

A new UV-curable PU resin obtained through a nonisocyanate process and used as a hydrophilic textile treatment

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Abstract A new UV-curable hydrophilic PU resin was obtained through a green, nonisocyanate, three-reaction process: (1) a bis(cyclic carbonate) (BCC) compound is prepared by inserting carbon dioxide into an epoxy resin (DGEBA) at atmospheric pressure; (2) an amino-terminated hydrophilic PU (NH_2 -PU) oligomer is obtained through the ring-opening polymerization of BCC utilizing a difunctional amino hydrophilic (polyether) compound such as Jeffamine D-2000; (3) the UV-curable acrylate-PU (UV-PU) prepolymer is obtained as an adduct from the Michael addition of NH_2 -PU to a diacrylate-terminated compound, 3-acryloyloxy-2-hydroxypropyl methacrylate (AHM). A polyester (PET) textile was treated with this hydrophilic UV-PU prepolymer and then cured by irradiation with UV light. The UV-PU resin was found to crosslink and anchor to the textile fibers after UV

irradiation, resulting in a long-lasting hydrophilic surface for the treated textile. The performance properties of the new PU resin on the treated textile were investigated.

Keywords Nonisocyanate process · Cyclic carbonate · Hydrophilic · PU · UV curing

Introduction

Polyurethane (PU) has been widely accepted by the market for a number of decades. Due to its diverse properties, it can be tailor-made from various available raw materials [1]. Furthermore, functionalizing PU with reactive groups such as epoxy, amine, isocyanate, acrylate, or carboxylic acid groups facilitates the generation of modified polymer resins. These modified PU resins have been used for various applications [2–11]. Both traditional and functionalized PU resins are prepared using the conventional process, which employs polyisocyanates and polyols as raw materials. However, the manufacture of polyisocyanates has become of great public concern, as the process involves handling the toxic substance polyisocyanate and its phosgene intermediate. Therefore, a method of preparing PU using a nonisocyanate process is urgently required.

Poly(hydroxyurethane)s are obtained via the ring-opening reaction of bis(cyclic carbonate) (BCC; synthesized from bisphenol A diglycidyl ether and carbon dioxide) with diamine [12–16]. The average molecular weight of the resulting poly(hydroxyurethane)s ranges from 10,000 to 21,900 g/mol. Recently, we discovered that the ring-opening reaction of BCC with a hydrophilic diamine (e.g., Jeffamine D-2000) in a solvent (e.g., ethyl lactate) can lead to an amino-terminated PU oligomer (NH_2 -PU) with a high amino/carbonate ratio (>1.5). The NH_2 -PU has a hydrophilic moiety and an average molecular weight of around 20,000 g/mol ($D=1.3$).

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NH₂-PU is a linear PU oligomer with poor mechanical, physical, and thermal properties. Therefore, it is necessary to further modify NH₂-PU to create polymers that are useful for particular applications [17–24]. In the work described in this paper, the terminal amino group of NH₂-PU was converted into an acrylate group, and this acrylate-terminated PU was used to create UV-curable PU (UV-PU). This UV-PU—synthesized via a nonisocyanate process—was applied onto a hydrophilic textile (e.g., PET) surface and then cured by UV irradiation [25], which caused the UV-PU to cross-link and anchor itself to the textile. The resulting treated PET textile was found to possess long-lasting hydrophilic properties due to the presence of the networked hydrophilic PU structure linking the fibers [26–30].

Experimental

Materials

2,2-Bis(4-glycidyloxyphenyl) propane (DGEBA), *n*-propyl amine (*n*-PA), and 3-acryloyloxy-2-hydroxypropyl methacrylate (AHM) were supplied by TCI Chemical Co. (Tokyo, Japan). Carbon dioxide was supplied by San Fu Chemical Co. (Taipei, Taiwan). Lithium chloride (LiCl), lithium bromide (LiBr), methyl methacrylate (MMA), methyl acrylate (MA), tripropylene glycol diacrylate (TPGDA), and ethyl acetate (EA) were supplied by Acros Organics (Geel, Belgium). Jeffamine D-2000 (with an average molecular weight of 2000 g/mol) was obtained from Huntsman (Houston, TX, USA). Triethylamine (TEA), tetrahydrofuran (THF), dichloromethane (DCM), acetone, and ethyl lactate (EL) were obtained from Tedia (Fairfield, OH, USA). All solvents were purified before use using the standard method.

Instruments

Thermogravimetric data were obtained using a high-resolution TGA 2950 TG-DTA thermogravimetric analyzer (TA Instruments, New Castle, DE, USA). Each sample was heated at a rate of 10 °C /min under a nitrogen atmosphere. The contact angle of a pure water droplet on the dried PU film was measured using a FACE contact angle meter (model CA-A, Kyowa Kaimenkagaku Co., Ltd., Tokyo, Japan). The molecular weight distribution of the sample was measured by gel permeation chromatography (GPC) in DMF (models JD-802 and KD-804, Shodex Co., Ltd., Tokyo, Japan). Each sample was analyzed at a flow rate 1.0 ml/min and a temperature of 35 °C. Infrared spectra were measured using an FT-720 FTIR (Horiba, Kyoto, Japan). Each IR spectrum was measured with a resolution of 4 cm⁻¹. FT-NMR spectra were recorded using an AC-300 spectrometer (Bruker, Rheinstetten, Germany). Chemical

shifts are reported in ppm relative to residual CHCl₃ (δ =7.26 for ¹H; δ =77.0 for ¹³C).

