

SYNTHESIS AND CHARACTERIZATION OF GRAFT COPOLYMER (ALGINATE-*g*-POLY(*N,N*-DIMETHYLACRYLAMIDE))

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Abstract The graft copolymerization of *N,N*-dimethylacrylamide onto alginate by free radical polymerization using potassium peroxymonosulphate-sarbose as a redox pair in an inert atmosphere was investigated. The reaction conditions for maximum grafting have been optimized by varying the reaction variables, including the concentration of *N,N*-dimethylacrylamide (7×10^{-2} mol/L to 23×10^{-2} mol/L), potassium peroxymonosulphate (2×10^{-3} mol/L to 18×10^{-3} mol/L), sarbose (0.4×10^{-3} mol/L to 3.4×10^{-3} mol/L), sulphuric acid (1×10^{-3} mol/L to 8×10^{-3} mol/L) and alginic acid (0.4 g/L to 1.8 g/L) along with time duration (60 min to 180 min) and temperature (25°C to 45°C). Water swelling capacity, metal ion sorption and flocculation studies of the synthesized graft copolymer have been performed. The graft copolymer has been characterized by FTIR spectroscopy and thermogravimetric analysis.

Keywords: Graft copolymer; Potassium peroxymonosulphate; Sarbose; IR Spectroscopy; Thermal analysis.

INTRODUCTION

Considerable interests have shown on chemical modification of natural polymers for imparting desirable properties. The graft copolymerization of vinyl monomers onto natural polysaccharides has received widespread attention in recent years^[1–3]. In our laboratory, by the process of grafting, physical and chemical properties of synthetic monomers are superimposed onto the properties of different natural polymers using redox system^[4, 5]. Recently few reports are available about the graft copolymers of alginate^[6–9]. In recent studies, alginate has been chosen as a backbone, which is one of the nontoxic sulphated polysaccharide. Chemically, it is an unbranched copolymer with homopolymeric blocks of β -1,4-linked D-mannuronic acid and α -1,4-linked L-glucuronic acid, covalently linked together^[10]. Algin or alginate is a gelatinous substance produced by brown algae and is used in a wide range of food, leather, pharmaceutical and industrial applications. Because it is one of the few hydrocolloids that are capable of both thickening and gelling water, alginate offers many useful properties, including viscosity control, improved freeze-thaw stability, film formation, rheology control and more^[11]. Alginate has many useful properties and is very user-friendly and consumer-friendly because it is renewable, biodegradable, vegetable and not animal in origin and wholly safe by all known tests^[12]. However, it is prone to enzymatic degradation and suffers from limitations in fabrication, which limit its application in some fields, for example, in controlled-release technology^[13]. Although alginate has wide range of uses and applications, it suffers from certain drawback like biodegradability, which limits its uses considerably. Poly(*N,N*-dimethylacrylamide) (PDMA) is being used in many fields due to its remarkable properties such as water solubility and biocompatibility^[14]. Homo- and co-polymers of DMA have been applied in various fields such as oil recovery^[15], slow release of drug^[16]. *N,N*-dimethylacrylamide has been chosen as a hydrophilic vinyl

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monomer to synthesize a new polymeric material *i.e.* alginate-*g*-poly(*N,N*-dimethylacrylamide) (AG-*g*-PDMAM) in order to remove not only drawback but also to increase the properties of alginate like swellability, metal ion uptake and flocculation thereby increasing its potential applications. The synthesized AG-*g*-PDMAM may be used as superabsorbent, coating materials and flocculant to remove impurities from coal mine waste water.

EXPERIMENTAL

Materials

N,N-dimethylacrylamide (DMAM) (Aldrich) was distilled under reduced pressure at 1.99×10^3 Pa and 55°C and only the middle fraction was used. Sodium alginate (AG) was purchased from Sigma (U.S.A.). Potassium peroxymonosulphate (PMS, Sigma) and Sarbose (E. Merck) were used as received. For maintaining hydrogen ion concentration sulphuric acid (E. Merck) was used, and all the solutions were prepared in triple distilled water. The other chemicals used were of analytical grade.

Procedure for Graft Copolymerization

For each experiment alginate solution has been prepared by addition of weighed amount of alginate into a reactor containing triple distilled water with rapid stirring. The calculated amount of DMAM, sarbose and sulphuric acid solutions were added to the reactor at constant temperature and a slow stream of pure nitrogen was passed. After 30 min, a known amount of deoxygenated PMS solution was added to initiate the reaction. The experiments were done in pure nitrogen gas. After desired time period, the reaction was stopped by letting air into the reactor. The grafted sample was precipitated by pouring it into water/methanol mixture (1:5, *V/V*). The grafted sample was separated by filtration, dried and weighed.

