

Synthesis and Rheological Investigations of Gum-ghatti-*cl*-poly(NIPA-co-AA)-Graphene oxide based Hydrogels

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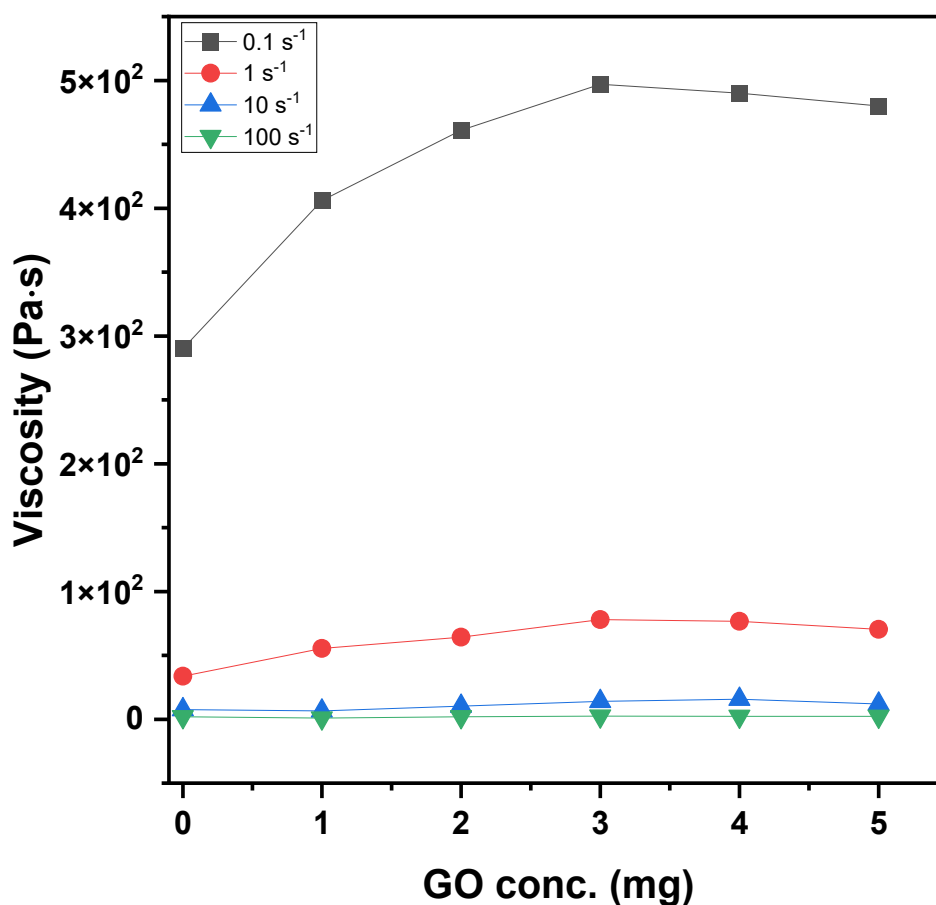


Figure S1 the effect of graphene oxide concentration (■) 0.1 s⁻¹, (●) 1 s⁻¹, (▲) 10 s⁻¹ and (▼) 100 s⁻¹ on the viscosity of GNAGO hydrogels at room temperature.

Table S1 Effect of graphene oxide concentration on the viscosity of GNAGO hydrogels at different shear rates. (mean \pm SD)

GO conc. (mg)	Shear rate (s ⁻¹)			
	0.1	1	10	100
0	290 \pm 5.2	33.7 \pm 2.1	7.53 \pm 1.7	1.88 \pm 0.3
1	406 \pm 8.4	55.5 \pm 3.2	6.47 \pm 1.2	0.862 \pm 0.2
2	461 \pm 9.7	64.2 \pm 4.4	10.3 \pm 1.4	1.9 \pm 0.4
3	497 \pm 7.4	78.0 \pm 2.4	14.0 \pm 1.1	2.53 \pm 0.5
4	490 \pm 9.8	76.6 \pm 3.4	15.7 \pm 1.5	2.21 \pm 0.7
5	480 \pm 8.0	70.4 \pm 2.8	11.9 \pm 2.1	2.21 \pm 0.4

Table S2 The values of storage modulus, loss modulus, complex viscosity and damping factor with angular frequency at 0.1, 1, 10 and 100 (rad/s) (mean \pm SD)