Preparation of bis(cyclic carbonate) (BCC)

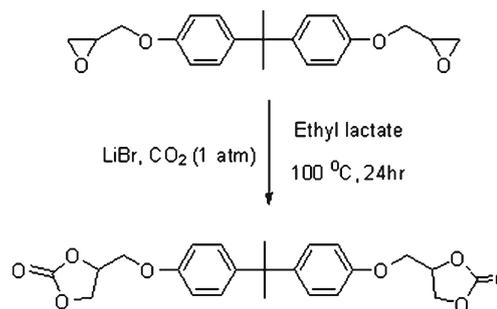
The bis(cyclic carbonate) (BCC) was prepared as follows (see Scheme 1). The epoxy resin 2,2-bis(4-glycidyloxyphenyl)propane (DGEBA; 0.5 mol) and LiBr (5 mol%) were mixed in a 500 mL four-necked reaction flask, and ethyl lactate (EL) (100 ml) was added. The reaction flask was equipped with a mechanical stirrer, a thermometer, a CO₂ bubbling tube, and a condenser with a CaCl₂ drying tube. The reaction mixture was kept at 100 °C for 24 h under atmospheric pressure until the absorption peak of oxirane at 910 cm⁻¹ disappeared and that of cyclic carbonate at 1800 cm⁻¹ appeared in the FT-IR spectrum (Fig. 1b). The reaction mixture was cooled and a white solid (BBC) precipitated out. The BBC was then washed with deionized water (in order to remove the LiBr) and acetone, dried under vacuum, and finally BCC was obtained with an 80% yield. Its ¹H NMR and ¹³C NMR spectra are shown in Figs. 2b and 3b, respectively.

¹H NMR (CDCl₃, 300 MHz, ppm): 1.65 (*s*, 6H), 4.12 and 4.20 (*m*, 4H), 4.59 (*m*, 4H), 5.02 (*s*, 2H), 6.81 (*d*, 4H), 7.12 (*d*, 4H).

¹³C NMR (CDCl₃, 60 MHz, ppm): 31.2, 42.1, 66.5, 67.2, 74.3, 114.2, 128.1, 144.5, 154.8, 155.9.

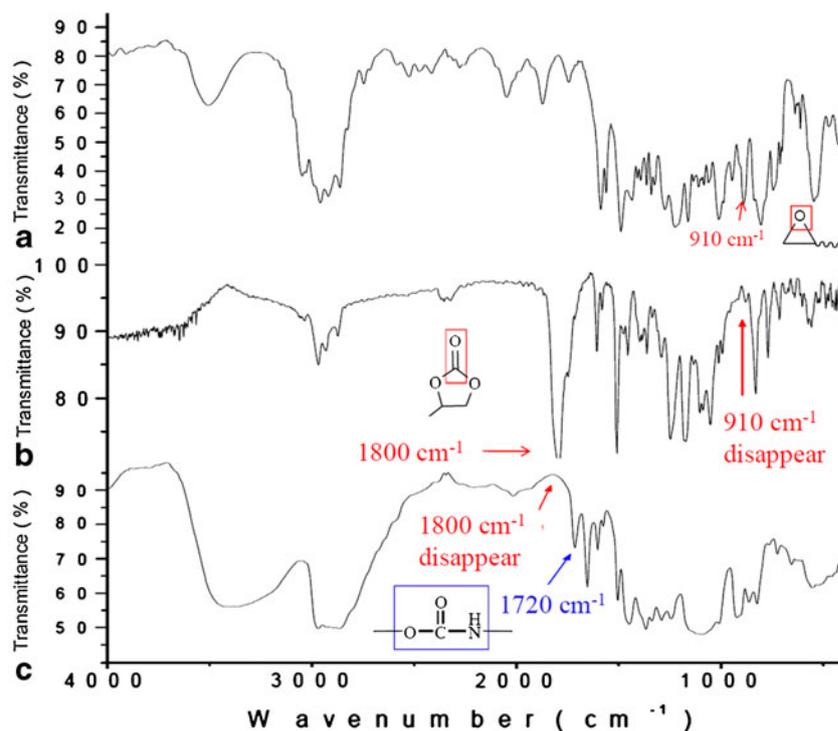
Amino-terminated PU (NH₂-PU) oligomer from BCC and diamine

The NH₂-PU was prepared in the following manner (see Scheme 2). A 300 ml ethyl acetate solution consisting of BCC (0.2 mol), a diamine (e.g., Jeffamine D-2000; 0.3 mol), and LiCl (5 mol%) were mixed in a 1 L three-necked round-bottom flask. The reaction flask was equipped with a magnetic stirrer, a thermometer, an N₂ inlet, and a condenser with a CaCl₂ drying tube. The reaction mixture was maintained at 130 °C for 48 h, until the absorption peak of carbonate carbonyl (at 1800 cm⁻¹) had disappeared and that of urethane carbonyl had appeared at 1720 cm⁻¹ in the FT-IR spectrum (Fig. 1c). The reaction mixture was then



Scheme 1 Preparation of bis(cyclic carbonate) (BCC)

Fig. 1a–c FT-IR spectra of **a** DGEBA, **b** BCC, and **c** NH₂-PU



washed with deionized water (in order to remove LiCl) and dried with anhydrous magnesium sulfate. An amino-terminated PU (NH₂-PU) oligomer was obtained after the solvent (EA) was removed under reduced pressure.

