Improvement of Properties of Natural Polymers with Organo–Metallic Complexes under Ultraviolet Radiation

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Received 3 June 1998; accepted 5 September 1998

ABSTRACT: Thin polymer films were prepared under ultraviolet radiation with a triacrylated aliphatic urethane oligomer that was diluted with reactive monomers such as *N*-vinyl pyrrolidone and tripropylene glycol diacrylate. These films were characterized. The effect of incorporation of a minute amount (>0.15%) of a titanium-pyridine complex and its ligands on the characterization of these polymers was investigated. Cotton and jute yarns were treated with the solutions containing these materials under the UV radiation. The change in tensile properties of the treated natural polymers (cotton and jute) was evaluated, and it was found that the titanium-pyridine-based complex substantially enhanced the tensile strengths (tenacity) for both cotton and jute. © 1999 John Wiley & Sons, Inc. J Appl Polym Sci 72: 1131–1138, 1999

Key words: natural polymers; cotton; jute; UV radiation; organo-metallic complex; ligands; modification

INTRODUCTION

Both synthetic and natural polymers are important and indispensable in modern society. They are versatile in their diverse applications, yet there is some limitation. in their applications. Synthetic polymers can be used as a shopping bag as well as a shaft in the skylab. On the other hand, natural polymers can be used from a kitchen napkin to a submarine propeller shaft. Characteristic properties of the synthetic polymers can be modified to the desired applications simply by incorporating the appropriate constituents/ingredients in the starting monomer solutions. However, the synthetic polymers are cursed for their unfriendly nature towards the environment after their end use. On the other hand, natural polymers are biodegradable and ecofriendly; but they have limitations in the diverse

applications with respect to durability, mechanical strength, sustainability, etc. But the combination of both natural and synthetic polymers could bring about a composite that might be quite versatile to meet the desired applications and, at the same time, they can be eco-friendly. With this aim in mind, many people are working to make plastic composite with natural polymers such as cotton, wood, jute, flax, etc. Thus, various products like wood plastic composite,¹ jute plastic composite,² thermoplastics reinforced with jute,³ composites of cotton, silk, and rayon,⁴ are already available. These products are yet to meet the desired applications.

It is known in the chemistry of surface coating that there are certain ingredients that make the coating fire retardant and scratch free with enhanced adhesion to the substrate.⁵ Recently, it was observed that an ethylenediamine-titanium complex substantially increased the tensile strength of jute and cotton threads.⁶ The present investigation reports on the modification of cotton and jute yarns with urethane acrylate under ul-

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Journal of Applied Polymer Science, Vol. 72, 1131-1138 (1999)

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A	ВНА				Pyridine			TiO ₂			Complex		
F	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
C M	$0.00 \\ 5.00$	$\begin{array}{c} 0.05 \\ 4.95 \end{array}$	$\begin{array}{c} 0.10\\ 4.90\end{array}$	$\begin{array}{c} 0.15 \\ 4.85 \end{array}$	$\begin{array}{c} 0.05 \\ 4.95 \end{array}$	$\begin{array}{c} 0.10\\ 4.90\end{array}$	$\begin{array}{c} 0.15 \\ 4.85 \end{array}$	$\begin{array}{c} 0.05 \\ 4.95 \end{array}$	$\begin{array}{c} 0.10\\ 4.90\end{array}$	$\begin{array}{c} 0.15 \\ 4.85 \end{array}$	$\begin{array}{c} 0.05 \\ 4.95 \end{array}$	$\begin{array}{c} 0.10\\ 4.90\end{array}$	$\begin{array}{c} 0.15 \\ 4.85 \end{array}$

Table I Composition of Formulations (% w/w)

F = formulations; A = additives; C = concentrations; M = MEK.

traviolet radiation as well as on the effect of the pyridine-titanium complex, particularly on the modification of these natural polymers.

