural properties, ISO 178
 - The test was performed at speed of 2 (mm/min)

5. **Raw materials:**

- 5.1. PA12, Grilamid L16 – EMS
- 5.2. Graphene – G2G

**6. Sample description:**

Compound #	Inj.#	%wt		Notes
		PA12	G2G	
-	M0	100		Reference
G2G-240425-C1	M1	95	5	
G2G-240425-C2	M2	92	8	
G2G-240425-C3	M3	88	12	

Table 1: Sample description

7. Results & Discussion**7.1. Visual appearance**

Figure 1: Typical compression molded plate

7.2. Typical Properties

			Sample #	M0	C1M1	C2M2	C3M3
Properties	Unit	Standard	PA12, Typical	PA12 (ref.)	5% G2G	8% G2G	12% G2G
Density	gr/cm ³	ISO 1183	1.01	1.00	1.03	1.05	1.07
Flexural Modulus (2 mm/min)	MPa	ISO 178	1,300	1,341	1,707	1,852	2,029
Bending Strength (2 mm/min)	MPa	ISO 178	60	54	63	64	66

Table 2: Typical properties

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8. Conclusions & Remarks:

- 8.1. Compounding went well.
- 8.2. The Graphene blending with PA12 appeared to be uniform, and its addition had no effect on processing parameters
- 8.3. The Modulus increases with higher Graphene loading, while Strength appears to be mainly affected by its presence.

Appendixes:

Appendix A - Mechanical properties, full results

Appendix B - Injection parameters

Appendix C - Extrusion parameters

With kind regards,

Dr. Yanir Shaked & Nitzan Hooker

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Appendixes

A. Mechanical properties

A.1. Flexural test results:

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Customer : G2G
Sample # : G2G-240525-M0
Note : PA12 reference
Injection date : 27.04.25

Test Name : 1_3 Point Bending - 64mm
Test Type : 3 Point Flexural
Test Date : 05/05/2025 13:51
Test Speed : 2.000 mm/min
Preload : 0.900 N
Width : 9.750 mm
Thickness : 3.950 mm
Span : 64.000 mm

Test No	Secant Modulus 0.050 to 0.250 % (MPa)	Bending Strength @ Peak (MPa)
1	1396.563	57.143
2	1421.741	57.547
3	1413.520	57.168
4	1235.032	49.166
5	1235.684	49.860
Min	1235.032	49.166
Mean	1340.908	54.177
Max	1421.741	57.547
S.D.	96.711	4.267

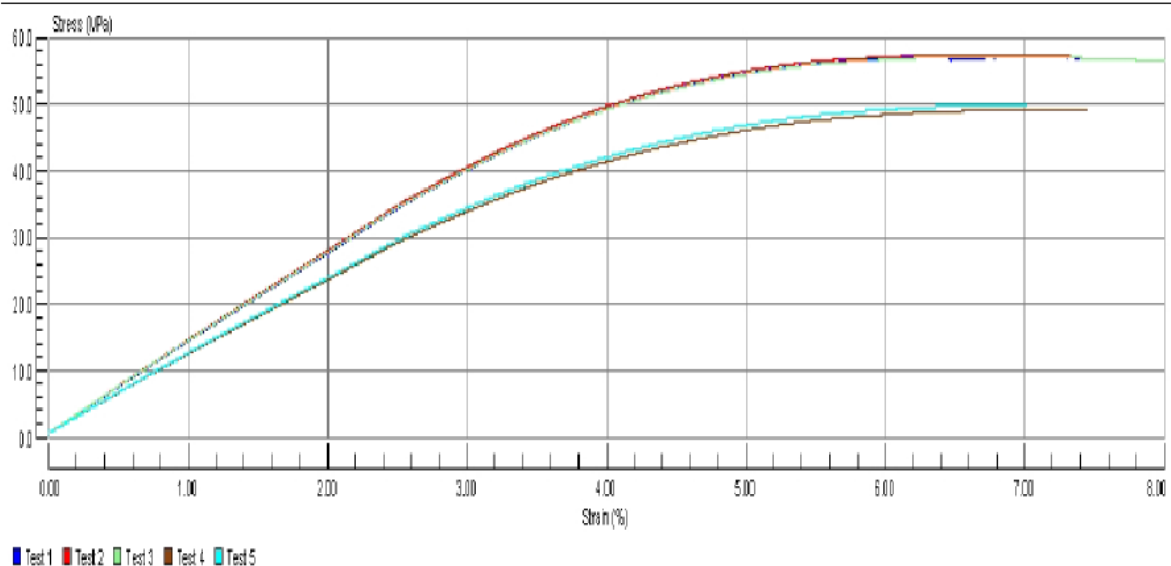


Figure 2: Flexural test results – M0

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Customer : G2G
Sample # : G2G-240525-C1M1
Note : 5%
Injection date : 27.04.25