Model reaction of amine with acrylate monomer via Michael addition

A 500 ml three-necked round-bottom flask was equipped with a magnetic stirrer, an N₂ inlet, and a condenser with a CaCl₂ drying tube. A mixture of methyl methacrylate (MMA) (0.2 mol), methyl acrylate (MA) (0.2 mol), and triethylamine (TEA) (5 mol%) was kept in an ice bath, and

then *n*-propylamine (n-PA) (0.5 mol) was added slowly and the reaction mixture was maintained at 0 °C for 0.5 h. The reaction mixture was then stirred at ambient temperature for an extra 12 h to complete the reaction. A solvent, dichloromethane (DCM, 50 ml), was added, and the mixture was washed with 50 ml 0.1 M HCl solution and then 100 ml deionized water (in order to remove excess n-PA and catalyst). The solvent (DCM) was removed under reduced pressure. The yield was more than 95%, and the Michael addition reaction product of n-PA with MA (no MMA addition product was found) is shown in Scheme 3, while its ¹H NMR and ¹³C NMR spectra can be viewed in Figs. 4c and 5c, respectively.

Fig. 2a–b ¹H NMR spectra of **a** DGEBA and **b** BCC

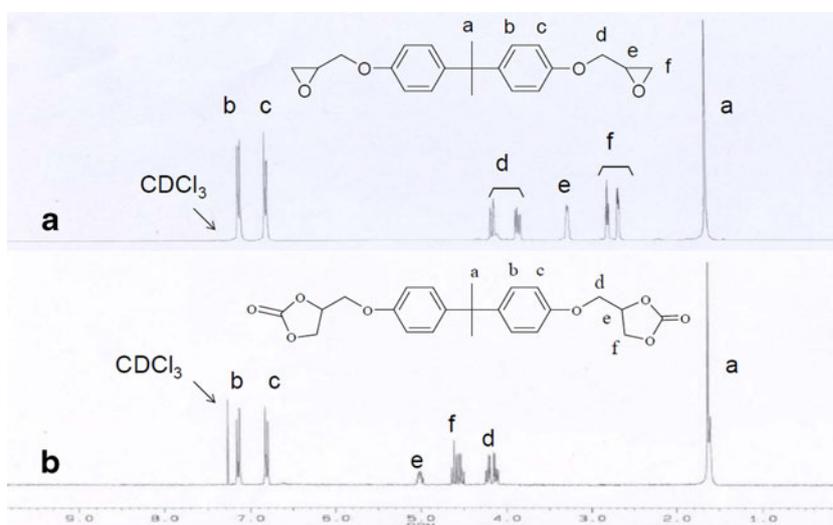
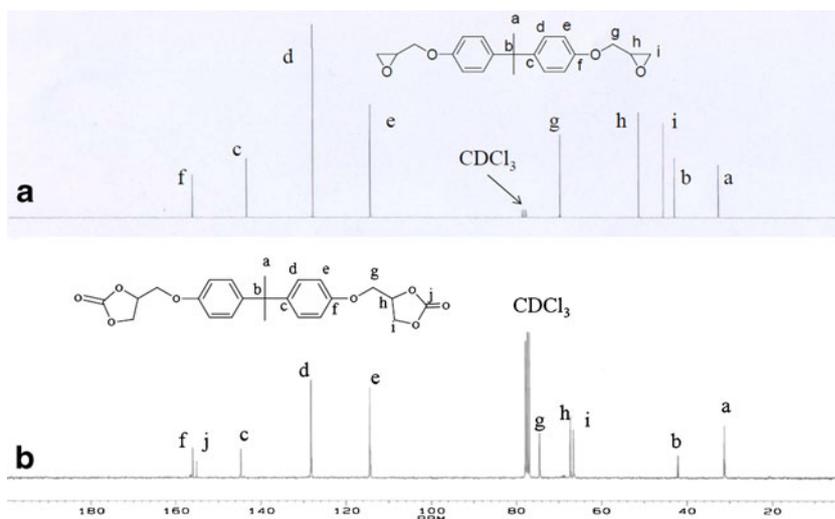


Fig. 3a–b ^{13}C NMR spectra of **a** DGEBA and **b** BCC



^1H NMR (CDCl_3 , 300 MHz, ppm): 0.85 (*t*, 3H), 1.45 (*m*, 2H), 2.40 (*t*, 2H), 2.45 (*t*, 4H), 2.79 (*t*, 4H), 3.65 (*t*, 6H).

^{13}C NMR (CDCl_3 , 60 MHz, ppm): 11.5, 20.2, 32.5, 49.2, 51.3, 55.6, 172.8.

using a magnetic stirrer. The reaction mixture was stirred at ambient temperature for an additional 24 h, and the final product (UV-PU prepolymer) was obtained without further treatment.