EXPERIMENTAL

Materials

Jute yarns and white cotton thread were collected from the local market. Ebcryl 264, an urethane triacrylate with aliphatic backbone, tripropylene glycol diacrylate (TPGDA), and *N*-vinyl pyrrolidone (NVP) were procured from Merck Co. (Germany). An antibubbling agent methyl ethyl ketone (MEK) and plasticizer diallyl phthalate (DP) were obtained from Aldrich Chemical Co.

Irgacur 184, a photoinitiator of Ciba-Geigy, was used to initiate radicals under ultraviolet light. Pyridine, benzo-hydroxamic acid (BHA), and titanium oxide (Ti 0_2), procured from BDH Co. Ltd. (UK), were used as ligands to synthesize the titanium-pyridine complex in the laboratory⁷ as well as to study their effect on the properties of the natural polymers.

Method

The urethane acrylate (UA) oligomer (Ebcryl 264) was diluted with the reactive monomer diluents (NVP and TPGDA) in the presence of plasticizer (DP), antibubbler (MEK), and photoinitiator (PI) in such a way that their proportions were as follows: UA : NVP : TPGDA : DP : PI : MEK = 45 : 20 : 18 : 9 : 3 : 5, w/w. In the preparation of subsequent formulations, the proportion of MEK was adjusted with the concentrations (e.g., 0.05, 0.1 and 0.15%) of the Ti complex and its ligands (BHA, Pyridine, and TiO₂), as shown in Table I. Only these three concentrations (0.05, 0.10, and 0.15) of the complex and ligands were chosen for study, because the Ti complex with ethylenediamine showed⁶ the maximum enhancement in dif-

ferent properties when their concentrations were 0.10% in the formulation.

Thin Films

The above formulations were used to prepare thin films by coating glass plate ($10 \times 8 \times 0.2$ cm) with these solutions using a bar coater No. 018 of Abbey Chemicals Co. (Australia). Thickness of the films was about $36 \pm 3 \mu$ m. The coating was irradiated under ultraviolet rays obtained from a Minicure 200-UV radiation unit of 1ST Technik (Germany). The unit has a 2-kW light intensity at 254–313 nm. The conveyor speed was 4 m/min. The UV cured films were characterized.

The hardness of the cured films was determined after 24 h of the irradiation of the films by using a Pendulum Hardness Tester (model 5854, BYK Labotron, Germany). The gel content was measured by the solvent extraction method; a known weight of the cured film was wrapped up in a stainless steel net that was put into a soxhlet and was extracted with hot benzene for 48 h. The loss in weight of the cured film after the extraction lead to the determination of the gel.

The tensile properties such as strength T_S and elongation at break E_b of the cured films were measured using a tensile property measurement machine INSTRON (model 1011, UK) with a crosshead speed of 0.003 m/min; gauge length was 1.2 cm. The INSTRON is within $\pm 1\%$ efficiency.

Application on Substrates

The substrates (jute and cotton threads) were pulled through the solution contained in a beaker with the help of a pulley at a speed of 4 m/min. and then irradiated under the UV lamp described above. Polymer loading (P_L) with the substrates was determined. The samples (15 cm) so prepared were used for measurement of their different properties. The INSTRON machine was used to measure tensile properties of both treated and

A		BHA			Pyridine			TiO ₂			Complex		
F	P1	P2	$\mathbf{P3}$	P4	P5	P6	$\mathbf{P7}$	P8	P9	P10	P11	P12	P13
С	0.00	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15
NP													
2	31	26	29	31	25	28	26	22	35	27	32	31	30
4	47	32	31	34	36	35	37	36	38	34	35	44	46
6	51	41	45	43	41	42	38	41	45	43	53	58	53
8	41	40	39	41	39	40	38	37	42	40	47	57	53
10	41	31	37	36	39	37	28	37	40	36	40	48	45
12	37	34	36	30	35	30	26	31	35	31	40	48	49