Test Name : 1_3 Point Bending - 64mm
Test Type : 3 Point Flexural
Test Date : 05/05/2025 14:34
Test Speed : 2.000 mm/min
Preload : 0.900 N
Width : 9.750 mm
Thickness : 4.000 mm
Span : 64.000 mm

Test No	Secant Modulus 0.050 to 0.250 % (MPa)	Bending Strength @ Peak (MPa)
1	1767.179	64.246
2	1733.077	63.877
3	1716.581	63.508
4	1726.154	63.385
5	1592.820	57.717
Min	1592.820	57.717
Mean	1707.162	62.546
Max	1767.179	64.246
S.D.	66.703	2.721

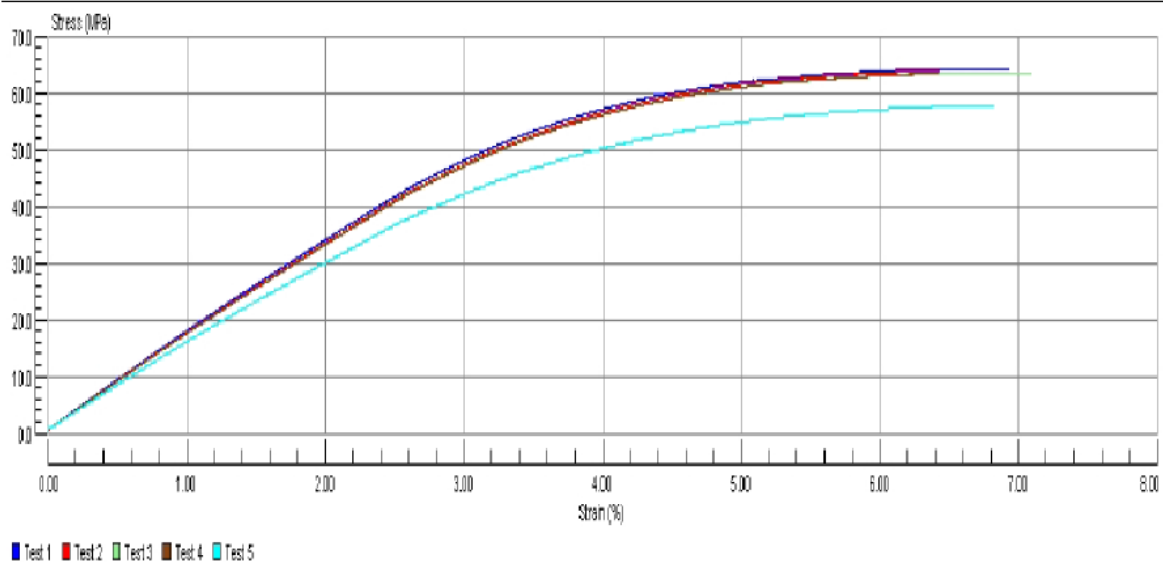


Figure 3: Flexural test results – C1M1



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Customer : G2G
Sample # : G2G-240525-C2M2
Note : 8%
Injection date : 27.04.25

Test Name : 1_3 Point Bending - 64mm
Test Type : 3 Point Flexural
Test Date : 05/05/2025 15:11
Test Speed : 2.000 mm/min
Preload : 0.900 N
Width : 9.750 mm
Thickness : 4.000 mm
Span : 64.000 mm

Test No	Secant Modulus 0.050 to 0.250 % (MPa)	Bending Strength @ Peak (MPa)
1	1933.333	66.031
2	1848.718	65.292
3	1885.128	65.538
4	1876.308	65.415
5	1714.872	59.065
Min	1714.872	59.065
Mean	1851.672	64.268
Max	1933.333	66.031
S.D.	82.337	2.922