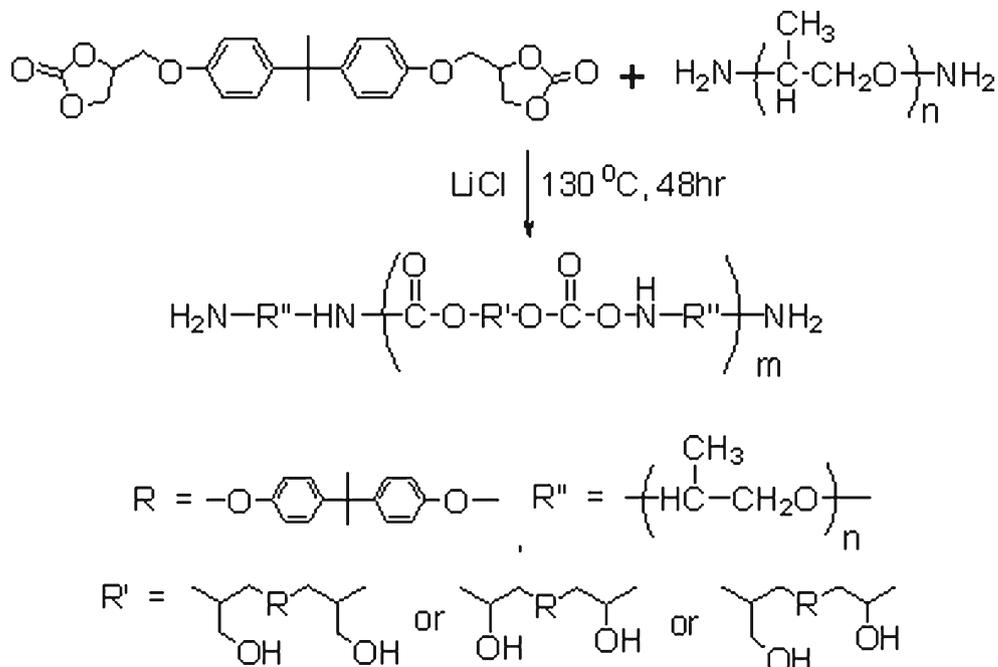
UV-curable hydrophilic PU (UV-PU)

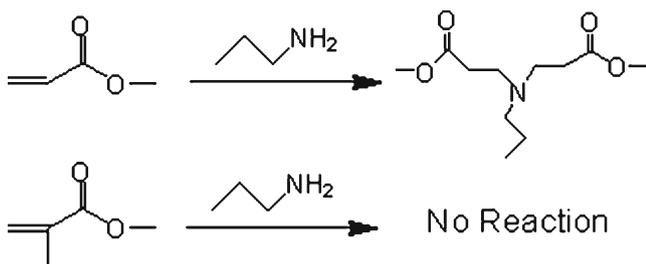
The UV-PU was prepared as follows (see Scheme 4). Amino-terminated PU ($\text{NH}_2\text{-PU}$) oligomer was obtained using the procedure described above, with BCC and Jeffamine D-2000 (carbonate/amine ratio was 1.0/1.5). Then a compound with both acrylate and methacrylate terminal groups, 3-acryloyloxy-2-hydroxypropyl methacrylate (AHM), was mixed with $\text{NH}_2\text{-PU}$ (amine/acrylate ratio was 1.0/2.0) in a 500 ml three-necked round-bottom flask

UV-curing system with UV-PU

The UV-curable PU system was formulated by mixing the UV-PU prepolymer with 1% photoinitiator (2-hydroxy-2-methylpropiophenone, DARCUR 1173) and various dosages of reactive diluents (e.g., TPGDA). The resulting UV-curable PU system was cast onto a glass plate for a free, dry PU film, or coated onto a PET textile and then cured by UV irradiation (using a UV light source with a medium-pressure mercury lamp). Both the UV-cured film and the treated

Scheme 2 Preparation of $\text{NH}_2\text{-PU}$





Scheme 3 Model Michael addition reaction

textile were placed in a vacuum oven at 50 °C for 24 h, and conditioned in a chamber at 75% relative humidity for one day before each measurement.

Physical properties

Gel content

A known weight of oven-dried film (W_1) was placed into a Soxhlet extractor for continuous extraction with tetrahydrofuran (THF) for 24 h. The polymer gel that remained after extraction was dried, and its weight was calculated (W_2). Three such tests were carried out, and the results of each were averaged for each PU sample. These results were then used to calculate the gel content of each sample (in %):

$$\text{Gel content\%} = (W_2/W_1) \times 100\%.$$

Water uptake

A known weight (W_0) of a dried PU film sample with dimensions of 60×60×1 mm was immersed in a deionized

water bath for seven days. The towel-dried sample weight (W_1) and the oven-dried sample weight (W_2) were obtained. The water uptake (W_w %) and weight loss (W_x %) of the PU film in water were calculated according to the following equations:

$$W_w\% = [(W_1 - W_2)/W_2] \times 100\%$$

W_w : amount of water taken up by PU film

$$W_x\% = [(W_0 - W_2)/W_0] \times 100\%$$

W_x : amount of PU film dissolved in the water.

Ethanol swollen

A known weight (W_0) of dried PU film with dimensions of 60×60×1 mm was immersed in a 95% ethanol bath for 24 h. The towel-dried sample weight (W_1) and the oven-dried sample weight (W_2) were obtained. Ethanol absorption (W_e %) and the weight loss (W_y %) of the PU film in ethanol were calculated using the following equations:

$$W_e\% = [(W_1 - W_2)/W_2] \times 100\%$$

W_e : amount of ethanol absorbed by the PU film

$$W_y\% = [(W_0 - W_2)/W_0] \times 100\%$$

W_y : amount of PU film dissolved in the ethanol solution.