Table II % Pendulum Hardness of UV-Cured Films Containing Different Additives

F =formulations; A =additives; C =concentrations; NP =number of passes.

untreated substrates using the self-tighting grips. Water uptake of the substrates was carried out by immersing the samples with suitable weight in water contained in a static bath at 25°C. Amount of water uptake was periodically monitored by taking the wet samples out of the bath and taking its weights after dabbing them with tissue paper for 10 s. The amount of water uptake was calculated as % water uptake = 100 $(W_t - W_o)/W_o$, where W_t is the weight of wet samples at any time, and W_o is the weight of the sample before immersion. The samples were kept immersed for about 6 h.

RESULTS AND DISCUSSION

Thin polymer films prepared with the formulated solutions using UV radiation were characterized and then the substrates (cotton and jute yarns) were treated with these solutions and irradiated under the same UV lamp. Various properties of the films and the treated substrates were studied and are described below.

Characterization of Polymer Films

Film Hardness

UV-cured films obtained on glass plates were used to measure film hardness by a pendulum method. The results of the pendulum hardness of the different films containing additives at different concentrations (0.05–0.15%) are shown in Table II. The P1 films do not contain any ligand or complex. Pendulum hardness (P_{H}) of the films increases with UV radiation and becomes maximum sectors.

mum at the sixth pass under the UV lamp and then decreases. The decrease in P_H could be caused due to the degradation of polymer at the surface with high radiation. Although the ligands $(BHA, pyridine and TiO_2)$ have suppressed the film hardness, the complex has enhanced the hardness. This indicates that the complex may have been associated with a polymerization process that increases crosslinking density, which is considered to be an index of hardness on the surface. The UV dose delivered with six passes to the coating yields the maximum P_H values in each case. The UV intensities with six passes required for obtaining the maximum curing of the films appear to be high in consideration to the output (2) kW) of the UV lamp used. The lamp is an old one, and its output may have been reduced during the long period of its use. It is also observed that the highest P_H values are obtained when concentration of each additive is 0.1%, and beyond this concentration the P_H values are decreased. The film P12 containing the complex at 0.1% has registered the highest P_H value at the sixth pass among the P_H values obtained at the sixth passes with other films containing different ligands. The P_H values are also decreased when the films are irradiated with UV intensities higher than six passes; the decrease could be associated with surface damage caused at higher irradiation.

Gel Content

Gel content of each film obtained at different UV passes is given in Table III. The results vary between 90 and 99%, depending on the type of films and UV dose represented by the number of passes. Gel content at 90% and above with two

A	А		BHA			Pyridine			${\rm TiO}_2$			Complex		
\mathbf{F}	P1	P2	$\mathbf{P3}$	P4	P5	P6	$\mathbf{P7}$	P8	P9	P10	P11	P12	P13	
С	0.00	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15	
NP														
2	95	92	91	92	92	94	94	90	91	91	95	93	95	
4	96	94	97	95	96	97	96	93	94	93	96	97	96	
6	99	94	97	95	95	96	94	92	94	93	96	96	96	
8	96	93	96	94	94	93	94	92	94	92	95	96	94	
10	95	93	94	94	92	92	91	91	93	92	93	94	93	
12	94	90	92	93	92	90	91	90	94	91	93	91	93	

Table III % Gel Content of the UV-Cured Films Containing Different Additives

F = formulations; A = additives; C = concentrations; NP = number of passes.

passes under UV radiation indicates that the polymerization process is quite fast. This means that the oligomer, the reactive diluents, and the additives are quite favorable for the crosslinking process. The highest gel contents are obtained with the films that contain 0.1% additives in each of the respective series. The UV radiation after the sixth pass may have damaged the films, and that may have caused reduction in gel content after the sixth pass in each case.