Separation of Homopolymer

The filtrate has been concentrated by distillation under reduced pressure in the presence of a little amount hydroquinone. The PDMAM was precipitated by pouring concentrated filtrate into pure methanol. The PDMAM thus obtained, was separated, dried and weighed.

Estimation of Grafting Parameters

The graft copolymer was characterized by the following parameters^[17]

$$\text{Grafting ratio } (G, \%) = \frac{\text{Grafted polymer}}{\text{Weight of substrate}} \times 100$$

$$\text{Add on } (A, \%) = \frac{\text{Synthetic polymer}}{\text{Graft copolymer}} \times 100$$

$$\text{Conversion } (C, \%) = \frac{\text{Polymer formed}}{\text{Monomer charged}} \times 100$$

$$\text{Grafting efficiency } (E, \%) = \frac{\text{Polymer in graft}}{\text{Polymer formed}} \times 100$$

$$\text{Homopolymer } (H, \%) = 100 - \text{Grafting efficiency } (\%)$$

Swelling

The preweighed graft copolymer samples (0.02 g) were immersed in 20 mL of triple distilled water and kept undisturbed for 10 h at room temperature until equilibrium swelling was reached. The swollen samples were then removed from triple distilled water, quickly wiped with filter paper to remove droplets on the surface and weighed. The percent swelling (P_s) and swelling ratio (S_r) were calculated by using the following expressions^[18].

$$P_s = \frac{\text{Wt. of swollen polymer} - \text{Wt. of dry polymer}}{\text{Wt. of dry polymer}} \times 100$$

$$S_r = \frac{\text{Wt. of swollen polymer} - \text{Wt. of dry polymer}}{\text{Wt. of dry polymer}}$$

Metal Ion Sorption Test

0.02 g of graft copolymer was put in 10 mL of metal ion solution of known concentration, and kept for 24 h. The strength of sorbed metal ion has been determined by titrating the remaining metal ions. The results of sorption behavior of alginate and its grafted polymer with DMAM were determined in terms of different parameters^[19] i.e. percent ion uptake (P_u), partition coefficient (K_d) and retention capacity (Q_r).

$$\text{Percent uptake } (P_u) = \frac{\text{Amount of metal ion in the polymer}}{\text{Amount of metal ion in feed}} \times 100$$

$$\text{Partition coefficient } (K_d) = \frac{\text{Amount of metal ion in the polymer}}{\text{Amount of metal ion left in the solution}} \times \frac{\text{Volume of solution (mL)}}{\text{Weight of dry polymer}}$$

$$\text{Retention capacity } (Q_r) = \frac{\text{Amount of metal ion in the polymer (m. Eq.)}}{\text{Weight of dry polymer (g)}}$$

Flocculation

In a 1.0 L beaker, 200 mL of 1 wt% coal suspension (in water) was added. The beaker was placed on flocculator dipping the stirrer blade in the suspension. Under a low stirring condition, required quantity of polymer solution was added to beaker to make predetermined dose with respect of suspension volume. After the addition of polymer solution, the suspension was stirred at a constant speed for 15 min. The flocs were allowed to settle down for half an hour. Clean supernatant liquid was drawn from a depth of 1.0 cm and its turbidity was measured using a digital nephelometer (DIGITAL NEPHELOMETER MODEL 341 (EI) supplied by ISO-TECH SYSTEM) to express the turbidity in nephelometric unit (N.T.U.).

Method of Characterization of Graft Copolymer AG-g-PDMAM

IR spectroscopy

The IR spectra of alginate and grafted samples were recorded with a JASCO FT/IR-5300 model in the range 500 cm^{-1} to 4000 cm^{-1} .

Thermogravimetric analysis

The thermograms were recorded on a NETZSCH-STA 409C/CD thermal analyzer from 0°C to 1400°C temperature range and with a heating rate of 15 K/min in nitrogen atmosphere.

RESULTS AND DISCUSSION

Effect of Concentration of PMS

The effect of peroxymonosulphate concentration on graft copolymerization of DMAM onto alginate has been studied by varying the concentration of PMS from 2×10^{-3} mol/L to 18×10^{-3} mol/L and results are summarized in Table 1. The grafting ratio, add on, conversion, efficiency and rate of grafting were found to increase with increasing the concentration of PMS from 2.0×10^{-3} mol/L to 10.0×10^{-3} mol/L and homopolymer decreased but beyond 10.0×10^{-3} mol/L, the grafting parameters decreased and homopolymer increased. The increment in grafting parameters might be due to the progressive reduction of PMS by sarbose, which produces primary free radicals ($R^{\bullet}$)^[20] and these primary free radicals generate more active sites on the alginate polymeric backbone, to which monomer addition takes place. The decrement in grafting parameters at higher concentrations of PMS, might be attributed to the premature termination of the growing grafted chains.