Thermogravimetric analysis (TGA)

The thermal stability of each PU sample (about 10 mg) was measured by a TA thermogravimetric analyzer by heating

Fig. 4a–c ^1H NMR spectra of **a** MA, **b** n-PA, and **c** PA-MA

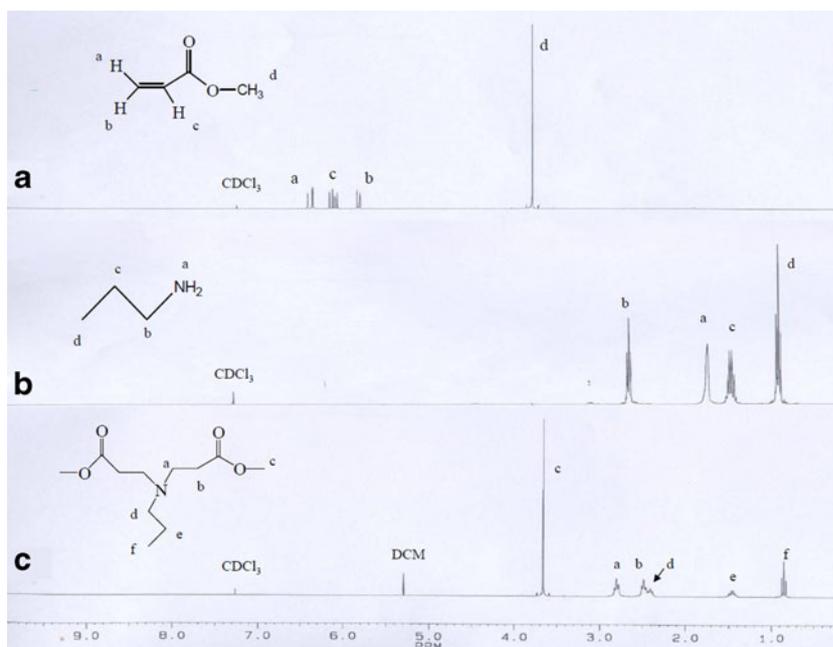
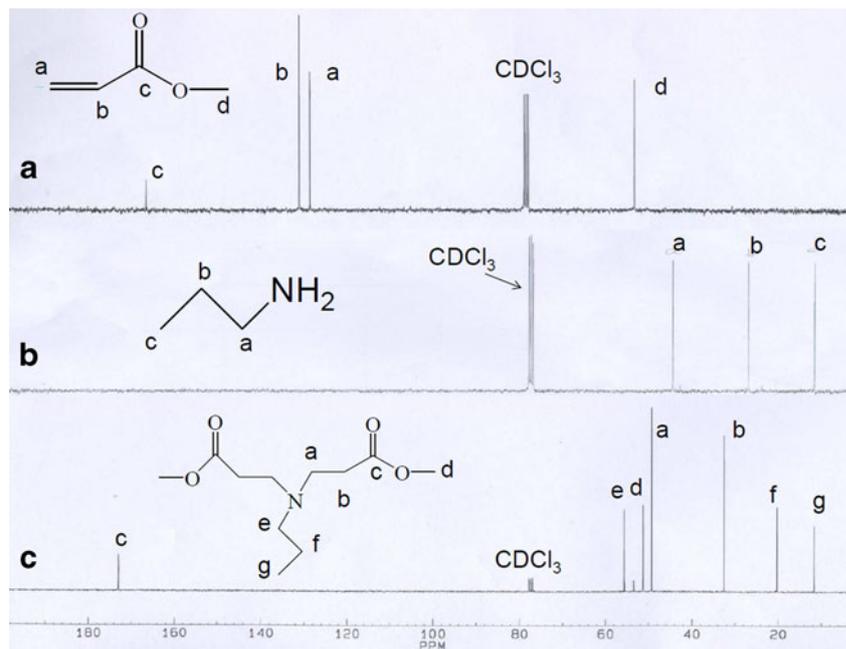


Fig. 5a–c ^{13}C NMR spectra of **a** MA, **b** n-PA, and **c** PA-MA



the samples at a rate of $10\text{ }^{\circ}\text{C}/\text{min}$ from room temperature to $600\text{ }^{\circ}\text{C}$ under a nitrogen atmosphere and with a flow rate of 1 ml/s .