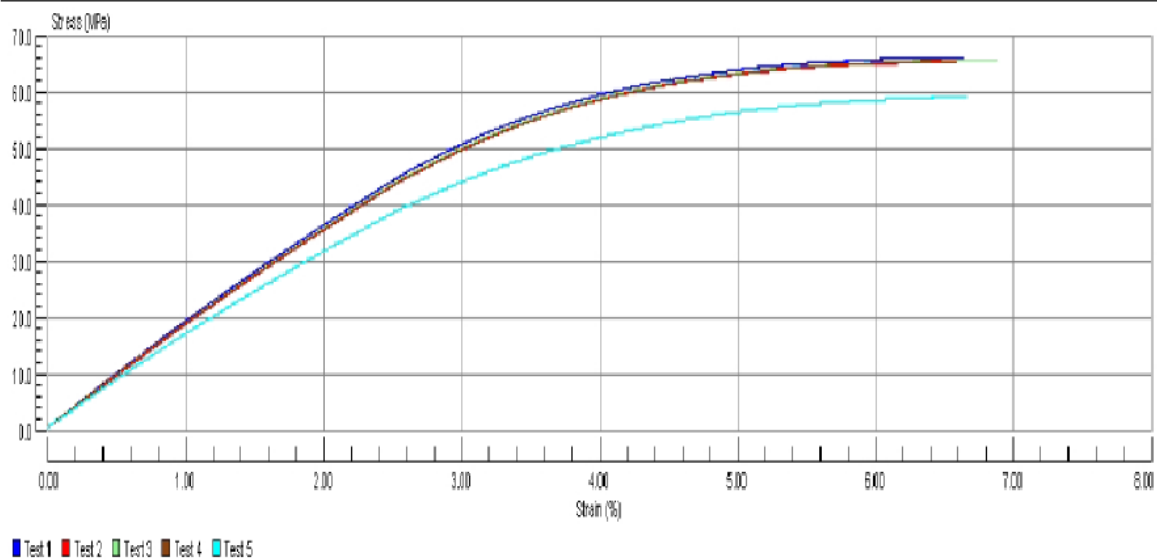


Figure 4: Flexural test results – C2M2



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Customer : G2G
Sample # : G2G-240525-C3M3
Note : 12%
Injection date : 27.04.25

Test Name : 1_3 Point Bending - 64mm
Test Type : 3 Point Flexural
Test Date : 05/05/2025 15:46
Test Speed : 2.000 mm/min
Preload : 0.900 N
Width : 9.750 mm
Thickness : 4.000 mm
Span : 64.000 mm

Test No	Secant Modulus 0.050 to 0.250 % (MPa)	Bending Strength @ Peak (MPa)
1	2096.154	67.385
2	2065.385	66.892
3	2036.410	66.646
4	2052.821	67.015
5	1892.308	61.458
Min	1892.308	61.458
Mean	2028.615	65.879
Max	2096.154	67.385
S.D.	79.278	2.486