Effect of Concentration of Sarbose

The variation of concentration of sarbose from 0.4×10^{-3} mol/L to 3.4×10^{-3} mol/L reveals that the grafting ratio, add on, conversion and efficiency increase with increasing the sarbose concentration up to 2.6×10^{-3} mol/L due to availability of more primary free radicals^[21], which might be formed due to reduction of PMS by sarbose. However, on further increasing the concentration of sarbose from 2.6×10^{-3} mol/L to 3.4×10^{-3} mol/L, the decrement in grafting parameters is found which is probably due to premature termination of DMAM radicals which causes more homopolymer. The results are presented in Fig. 1.

Table 1. Effect of concentration of PMS on graft copolymerization

[PMS] $\times 10^3$ (mol/L)	G (%)	E (%)	A (%)	C (%)	H (%)
2	160	56.2	61.5	12.4	43.8
6	178	58.6	64.0	13.7	41.4
10	188	65.3	65.3	14.3	34.7
14	176	56.9	61.5	12.2	43.1
18	162	57.8	61.8	12.1	42.2

[AG] = 1.0 g/L, [Sarbose] = 1.8×10^{-3} mol/L, [DMA] = 15×10^{-2} mol/L, $[H^+] = 4 \times 10^{-3}$ mol/L;
Temperature = 35°C; Time = 120 min

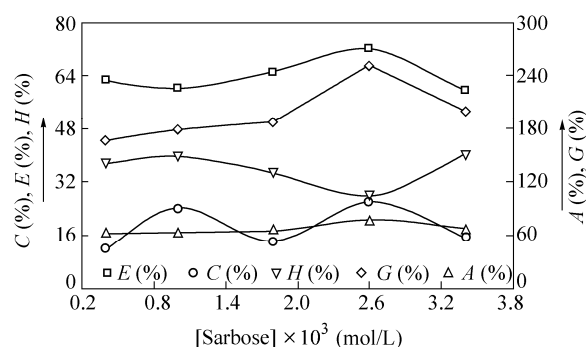


Fig. 1 Effect of concentration of sarbose on graft copolymerization

[AG] = 1.0 g/L, [PMS] = 10×10^{-3} mol/L, [DMAM] = 15×10^{-2} mol/L, $[H^+] = 4 \times 10^{-3}$ mol/L;
Temp. = 35°C, Time = 120 min

Effect of Concentration of Alginate

The effect of concentration of alginate (from 0.4 g/L to 1.8 g/L) on grafting parameters was studied. It is observed that the grafting parameters increase continuously with increasing the concentration of alginate (Fig. 2), this may be due to the great availability of grafting site at alginate backbones.

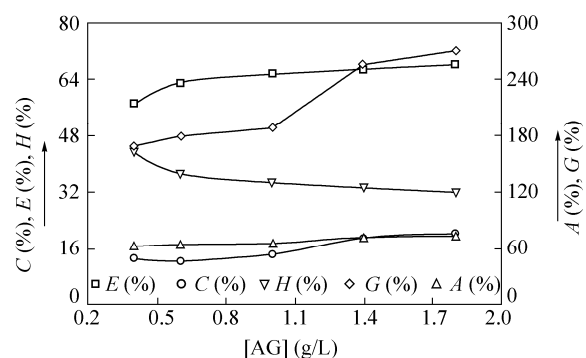


Fig. 2 Effect of concentration of alginate on graft copolymerization

[PMS] = 10×10^{-3} mol/L, [DMAM] = 15×10^{-2} mol/L, $[H^+] = 4 \times 10^{-3}$ mol/L,
[Sarbose] = 1.8×10^{-3} mol/L; Temp. = 35°C; Time = 120 min

Effect of Concentration of Hydrogen Ion

The concentration of hydrogen ion plays an important role during the reaction. The effect of hydrogen ion concentration was studied by varying the concentration from 1.0×10^{-3} mol/L to 8.0×10^{-3} mol/L. The results are given in Table 2 and found that grafting ratio, add on, conversion and efficiency increase, but on further increasing the concentration of $[H^+]$ ions beyond 6.0×10^{-3} mol/L, the grafting parameters decrease while homopolymer increases. It could be explained by the following reason: On increasing the hydrogen ion concentration, the formation of inactive species (H_2SO_5) increases due to which the concentration of HSO_5^- decreases resulting in production of less free radicals, thereby decreasing the grafting parameters.