Contact angle (CA) on the surface of the textile

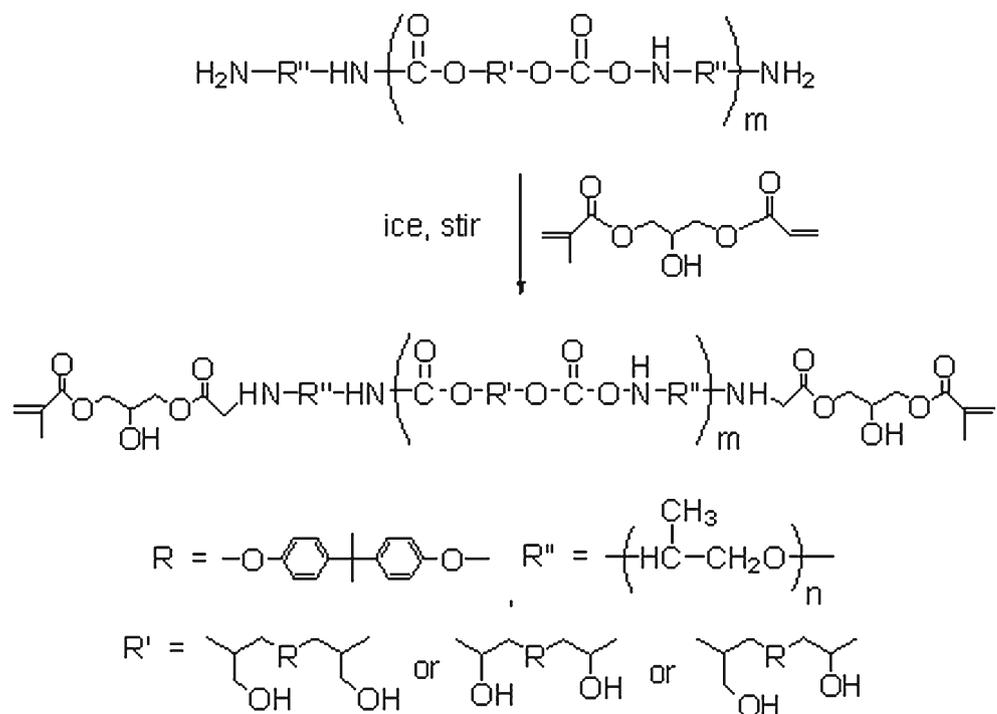
Contact angles of deionized water droplets on the UV-cured PU film or on the treated textile surface were measured after 30 s for every water droplet applied at room temperature. Five measurements were made for each sample, and the

Scheme 4 Preparation of UV-PU via Michael addition

three closest readings were chosen and averaged to get the mean value. The contact angle was calculated by the following equation:

$$\text{Contact angle} = 2 \tan^{-1}(h/r),$$

where h is the height of the spherical segment of the water droplet, and r is the radius of the spherical segment.



Results and discussion

The conventional PU resin has found great popularity when used as a breathable textile treatment (with hydrophilicity) in the textile industry, mainly due to the versatile properties of the hydrophilic PU resin, which can be tailored to particular applications. Ever since PU was discovered more than seven decades ago, most conventional PU resin has been prepared by the conventional isocyanate route. The properties of PU resin make it overwhelmingly advantageous for various applications. For example, hydrophilic and hydrophobic PU resins have been prepared for use on textiles intended for different functional applications [8–9]. However, one of the main raw materials used in the synthesis of PU, polyisocyanate, is manufactured via a phosgene-based process, leading to great concern over the toxicity and possible environmental impacts of this process. Therefore, a nonisocyanate process for synthesizing PU resin has become highly desirable.

The ring-opening polyaddition reaction of cyclic carbonate with a diamine results in the formation of poly(hydroxyurethane)s, as discovered almost two decades ago [12–16]. Bis(cyclic carbonate) (BCC) is obtained from the insertion of carbon dioxide into the oxirane rings of 2,2-bis(4-glycidyoxyphenyl) propane (DGEBA) (epoxy resin) at atmospheric pressure with the aid of catalyst [12, 14–15]. The diamine compound can be a long-chain diamine with an ether linkage, such as Jaffamine D-2000, which, besides providing hydroxyl groups for the final poly(hydroxyurethane) (NH_2 -PU) adduct, enhances its hydrophilicity. This hydrophilic NH_2 -PU is obtained via a nonisocyanate process. However, this is a linear oligomer with a relatively low average molecular weight ($M_w \sim 20,000$ g/mol) and poor mechanical, physical, and thermal properties.

The amino-terminated PU (NH_2 -PU) oligomer can be modified by reacting it with the terminal acrylate group of 3-acryloyloxy-2-hydroxypropyl methacrylate (AHM) via Michael addition, which leaves the methacrylate group untouched (Scheme 4). The final methacrylate-terminated poly(hydroxyurethane) is a UV-curable PU (UV-PU) prepolymer. A UV-PU system can then be formulated, including a photoinitiator and a reactive diluent (e.g., tripropylene glycol diacrylate, TPGDA). This UV-PU system is cast onto a glass plate or coated onto PET textile, before being cured by UV irradiation. The properties of this final UV-PU film and treated textile were also evaluated in this study (see “UV-PU for textile treatment”).

CO_2 insertion adduct (BCC)

The adduct bis(cyclic carbonate) (BCC) is obtained by inserting CO_2 into the terminal oxirane groups of DGEBA