Sample id	Angular Frequency (rad/s)															
	0.1				1				10				100			
	G'	G''	tan δ	η^*	G'	G''	tan δ	η^*	G'	G''	tan δ	η^*	G'	G''	tan δ	η^*
GNAGO-0	102	11.1	0.108	1030	88	9.78	0.111	88.5	98.8	13.6	0.137	9.98	63.9	18	0.281	0.663
	\pm	± 0.3	\pm	± 11.4	± 1.3	± 0.1	\pm	± 4.2	± 2.1	± 0.5	\pm	\pm	± 1.5	± 0.8	± 0.03	± 0.05
	2.7		0.002				0.004				0.003	0.03				
GNAGO-1	142	14.4	0.101	1430	108	10.3	0.095	108	118	14.3	0.121	11.9	111	21.3	0.191	1.13
	\pm	± 0.2	± 0.03	± 16.2	± 2.3	\pm	\pm	± 5.1	± 3.0	± 0.2	0.001	\pm	± 2.3	± 0.2	± 0.01	± 0.06
	5.1					0.17	0.002					0.035				
GNAGO-2	150	18.5	0.123	1510	126	10.2	0.080	126	135	13.17	0.097	13.8	163	58	0.335	1.78
	\pm	\pm	\pm	± 20	± 2.7	\pm	± 0.01	± 3.2	± 3.1	± 0.4	0.002	\pm	± 3.5	± 0.5	± 0.05	± 0.03
	4.7	0.52	0.006			0.21						0.04				
GNAGO-3	176	19.3	0.109	1770	168	14.4	0.085	169	186	19.9	0.106	18.7	216	67	0.310	2.17
	\pm	\pm	\pm	± 12.3	\pm	\pm	\pm	± 2.2	± 1.1	± 0.11	0.001	\pm	± 4.0	\pm	\pm	± 0.02
	7.3	0.33	0.0011		1.11	0.11	0.003					0.02		0.11	0.011	
GNAGO-4	158	18.2	0.115	1580	158	16.9	0.106	163	178	21.8	0.122	18.8	166	3.69	0.022	1.88
	\pm	± 0.9	\pm	± 15.2	± 3.1	\pm	\pm	± 7.5	± 4.0	± 0.7	0.004	\pm	± 3.0	± 0.3	\pm	± 0.04
	4.0		0.002			0.34	0.004					0.05			0.001	
GNAGO-5	157	21	0.133	1600	162	20	0.123	158	186	27.1	0.145	17.9	188	4.48	0.023	1.66
	\pm	± 0.5	± 0.04	± 26.2	± 3.3	\pm	\pm	± 5.2	± 3.5	± 0.33	0.003	\pm	± 0.5	\pm	\pm	± 0.03
	3.7					0.27	0.008					0.043		0.11	0.002	

Table S3 Storage and loss moduli values of GNAGO-0 to GNAGO-5 at the temperatures 40°C and 60 °C for heating. (mean ± SD)

Hydrogel Code	Temperature 40 °C		Temperature 60 °C	
	G'	G''	G'	G''
GNAGO-0	67.8 ± 2.2	19.1 ± 1.0	1620 ± 12.9	1020 ± 9.2
GNAGO-1	97.3 ± 4.1	15.6 ± 0.9	113 ± 4.2	15.9 ± 1.2
GNAGO-2	81.3 ± 3.5	12 ± 0.8	180 ± 5.2	73.7 ± 2.2
GNAGO-3	157 ± 3.2	21.2 ± 0.5	629 ± 2.2	269 ± 3.5
GNAGO-4	40.4 ± 1.2	6.11 ± 0.8	138 ± 1.2	35.4 ± 2.0
GNAGO-5	40.8 ± 2.2	3.03 ± 0.2	48 ± 2.0	4.17 ± 0.2

Table S4. The value of elastic and viscous moduli and tanδ at 10, 25 and 99.8 % of strain of GNAGO-0 to GNAGO-5 (mean ± SD)