Table 2. Effect of concentration of hydrogen ion on graft copolymerization

$[H^+] \times 10^3$ (mol/L)	<i>G</i> (%)	<i>E</i> (%)	<i>A</i> (%)	<i>C</i> (%)	<i>H</i> (%)
1	175	59.7	63.6	13	40.3
2	180	60.5	64.3	13.3	39.6
4	188	65.3	65.3	14.3	34.7
6	252	67.6	71.6	18.4	32.5
8	220	64.1	68.8	16.3	35.9

[AG] = 1.0 g/L, [PMS] = 10×10^{-3} mol/L, [DMA] = 15×10^{-2} mol/L, [Sarbose] = 1.8×10^{-3} mol/L;
Temperature = 35°C; Time = 120 min

Effect of Concentration of DMAM

The effect of concentration of DMAM on grafting parameters was investigated by varying the concentration of DMAM from 7.0×10^{-2} mol/L to 23.0×10^{-2} mol/L and results are presented in Fig. 3. It has been observed that grafting ratio, add on and efficiency increase with increasing the concentration up to 19×10^{-2} mol/L and thereafter, the grafting parameters decrease. However the formation of homopolymer shows a reverse trend with respect to grafting efficiency. This behavior is attributed to accumulation of monomer molecules at close proximity of polymeric backbones. The monomer molecules, which are at the immediate vicinity of reaction sites, become acceptors of alginate radicals resulting in chain initiation and according themselves become free radical donors to the neighbouring molecules. But on further increasing the concentration of DMAM, decrease in grafting parameter is observed which is due to viscosity increase of the medium, which in turn hinders the movement of free radicals.

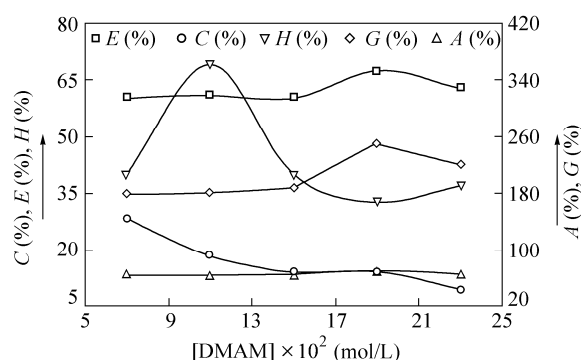


Fig. 3 Effect of concentration of DMAM on graft copolymerization

[AG] = 1.0 g/L, [PMS] = 10×10^{-3} mol/L, $[H^+] = 4 \times 10^{-3}$ mol/L, [Sarbose] = 1.8×10^{-3} mol/L;
Temp. = 35°C; Time = 120 min

Effect of Temperature

The results obtained are summarized in Table 3 at different temperatures and it is observed that on changing the temperature from 25°C to 45°C, the grafting parameters increase up to 40°C and then decrease. The increment in grafting parameters up to 40°C is attributed to the increase in the formation of active sites on account of enhanced

production of primary free radicals with increase in temperature.

The decrement in grafting parameters could be explained as follows: (1) It may be due to the premature termination of growing grafted chains by excess free radicals at higher temperature. (2) The increase in temperature may lead to the decomposition of PMS into HSO_4^- , H_2O and O_2 . Since O_2 acts as a scavenger for free radicals, which reacts with primary free radicals thereby lowering the free radical concentration.

Table 3. Effect of reaction temperature on graft copolymerization

Temperature ($^{\circ}\text{C}$)	G (%)	E (%)	A (%)	C (%)	H (%)
25	159.5	54.0	61.5	13.1	46.0
30	169.5	54.9	62.9	14.1	45.1
35	188.0	65.3	65.3	14.3	34.7
40	239.2	66.7	70.5	17.4	33.3
45	220.6	68.5	68.8	14.9	31.5

[AG] = 1.0 g/L, [PMS] = 10×10^{-3} mol/L, [DMA] = 15×10^{-2} mol/L, $[\text{H}^+] = 4 \times 10^{-3}$ mol/L;

[Sarbose] = 1.8×10^{-3} mol/L; Time = 120 min

Effect of Time

To investigate the effect of time on graft copolymerization, the reaction has been carried out by varying the duration of reaction from 60 min to 180 min. The results are given in Table 4. It is found that grafting ratio, add on, conversion and efficiency increase from 60 min to 150 min, and thereafter, these parameters decrease. This is attributed to propagation of grafting chains which takes place due to availability of more active species, which account for the higher grafting. On further increasing the time interval beyond 150 min, all the active sites get exhausted as the mutual annihilation of growing grafted chains occurs, so that grafting parameters decrease.

Table 4. Effect of reaction time on graft copolymerization

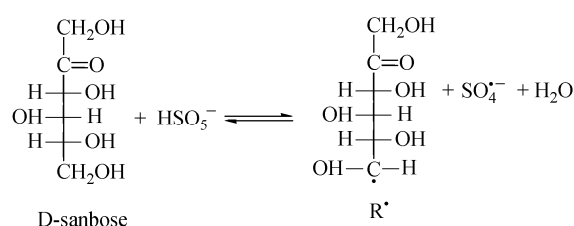
Time (min)	G (%)	E (%)	A (%)	C (%)	H (%)
60	165	55.8	62.3	13.2	44.2
90	173	56.7	63.4	13.8	43.4
120	188	65.3	65.3	14.3	34.7
150	256	68.5	71.9	18.4	31.5
180	240	67.0	70.6	17.4	33.1

[AG] = 1.0 g/L, [PMS] = 10×10^{-3} mol/L, [DMA] = 15×10^{-2} mol/L, $[\text{H}^+] = 4 \times 10^{-3}$ mol/L;

[Sarbose] = 1.8×10^{-3} mol/L; Temperature = 35°C

Mechanism

A tentative mechanism has been proposed on the basis of results obtained. Initially sarbose reacts with PMS (KHSO_5) to give primary free radicals $\text{R}^{\bullet}$ (sarbose radical) and sulphate ion radicals.