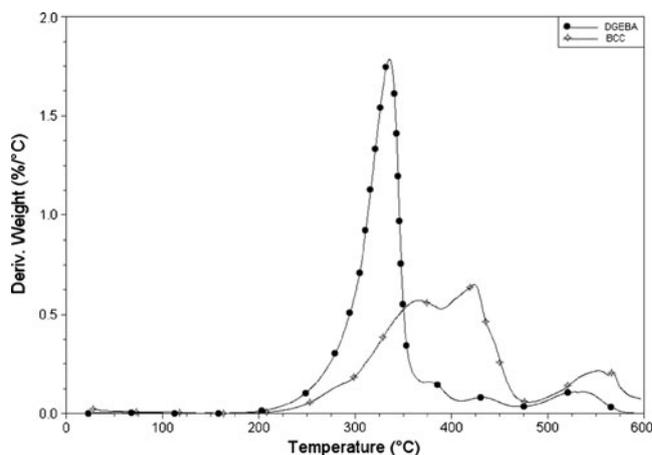


Fig. 6 DTA thermograms obtained under a nitrogen atmosphere: filled circles DGEBA, open diamonds BCC

at atmospheric pressure with the aid of a catalyst (LiBr). DGEBA has a characteristic IR absorption peak from oxirane at 910 cm^{-1} ; following the reaction, this disappears and is replaced by a new absorption peak from the carbonate carbonyl ($\text{C}=\text{O}$) of BCC at 1800 cm^{-1} in the FT-IR spectrum (Fig. 1a and b, respectively).

The chemical shifts of the methylene protons (e and f) on the oxirane groups of DGEBA in the ^1H NMR spectrum are centered at 3.3 and 2.8 ppm (Fig. 2a), and these shift to 5.0 and 4.5 ppm (Fig. 2b), respectively, when BCC is obtained by inserting CO_2 into DGEBA.

The chemical shifts of the methylene carbons (g, h, and i) on the oxirane groups of DGEBA are at 68.0, 49.9, and 44.0 ppm in the ^{13}C NMR spectrum (Fig. 3a), and these shift to 74.0, 68.6, and 66.0 ppm, respectively, for BCC, which also exhibits a new carbon (carbonyl) chemical shift at 156 ppm (Fig. 3b).

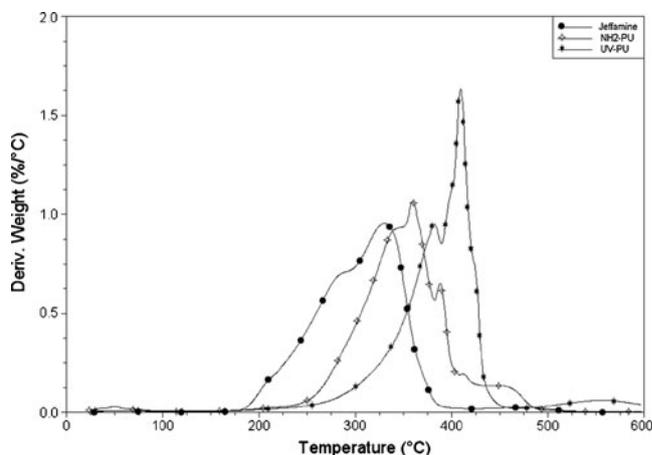


Fig. 7 DTA thermograms obtained under a nitrogen atmosphere: filled circles Jeffamine, open diamonds NH_2 -PU, asterisks UV-PU

Table 1 Thermal stabilities of nonisocyanate UV-cured PU and its raw materials

TGA ^a	$T_{d \text{ first}}$ (°C)	$T_{d \text{ max}}$ (°C)
BCC	230	424
Jeffamine D2000	182	330
NH ₂ -PU	218	358
UV-PU ^b	257	410

^a Thermal properties were measured under an N₂ atmosphere at a heating rate of 10 °C/min

^b UV-PU is the UV-curable system without the reactive diluent TPGDA

Amino-terminated PU (NH₂-PU) oligomer

Propylene cyclic carbonate (PCC) has a distinct carbonyl absorption peak at 1800 cm⁻¹ that disappears to be replaced by a urethane carbonyl absorption peak at 1720 cm⁻¹ after the ring-opening reaction with *n*-butylamine (BA), which is one of the main indicators that ring-opening polymerization of BCC with a diamine (e.g., Jeffamine D-2000) has occurred (Fig. 1c). The cyclic carbonate/amine ratio of BCC is 2/3, and the final ring-opening product is an amino-terminated PU (NH₂-PU) oligomer with an average weight-average molecular weight of 20,000 g/mol ($D=1.3$) according to the GPC method.

UV-curable PU system

In the model reaction, *n*-propylamine reacts mainly (via Michael addition) with methyl acrylate rather than methyl methacrylate due to steric hindrance (Figs. 4 and 5).

Table 2 Physical properties of UV-PU films

	TPGDA ^a		
	0 phr	3 phr	5 phr
Gel content (%)	76.8	82.1	85.6
W_A (%)	71.2	49.4	30.7
W_L (%)	30.0	16.4	7.6
E_A (%)	130.5	115.6	103.6
E_L (%)	29.9	27.4	21.8
CA (°)	40	45	51

^a UV-PU system with 1 phr photoinitiator (DARCUR 1173) and 0, 3, or 5 phr of TPGDA

W_A water uptake by UV-PU films for 7 days

W_L UV-PU film dissolved in water for 7 days

E_A ethanol absorption by UV-PU films for 48 h

E_L UV-PU films dissolved in ethanol for 48 h

CA contact angle with pure water

Table 3 Thermal stability of nonisocyanate UV-cured PU with various dosages of TPGDA

TGA ^a	TPGDA		
	0 phr	3 phr	5 phr
$T_{d \text{ first}}$ (°C) ^b	257	208	201
$T_{d \text{ max}}$ (°C) ^c	410	401	393

^a Thermal properties were measured under an N₂ atmosphere at a heating rate of 10 °C/min