Tensile Properties

Tensile strengths T_S of different films at various passes are given in Table IV. The maximum T_S value of film P1 is obtained at the sixth pass, after

					Tens	ile Strer	ngth (kg/	cm ²)					
A		BHA			Pyridine			${ m TiO}_2$			Complex		
\mathbf{F}	P1	P2	P3	P4	P5	P6	$\mathbf{P7}$	P8	P9	P10	P11	P12	P13
С	0.00	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15
NP													
2	3.17	3.40	3.74	3.24	2.75	3.95	2.96	2.11	5.29	4.30	2.98	3.24	3.17
4	3.30	4.44	5.71	4.93	4.23	5.00	4.41	5.64	6.27	6.06	4.48	8.85	6.20
6	4.44	4.23	4.65	3.74	3.95	4.37	3.88	3.74	5.00	5.36	3.74	5.36	3.74
8	3.52	2.95	4.65	3.52	3.38	3.74	3.03	4.23	3.73	4.93	3.74	4.86	3.31
10	3.52	3.24	3.45	3.10	2.75	3.45	3.03	3.03	3.73	4.30	3.45	3.74	2.82
12	3.60	2.13	3.17	2.82	3.13	3.13	2.90	2.82	3.52	4.30	3.54	4.02	2.82
					%]	Elongati	on at bre	eak					
NP													
2	10	12	12	8	8	10	8	12	14	13	10	10	9
4	11	13	14	12	12	13	12	14	15	15	16	17	12
6	13	13	14	9	10	13	10	14	14	13	13	14	9
8	10	12	13	10	8	12	8	11	12	13	13	14	9
10	10	12	10	8	8	10	8	10	12	12	10	13	8
12	11	11	11	8	7	8	8	10	11	10	8	12	6

Table IV % Tensile Properties of the UV-Cured Films Containing Different Additives

F =formulations; A =additives; C =concentrations; NP =number of passes.

						Tenacity	y Factor							
A	Α		BHA			Pyridine			${ m TiO}_2$			Complex		
F	P1	P2	P3	P4	P5	P6	$\mathbf{P7}$	P8	P9	P10	P11	P12	P13	
С	0.00	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15	
NP														
2	1.0	1.08	1.02	1.09	1.08	1.04	1.08	1.08	1.0	1.02	1.33	1.33	1.34	
4	1.2	1.40	1.50	1.30	1.36	1.44	1.26	1.28	1.42	1.23	1.44	1.67	1.55	
6	1.25	1.30	1.38	1.23	1.28	1.36	1.21	1.15	1.14	1.20	1.37	1.44	1.38	
8	1.22	1.26	1.32	1.23	1.24	1.22	1.15	1.12	1.23	1.16	1.43	1.43	1.41	
10	1.11	1.13	1.21	1.07	1.14	1.10	1.15	1.12	1.30	1.13	1.20	1.27	1.44	
12	1.11	1.13	1.08	1.06	1.14	1.05	1.13	1.08	1.30	1.06	1.19	1.16	1.23	
					I	Elongatio	on Factor	r						
NP														
2	1.02	1.30	1.42	1.36	1.18	1.21	1.15	1.16	1.43	1.34	1.63	1.44	1.63	
4	1.45	1.74	1.94	1.78	1.71	1.90	1.80	1.76	1.89	1.81	1.85	2.05	1.89	
6	1.60	1.74	1.86	1.69	1.62	1.73	1.80	1.58	1.84	1.68	1.76	1.70	1.72	
8	1.60	1.61	1.76	1.49	1.62	1.54	1.49	1.48	1.74	1.55	1.76	1.61	1.72	
10	1.42	1.58	1.67	1.49	1.31	1.44	1.33	1.29	1.55	1.45	1.27	1.44	1.92	
12	1.42	1.34	1.59	1.40	1.28	1.44	1.15	1.29	1.71	1.45	1.27	1.41	1.54	

Table V Tensile Properties of the UV-Cured Cotton Composite

F = formulation; C = concentration; A = additive; NP = number of passes.