These radicals abstract hydrogen atom from the alginate molecules (AOH) to produce radicals of alginate ($\text{AO}^{\bullet}$). The monomer molecules, which are in close vicinity of the reaction sites, become acceptors of radicals of alginate resulting in chain initiation and thereafter themselves become free radical donors to neighboring molecules. In this way grafted chain grows. These grafted chains terminate by coupling to give graft copolymer. The tentative mechanism of graft copolymerization is similar to that in our previous paper^[5].

Evidence of Grafting

IR spectra of alginate and AG-g-PDMAM are shown in Fig. 4. On comparing the IR spectra of alginate and AG-

g-PDMAM, a band at 3452.3 cm^{-1} is due to OH stretching vibration in the spectrum of alginate. It is observed that there are variation in intensity of OH stretching vibration and shifting of this peak from 3452.3 cm^{-1} to 3454.4 cm^{-1} in the spectrum of graft copolymer respectively, indicating the participation of hydroxyl groups in chemical reaction. The graft copolymerization is further confirmed by characteristic absorption bands of tertiary amide at 1638.7 cm^{-1} due to $>\text{C}=\text{O}$ stretching vibration, and at 1113.1 cm^{-1} due to $-\text{CN}$ stretching vibration of monomer molecule respectively. The appearance of additional peaks in spectrum of graft copolymer and shifting of OH stretching vibration band of alginate showed that grafting might have taken place on OH sites of alginate.

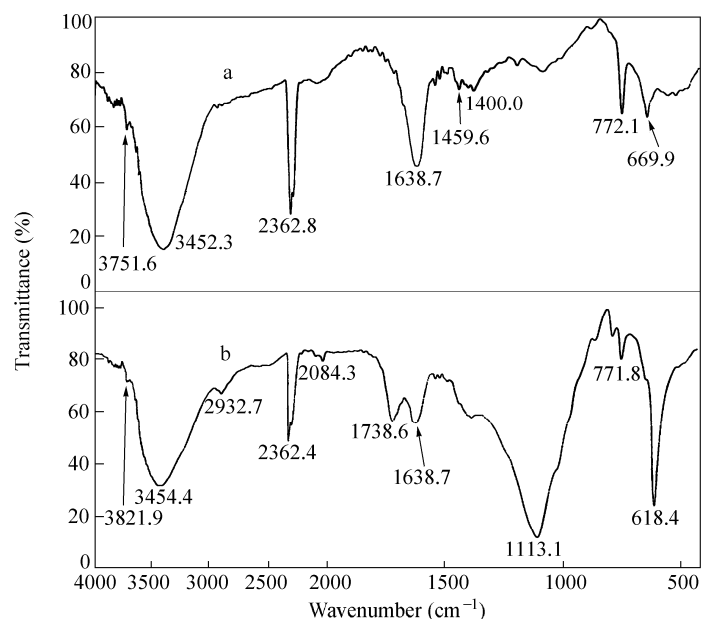


Fig. 4 IR spectra of (a) alginate and (b) AG-g-PDMAM

Thermogravimetric Analysis

Thermogravimetric analysis curve of alginate is presented in Fig. 5. The 0.4% weight loss at 71.4°C might be due to loss of absorbed water. It starts to degrade at 100.0°C . The polymer decomposition temperature (PDT) was found to be at 200.0°C . The rate of weight loss increases with increase at temperatures from 200.0°C to 250.0°C and attains a maximum value at about 252.8°C . T_{max} , temperature at which maximum degradation occurred, is 211.3°C which is also confirmed by the peak appeared in differential thermal analysis curve (DTA) of alginate (Fig. 6). The final decomposition temperature (FDT) and integral procedural decomposition temperature (IPDT) were found at 900.0°C and 267.3°C respectively. But in case of AG-g-PDMAM, the weight loss 2.2% at about 50°C might be due to loss of absorbed water. The PDT was found at 160°C . AG-g-PDMAM (Fig. 5) shows three step degradations. It is found that degradation of AG-g-PDMAM starts at about 100°C temperature (Fig. 6). The rate of weight loss increases with increase in temperature from 105°C to 150°C and thereafter decreases and attains maximum at about 200°C . First T_{max} at 200°C is due to elimination of COO^- groups which is also confirmed by a peak appeared in DTA curve of alginate (Fig. 6). The second T_{max} at 394.9°C is due to elimination of $\text{N}(\text{CH}_3)_2$ groups, confirmed by a peak appeared at about 432.5°C in DTA curve. The third T_{max} at 452.2°C is due to elimination of CO molecule from pendent chains attached to alginate (Scheme 1). The IPDT and FDT were found at about 289.8°C and 1100°C respectively. On comparing the thermograms of parent backbone (alginate) and AG-g-PDMAM, it is observed that the final decomposition and integral procedural decomposition temperatures are found to be higher for graft copolymer. This indicates that the graft copolymer is thermally stable than the backbone.