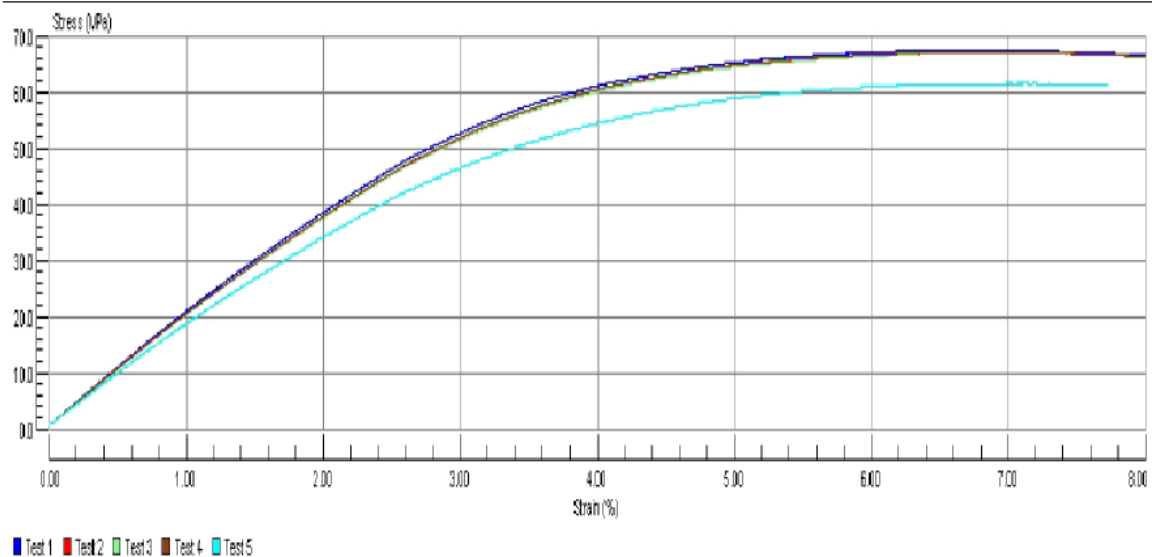


Figure 5: Flexural test results – C3M3



B. Injection parameters:

Project: G2G		Trial number: 1		Operator: Morad		Date: 27.04.25
	Sample number	M0	M1	M2		25.04.25
Temp.	T1: rear [°C]	210	210	210		210
	T2 [°C]	220	220	220		220
	T3 [°C]	230	230	230		230
	T4 [°C]	240	240	240		240
	T5: nozzle [°C]	250	250	250		250
	Tmold [°C]	89	89	89		89
Dosing	Materials	L16	G2G-240425-C1	G2G-240425-C2		G2G-240425-C3
	Material ratio [phr]	100	100	100		100
	Stroke [mm]	60	60	60		60
	Screw speed [rpm]	150	150	150		150
	Back pressure [bar]	5	5	5		5
	Dosing time [s]	9	8.5	8.1		8.3
	Decompression [mm]	2	2	2		2
	Sprue break, Retraction	in contact	in contact	in contact		in contact
	Delay [s]	15	15	15		15
Injection parameters	Injection speed [mm/s]	150	150	150		150
	Max. injection pressure [bar]	60	65	65		65
	Max. actual pressure [bar]	59	62	62		63
	Holding pressure [bar]	33	38	38		38
	Injection time [s]	0.72	0.61	0.62		0.62
	Holding P. time [s]	15	15	15		15
	Switch over point [mm]	8	8	8		8
	Cushion [mm]	2.8	2.8	2.8		3.2
Mold	Mold	PA2	PA2	PA2		PA2
	Impact ASTM [Y/N]	Y	Y	Y		Y
	Flexural / Impact ISO [Y/N]	Y	Y	Y		Y
	Color Chip [Y/N]	N	N	N		N
	Wear [Y/N]	N	N	N		N
	Micro tensile [Y/N]	N	N	N		N
	Tensile [Y/N]	Y	Y	Y		Y
	Cooling time [s]	30	30	30		30
	Cycle time [s]	54	54	54		54
	Mode	auto	auto	auto		auto
	Full shot weight [g]	22.4	23.4	23.7		24.3
	No. of samples collected	12	12	13		12

Table 3: Injection parameters



A. Extrusion Parameters:

Project: G2G				Trial: 1		Operator: Morad' Ahmad		Date: 24.04.25	
	Sample number			G2G-240425-C1		G2G-240425-C2		G2G-240425-C3	
Materials	Feeder 1 - name			A15		A15		A15	
	Feeder location			B1		B1		B1	
	Feeder materials			Grilamid L16		Grilamid L16		Grilamid L16	
	Feeder material ratio			100		100		100	
	Feeder output [rpm]			41.9		44		43	
	Feeder output [Kg/hr %]			3.84	95%	3.84	92%	3.8	88%
	Feeder 3 - name			KT20		KT20		KT20	
	Feeder location			B4		B4		B4	
	Feeder materials			G2G		G2G		G2G	
	Feeder material ratio			100		100		100	
	Avg. Drive command [%]			3		5		6	
	Feeder output [Kg/hr %]			0.2	5%	0.33	8%	0.524	12%
	Screw design			Comp.6.2		Comp.6.2		Comp.6.2	
	Screw speed [1/min]			350		350		350	
Working parameters	Torque [%]			21		21		23	
	Side feeder Y/N [rpm]			Y	350	Y	350	Y	350
	Pressure [bar]			5		5		7	
	Total output [Kg/hr]			4.0		4.2		4.3	
	Vent#1	Vent#2	Vac. [mbar]	O	O	O	O	O	O
	Die			2 holes, 3 mm		2 holes, 3 mm		2 holes, 3 mm	
	Conveyer frequency [Hz]								
	Pelletizer speed [m/min]			21.6		20.4		20.4	
	Tm [°C]			245		245		244	
	T1 [°C]			250	250	250	250	250	250
Temp	T2 [°C]			250	250	250	250	250	250
	T3 [°C]			250	250	250	250	250	250
	T4 [°C]			250	250	250	250	250	250
	T5 [°C]			250	250	250	250	250	250
	T6 [°C]			250	250	250	250	250	250
	T7 [°C]			250	250	250	250	250	250
	Sample size [kg]			1.2		1.2		1.2	

Table 4: Extrusion parameters