which the film strength decreases, indicating eventual film damage at higher radiation doses. The film strength has substantially been enhanced after incorporation of additives (ligands and complex), indicating involvement of the additives in the polymer formation process. The maximum T_S values are attained at the fourth pass in each case of films P2 to P13. This means that the additives have played some role to reduce the amount of radiation required for attaining the maximum curing; this leads to a lower cost of radiation; at the same time, the additive has increased the film strength. The highest T_S value is obtained in the presence of the Ti complex at 0.1% concentration. The T_S value of film P12 is double the T_S value of the film P1. This is a significant achievement. TiO_2 has also increased the T_S value of the film by one and a half times the T_S of P1.

The film containing the complex also has the highest elongation E_b at 0.1% concentration (Table IV). TiO₂ has induced the second highest E_b . The stretching ability of other films containing BHA and Pyridine is not changed much. The maximum E_b values are obtained at the fourth pass in

the presence of additives. Enhancement of both film strength and elongation is a good sign for a film that can be considered for diverse applications.

On having characterized the polymer films made with the formulated solutions, these were used to treat cellulose substrates like cotton and jute with an aim to improve their properties.

Application on Cotton

Cotton thread soaked into the above formulated solutions was irradiated with UV light at different doses represented by number of passes. Enhancement of tenacity of the treated cotton is expressed as tenacity factor T_f , that is, the ratio of tenacity of the treated sample T_{St} to that of the untreated cotton T_{So} . This means $T_f = T_{St}/T_{So}$. The T_f values thus obtained for all the films (P1–P13) at different passes are shown in Table V. The maximum T_f values are obtained at the fourth pass for all samples except the sample treated with formulation P1 (without any additive), which yields the maximum tenacity at the sixth pass. The highest T_S values are obtained at

0.1% concentration in each case of additives. It is observed that the treatment of cotton thread with formulation P1 has increased the tenacity by 25% at the sixth pass. The tenacity has been further enhanced when the ligands (BHA, Pyridine, and TiO_2) and complex were added to the formulation P1, and in that case, the maximum tenacity was obtained at the fourth pass in each case of additives. The highest tenacity T_f was obtained at the 0.1% concentration in the corresponding series of ligands and complex. Thus, BHA increased tenacity by 50% (T_f = 1.50), pyridine by 44% (T_f = 1.44), TiO₂ by 42% (T_f = 1.42), and the Ti-pyridine complex by 67% (T_f = 1.67). It was also observed in Table V that the tenacity of cotton treated with each of these additives has been increased irrespective of their concentration in the formulation. The highest tenacity is imparted by the presence of the Ti-pyridine complex, followed by BHA, pyridine, and Ti0₂.

Cotton thread has gained enhanced stretching ability as a result of the composite formation with the formulation P1. The maximum elongation achieved is 60% ($E_f = 1.60$) at the sixth pass. Elongation factors expressed as $E_f = Eb_{\text{treated}}/$ $Eb_{\text{untreated}}$ are determined for all the other samples treated with 12 different formulations at different passes. The results are given in Table V. Enhanced elongation has been reduced slightly after the sixth pass with an increase of UV radiation. The maximum elongation is obtained at the fourth pass in the presence of each additive. The highest elongation is achieved in the presence of the complex. It is significant that the cotton thread can be stretched by 105% ($E_f = 2.05$) more, when the cotton composite is made with only 0.1%of the Ti-pyridine complex. With each additive, the highest elongation is obtained at 0.1% concentration in the respective series. At the enhancement of tenacity by 67% and elongation by 105%, it is possible that the Ti complex has entered into the cotton cellulose backbone during the polymerization process of the oligomer with the cellulose backbone in the presence of other reactive monomers (NVP and TPGDA) under the UV radiation.