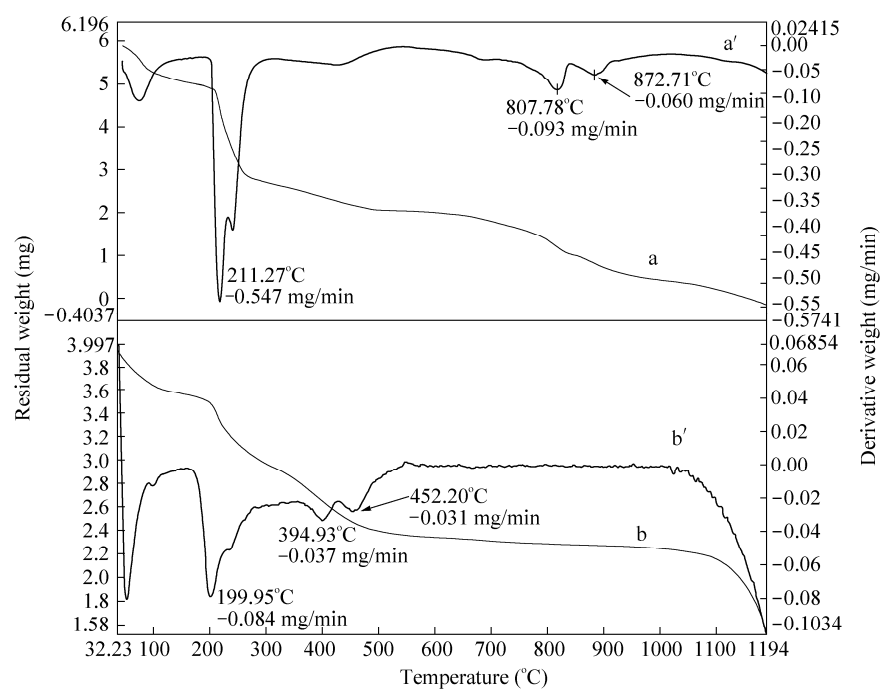


Fig. 5 Thermogravimetric curves of (a, a') alginate and (b, b') AG-g-PDMAM

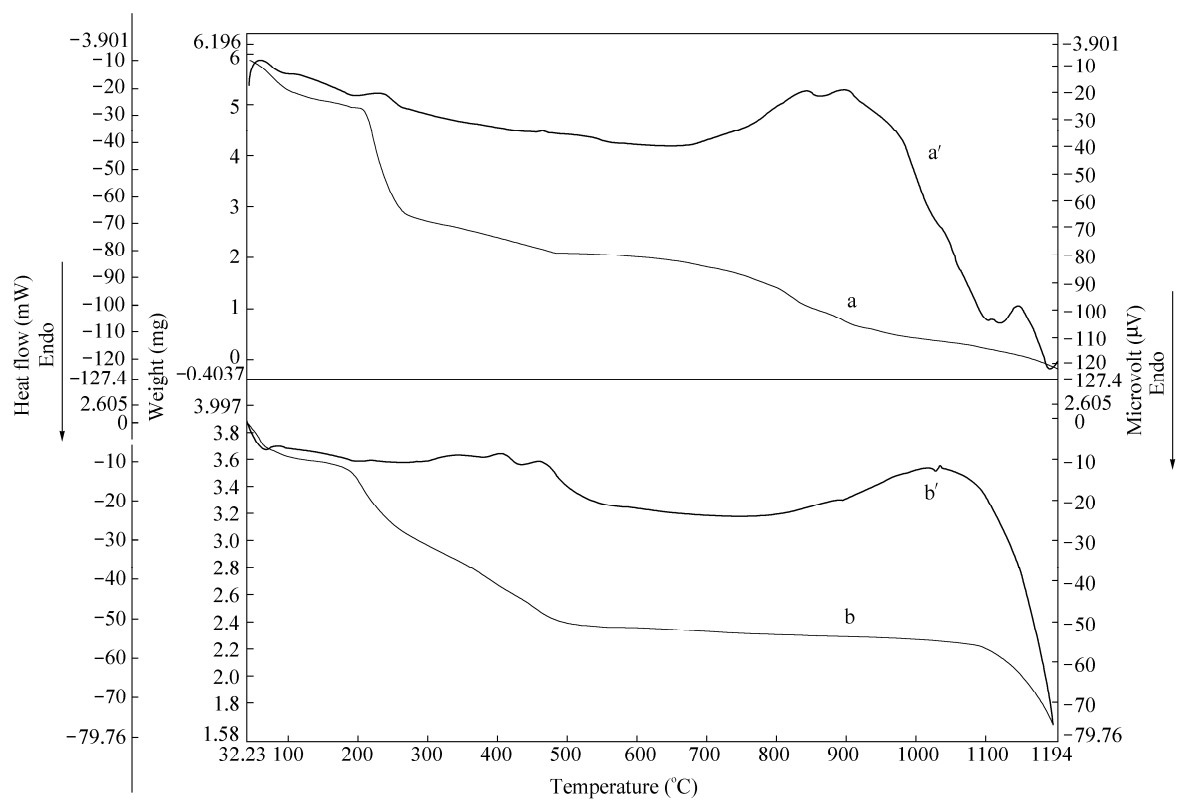
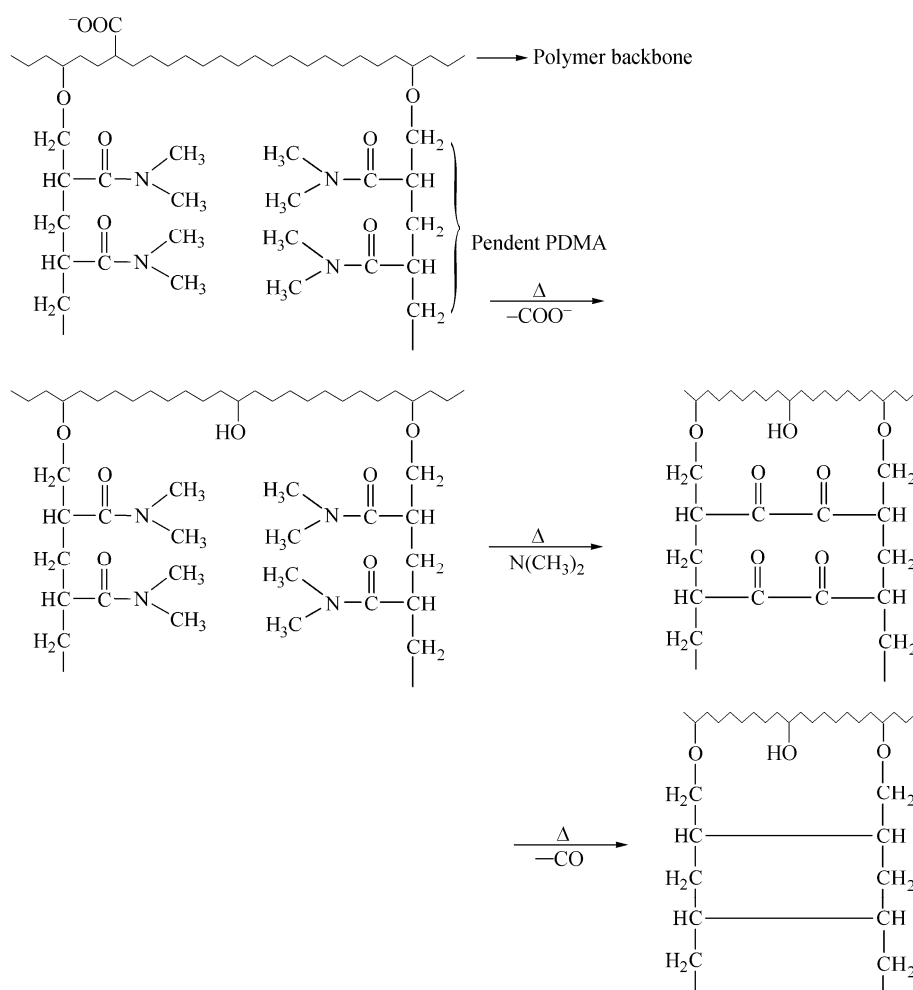


Fig. 6 Differential thermal curves of (a, a') alginate and (b, b') AG-g-PDMAM



Scheme 1 Schematic presentation of degradation steps of graft copolymer

Swelling Behavior of AG-g-PDMAM

An increase in weight of graft copolymer was recorded by performing swelling test. The results are summarized in Table 5, which indicates that swelling ratio and swelling per cent depend on the concentration of monomer used for grafting. Since DMAM is a hydrophilic monomer, it increases the water retention capacity of the graft copolymer. On increasing the concentration of DMAM grafting is increased, which may result in coiling network of PDMAM, thus imbibes more water. The amide group of substrate and a hydrophilic monomer, both factors are responsible for good swelling capacity of the graft copolymer. The swelling per cent is increased with increasing percent grafting because with increasing DMAM concentration, pendant chains of PDMAM grows thereby the swelling capacity of the graft copolymer increases.