Hydrogel Code	1 % strain			10 % strain			25 % strain			99.8 % strain		
	G'	G''	tanδ	G'	G''	tanδ	G'	G''	tanδ	G'	G''	tanδ
GNAGO-0	100	12.1	0.136	96.9	13	0.135	90.3	14.1	0.156	65.4	16.8	0.258
	±	±	±	±	±	±	±	±	±	±	±	±
	4.2	0.4	0.002	0.8	0.2	0.002	1.0	0.8	0.004	0.7	0.2	0.28
GNAGO-1	105	12.2	0.125	104	13.2	0.128	96.4	14.5	0.151	71.3	17.1	0.24
	±	±	±	±	±	±	±	±	±	±	±	±
	4.0	0.3	0.001	1.2	0.7	0.004	1.2	1.1	0.002	1.1	0.8	0.02
GNAGO-2	131	11.6	0.103	128	13	0.101	122	13.7	0.112	101	16.3	0.161
	±	±	±	±	±	±	±	±	±	±	±	±
	3.8	0.22	0.003	1.9	0.4	0.003	1.4	0.5	0.003	1.29	0.5	0.01
GNAGO-3	198	25.6	0.129	193	27.2	0.141	179	30.4	0.17	116	38.9	0.334
	±	±	±	±	±	±	±	±	±	±	±	±
	2.2	0.2	0.001	2.0	0.2	0.002	1.1	0.9	0.002	1.4	0.52	0.02
GNAGO-4	196	21.3	0.1	187	23.3	0.124	170	26.9	0.159	101	31.9	0.316
	±	±	±	±	±	±	±	±	±	±	±	±
	3.0	1.2	0.003	3.2	0.9	0.003	1.33	0.82	0.004	2.5	0.7	0.06
GNAGO-5	188	21.2	0.114	177	25.1	0.142	157	29.8	0.19	104	39	0.376
	±	±	±	±	±	±	±	±	±	±	±	±
	4.7	0.9	0.002	2.7	1.2	0.008	1.27	1.1	0.003	3.2	0.82	0.07

Table S5 The value of shear stress (pa) at 0.1, 10, 25.1 and 99.8 % of strain of GNAGO-0-GNAGO-5 (mean \pm SD)

Sample code	0.1 % strain	1 % strain	10 % strain	25.1 % strain	99.8 % strain
GNAGO-0	0.0971 \pm 0.002	1 \pm 0.04	9.76 \pm 0.5	22.9 \pm 0.2	67.2 \pm 1.4
GNAGO-1	0.103 \pm 0.009	1.06 \pm 0.02	10.4 \pm 0.8	24.4 \pm 1.2	73 \pm 1.7
GNAGO-2	0.131 \pm 0.005	1.31 \pm 0.03	12.9 \pm 0.2	30.7 \pm 1.1	102 \pm 1.3
GNAGO-3	0.198 \pm 0.002	1.99 \pm 0.01	19.4 \pm 0.1	45.4 \pm 0.6	122 \pm 1.0
GNAGO-4	0.192 \pm 0.007	1.97 \pm 0.04	18.9 \pm 0.4	43.2 \pm 1.6	106 \pm 1.2
GNAGO-5	0.218 \pm 0.003	1.89 \pm 0.01	17.8 \pm 0.3	40 \pm 1.3	110 \pm 1.8

FT-IR analysis

The FT-IR spectra of GG, GO, GG-*g*-*P*(NIPAM-*co*-AA) (GNAGO-0) and GG-*g*-*P*(NIPAM-*co*-AA) (GNAGO-3) is shown in the Fig.1. The FT-IR spectra of GG confirmed about feature functional groups presence in GG. The bands at 3340 cm^{-1} (broad peak) and 2934 cm^{-1} corresponded to stretching vibration of O-H and C-H respectively^{1,2}. The band visualized at 1004 cm^{-1} ascribed of strong vibration of C-O and band at 541 cm^{-1} (low intense) assigned to bending vibration of C-O or O-H functionality^{1,3}. The strong band found at 1710 cm^{-1} revealed of stretching vibration of C=O group of carboxylic acid group of AA present in GG-*g*-*P*(NIPAM-*co*-AA)(GNAGO-0)⁴. The stretching vibration of N-H of amide functional group of PNIPAM attributed at 1600 cm^{-1} (low intense band)⁴⁻⁶. The band at 3750 cm^{-1} can be assigned to stretching vibration of hydroxyl functional group of carboxylic acid of AA. The FT-IR spectra of GO showed that required functionality found in the GO⁷. The FT-IR spectra of GG-*g*-*P*(NIPAM-*co*-AA) indicated that after loading of GO did not alter the spectra of GG-*g*-

P(NIPAM-co-AA). The special bands of GO did not evaluate in the GG-*g*-Poly (*NIPAM-co-AA*) which is the signing of homogeneous dispersion of GO over to GG-*g*-*P(NIPAM-co-AA)*.