Water Uptake

Water uptake was determined for both treated and untreated cotton samples, soaked in water for about 6 h at 25°C. There was rapid uptake of water at the initial period (1 h), after which it was slow and then eventually an equilibrium condition was attained within 3 h (Fig. 1). The sample

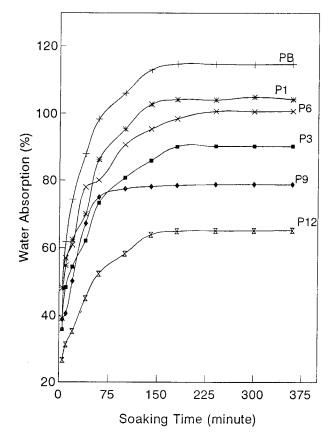


Figure 1 Water absorption of treated and untreated cotton against soaking time.

treated with the Ti-pyridine complex (P12) has the least water uptake (about 60%). The highest water absorption is obviously by the virgin cotton sample. When TiO₂ was added to the formulation, the water absorption was less than 80%. The organo-metallic complex may have occupied void space as well as OH groups present in the cellulose. But this needs further investigation. The trend of water absorption by cotton samples treated with different formulations is P12 < P9< P3 < P6 < P1 in order of the lowest to the highest water absorption. Because OH groups of the cellulose backbone chain of the treated samples are mostly occupied with moieties of ligands, complex, monomers, or additives, there is very little chance for the water molecule to be associated or absorbed with the cellulose moiety. Thus, the treated samples show less water absorption than the untreated samples.

Application on Jute

Jute yarn was treated with the solutions of the above 13 formulations and cured under UV radi-

						Tenacity	y Factor							
A			BHA			Pyridine			${ m TiO}_2$			Complex		
F	P1	P2	P3	P4	P5	P6	$\mathbf{P7}$	P8	P9	P10	P11	P12	P13	
С	0.00	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15	
NP														
2	1.09	1.04	1.0	1.41	1.09	1.38	1.13	1.02	1.04	1.00	2.07	2.14	2.25	
4	1.08	1.62	1.84	1.50	1.52	1.66	1.26	2.35	2.44	2.28	2.92	3.22	2.92	
6	1.25	1.62	1.71	1.10	1.48	1.46	1.26	1.81	1.88	2.15	2.62	2.52	2.58	
8	1.25	1.41	1.47	1.10	1.57	1.24	1.21	2.20	1.79	1.63	2.21	2.52	2.48	
10	1.13	1.25	1.46	1.06	1.07	1.21	1.02	2.27	1.14	1.63	1.91	2.32	2.45	
12	1.08	1.28	1.25	1.04	1.40	1.21	1.02	1.14	1.14	1.34	1.81	2.32	2.40	
					1	Elongatio	on Factor	r						
NP														
2	0.86	1.00	0.87	1.11	1.01	1.22	1.16	1.00	0.85	1.10	1.49	1.52	1.39	
4	1.03	1.28	1.56	1.46	1.38	1.43	1.33	1.41	1.47	1.39	1.84	1.96	1.89	
6	1.35	1.23	1.20	1.35	1.32	1.33	1.28	1.41	1.44	1.38	1.65	1.56	1.61	
8	1.22	1.16	1.12	1.22	1.24	1.11	1.29	1.32	1.33	1.26	1.53	1.58	1.53	
10	1.17	1.09	1.08	1.16	1.17	1.09	1.18	1.21	1.31	1.22	1.36	1.44	1.48	
12	1.15	1.21	1.00	1.02	1.17	1.09	1.20	1.10	1.32	1.22	1.17	1.44	1.44	

Table VI Tensile Properties of the UV-Cured Jute Yarn

F = formulation; A = additive; C = concentration; and NP = number of passes.

ation at different passes. Tensile properties (both tenacity and elongation at break) were measured and are given in Table VI in the form of tenacity factor, T_f , and elongation factor, E_f . The tenacity of treated jute yarn has increased by 25% (T_f = 1.25) at the sixth pass, with the formulation P1 like that of the treated cotton (Table V). However, the tenacity increment is 50-84% ($T_f = 1.50-$ 1.84) for BHA, 26–66% ($T_f = 1.26$ –1.66) for pyridine, 128-144% ($T_f = 2.28-2.44$) for TiO₂, and 192–222% ($T_f = 2.92-3.22$) for the complex, depending on the proportion of the different additives used. The enhancement was maximum at the fourth pass in the presence of each additive. The highest tenacity $(T_f = 3.22)$ is obtained with the complex (P12).