Table 5. Swelling capacity of AG-g-PDMAM with different DMAM contents

Sample code	[DMAM] $\times 10^2$ (mol/L)	G (%)	P_s	S_r
A	7	179	390	3.9
B	11	181	480	4.8
C	15	188	610	6.1
D	19	250	720	7.2
E	23	220	580	5.8

[AG] = 1.0 g/L, [PMS] = 10×10^{-3} mol/L, $[\text{H}^+] = 4 \times 10^{-3}$ mol/L, [Sarbose] = 1.8×10^{-3} mol/L;
Temperature = 35°C; Time = 120 min

Metal Ion Sorption Behavior of Alginate and AG-g-PDMAM

The results of sorption behavior of alginate and AG-g-PDMAM were determined in terms of percent ion uptake (P_u), partition coefficient (K_d) and retention capacity (Q_r). The results are given in Table 6. It is observed that the values of P_u , K_d and Q_r increase directly as the percent grafting increases, which might be due to the fact that as grafting increases, the sorption sites for metal ions are increased due to availability of additional functional groups of grafted DMAM, and increment in sorption capacity takes place due to the incorporation of the pendant chain of PDMAM, so greater the grafting, greater will be the sorption of metal ion. Results also show that Pb^{2+} was least uptakable in comparison with Zn^{2+} and Ni^{2+} metal ions.

Table 6. Metal ion sorption behavior of alginate and graft copolymer samples

Sample	[DMA] $\times 10^2$ (mol/L)	G (%)	Partition coefficient (P_u)			Partition coefficient (K_d)			Retention capacity (Q_r)		
			Pb^{2+}	Ni^{2+}	Zn^{2+}	Pb^{2+}	Ni^{2+}	Zn^{2+}	Pb^{2+}	Ni^{2+}	Zn^{2+}
Alginate			3.1	5.1	4.3	16.4	24.1	19.5	2.8	3.5	3.2
A	7	179	4.5	8.0	7.8	21.2	41.5	31.5	3.8	4.8	4.0
B	11	181	5.8	10.5	9.2	43.6	49.3	49.5	4.5	5.7	5.6
C	15	188	7.3	11.5	10.1	49.6	56.8	53.6	5.1	6.2	5.8
D	19	250	10.3	16.5	13.5	51.3	61.5	57.2	5.8	6.8	6.0
E	23	220	11.7	19.2	16.4	56.6	69.9	60.3	5.6	7.4	5.9

[AG] = 1.0 g/L, [PMS] = 10×10^{-3} mol/L, $[H^+] = 4 \times 10^{-3}$ mol/L, [Sarbose] = 1.8×10^{-3} mol/L;
Temperature = 35°C; Time = 120 min

Flocculating Properties

Plots of supernatant turbidity versus polymer dosage for coking and non-coking coals are given in (Fig. 7). It is found that AG-g-PDMAM gives better performance by showing lower turbidity than alginate itself. This phenomenon could be explained by considering bridging mechanism^[22, 23]. In grafted copolymer, the dangling PDMAM chains have better approachability to the contaminant coal particles and hence increase the flocculation capability. The difference in turbidity value in coking coal and noncoking coal in coal suspension is due to difference in negative charge density, which is higher for non-coking coal in aqueous solution^[24]. For flocculation properties there are few recent reports available about the graft copolymers of alginate^[25–27]. Thus, by grafting of PDMAM onto alginate, efficient flocculants have been obtained and it could be used for the treatment of coal wastewater.

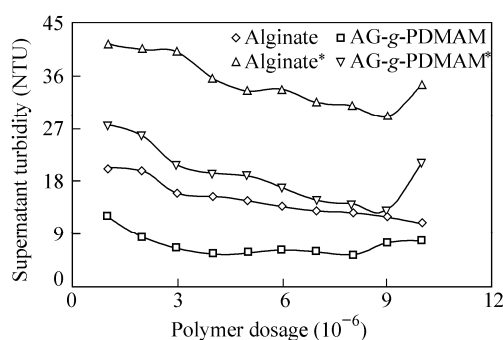


Fig. 7 Effect of polymer dosage on turbidity for coking coal and non coking coal*

CONCLUSIONS

The thermal data show that the synthesized graft copolymer is thermally more stable than the pure alginate. The synthesized graft copolymer *i.e.* AG-g-PDMAM shows better results for swelling and flocculating properties in comparison with alginate, this could be interpreted that the graft copolymer shows the enhancement in these properties. The spectroscopic data confirm that the grafting of DMAM might have taken place at hydroxyl groups,

which is supported by a tentative mechanism suggested for grafting. The thermal analysis data show that the graft copolymer, a hybrid material in which properties of monomer is added by grafting, could be exploited very well industrially.

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