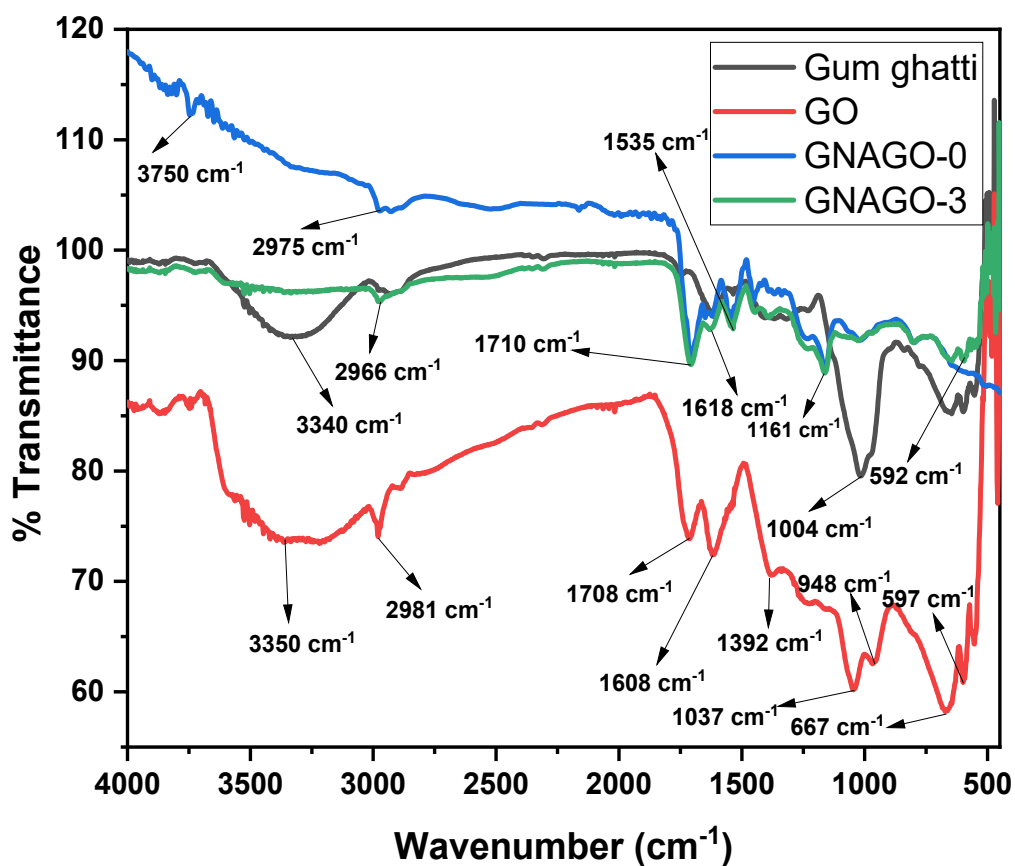


Figure. S2 FT-IR of GG, GO, GNAGO-0 and GNAGO-3

SEM images

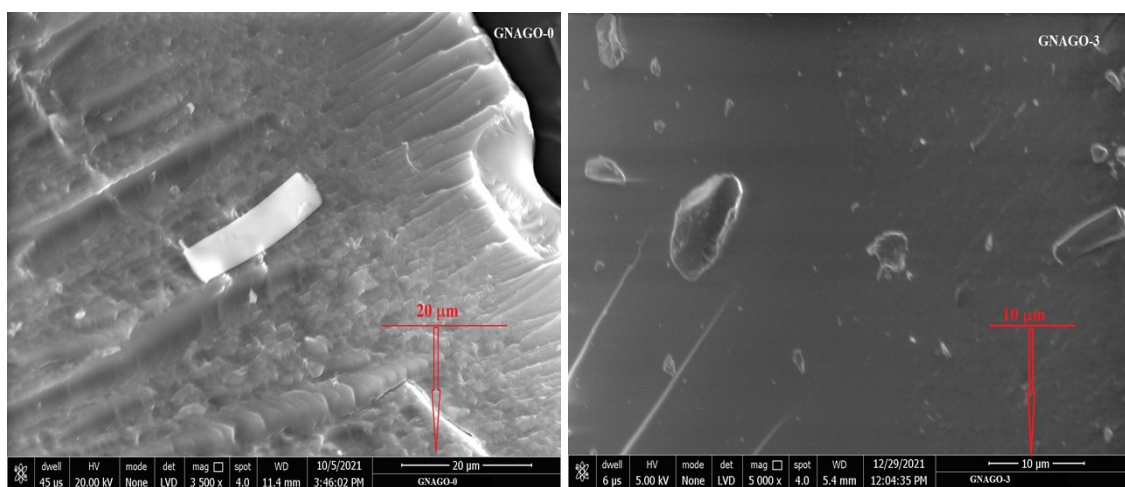


Figure. S3 SEM images of GNAGO-0 and GNAGO-3

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