Similarly, the highest elongation, 96% ($E_f = 1.96$) is obtained with jute yarn in the presence of the complex at the fourth pass with formulation P12 (Table VI). The highest elongation was achieved with 0.1% each of the additives of the corresponding series. The increment of elongation from 35% ($E_f = 1.35$ for P1) to 96% is important and significant.

Water Uptake

Both treated and untreated jute samples were immersed in water for 6 h at 25°C. The amount of water taken up by different samples is plotted in Figure 2 against the time of immersion. The water absorption is quick during the initial soaking period. The untreated virgin jute sample attained the highest water absorption (115%). The lowest absorption is shown by the sample containing the complex. This is similar to the observation with cotton sample. Treated jute samples (Fig. 2) have shown a relatively high amount of water absorption compared to the corresponding cotton samples (Fig. 1). The reason for less water absorption with the treated samples can be similarly explained as in the case of cotton samples above.

CONCLUSION

Polymer films obtained under UV radiation with Ebcryl urethane acrylate combined with reactive diluent monomers have attained increased film hardness and tensile strength T_S in the presence

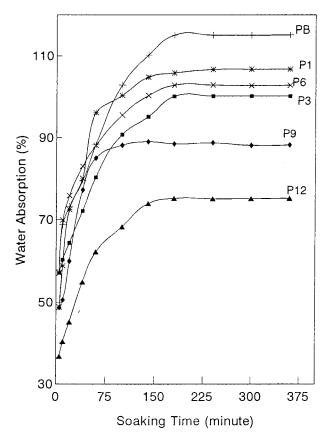


Figure 2 Water absorption of treated and untreated jute against soaking time.

of a Ti–pyridine complex and its ligands (BHA, Pyridine, and TiO₂). The increment of T_S of the UV-cured film by twofold in the presence of the Ti complex is quite significant.

When natural fibers (jute and cotton) were treated with the solutions formulated in this investigation and irradiated under a UV lamp, the enhancement of tenacity and elongation at break is substantial for both cotton and jute; this is more so in the presence of the Ti complex and the ligands. Cotton thread has attained tenacity increment upto 67%, with stretching ability by 105% in the presence of the Ti complex. Similarly, tenacity enhancement of jute yarn is up to 114%, and that of elongation is about 96% in the presence of the Ti complex. The treatment of natural fiber with an organo-metallic complex is an important study. This will open a new area for finding diverse applications of cotton and jute.

REFERENCES

- Husain, M. M.; Khan, M. A.; Idriss Ali, K. M.; Hossain, A. Y. M. Radiat Phys Chem 1995, 45, 623.
- Khan, M. A.; Uddin, M. K.; Islam, M. N.; Idriss Ali, K. M. J Appl Polym Sci 1995, 58, 31.
- Karmaker, A. C.; Hinrichsan, G. Polym Technol Eng 1991, 30, 609.
- Bashar, A. S.; Khan, M. A.; Idriss Ali, K. M. Radiat Phys Chem 1995, 45, 735.
- 5. Khan, M. A.; Rahman, M.; Idriss Ali, K. M. Polym Technol Eng, to appear.
- Zaman, M. H.; Khan, M. A.; Idriss Ali, K. M. J Appl Polym Sci 1997, 65, 1571.
- Zaman, M. H.; Mustafa, A. I.; Hossain, M. Dhaka Univ J Sci 1995, 43, 215.