$T_{d \text{ first}}$ first decomposition temperature of the sample

$T_{d \text{ max}}$ maximum decomposition temperature of the sample

Therefore, each terminal amino group of NH₂-PU oligomer reacts with the acrylate end group of AHM (3-acryloyloxy-2-hydroxypropyl methacrylate) via Michael addition and leaves the methacrylate group untouched (Scheme 4), resulting in the formation of a UV-curable PU (UV-PU) prepolymer. This UV-PU is then included in a formulation with 1 phr of photoinitiator (2-hydroxy-2-methylpropiophenone, DARCUR 1173) and various dosages of reactive diluent (e.g., TPGDA). The resulting UV-curable PU system is cast onto glass plate to get a free PU film, or is coated onto a PET textile, and is then cured by UV irradiation (from a medium-pressure mercury lamp).

Thermal properties

The amino-terminated PU (NH₂-PU) oligomer is derived from bis(cyclic carbonate)—BCC—with an M_w of 20,000 and a diamine compound, Jeffamine D-2000. Its cyclic carbonate/amine ratio is 2/3 and its weight ratio is 87/13. The thermal stability (the thermodecomposition temperature under an N₂ atmosphere) of the ring-opening product NH₂-PU is a compromise between these two starting materials. For NH₂-PU, $T_{d \text{ first}}$ is 218 °C and $T_{d \text{ max}}$ is 358 °C; for

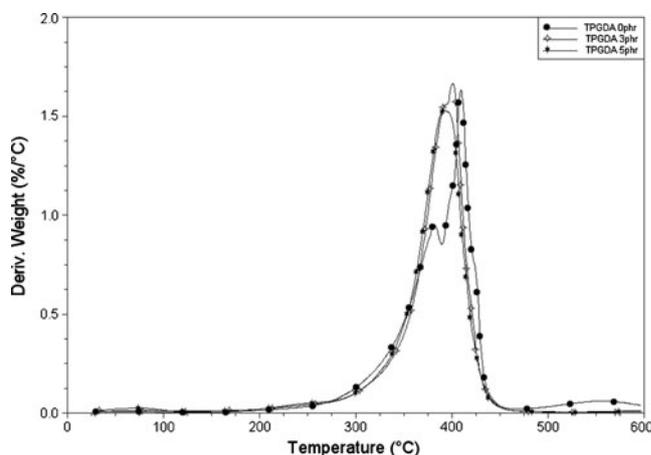
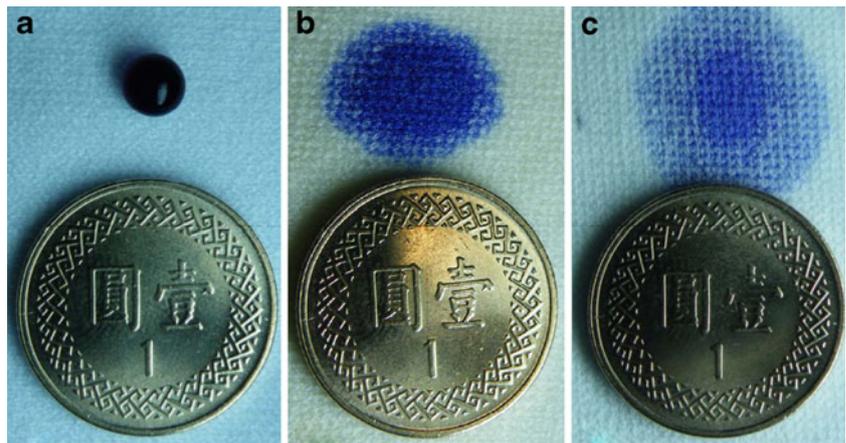
**Fig. 8** DTA thermograms obtained under a nitrogen atmosphere: filled circles 0 phr, open diamonds 3 phr, asterisks 5 phr

Fig. 9a–c Photos of **a** the original PET textile, **b** the textile after coating it with UV-PU, and **c** the coated textile after 30 washing cycles



BCC, $T_{d \text{ first}}$ is 230 °C and $T_{d \text{ max}}$ is 424 °C; and for Jeffamine-D2000, $T_{d \text{ first}}$ is 182 °C and $T_{d \text{ max}}$ is 330 °C (Figs. 6 and 7; Table 1).

The $T_{d \text{ first}}$ and $T_{d \text{ max}}$ values of UV-cured PU (without the reactive diluent TPGDA) are 257 and 410 °C (Fig. 7; Table 1), respectively. Thus, it is more thermally stable than its raw materials. This is due to the formation of a polymeric network among the UV-curable PU prepolymers after curing. Even though the gel content of UV-cured PU increases (Table 2) as the dosage of the reactive diluent TPGDA is increased, its $T_{d \text{ first}}$ decreases drastically with increasing

TPGDA dosage Table 1, and $T_{d \text{ max}}$ decreases too (Table 3). This may be due to the low thermal stability $T_{d \text{ first}}$ of the polyacrylate, so that most of the polyacrylate has already decomposed when it reaches $T_{d \text{ max}}$, with only the aromatic skeleton remaining (Fig. 8).

Physical properties

A film sample of uncured UV-PU dissolved in THF completely. The UV-cured films obtained from the UV-PU systems with 3 and 5 phr of the reactive diluent TPGDA

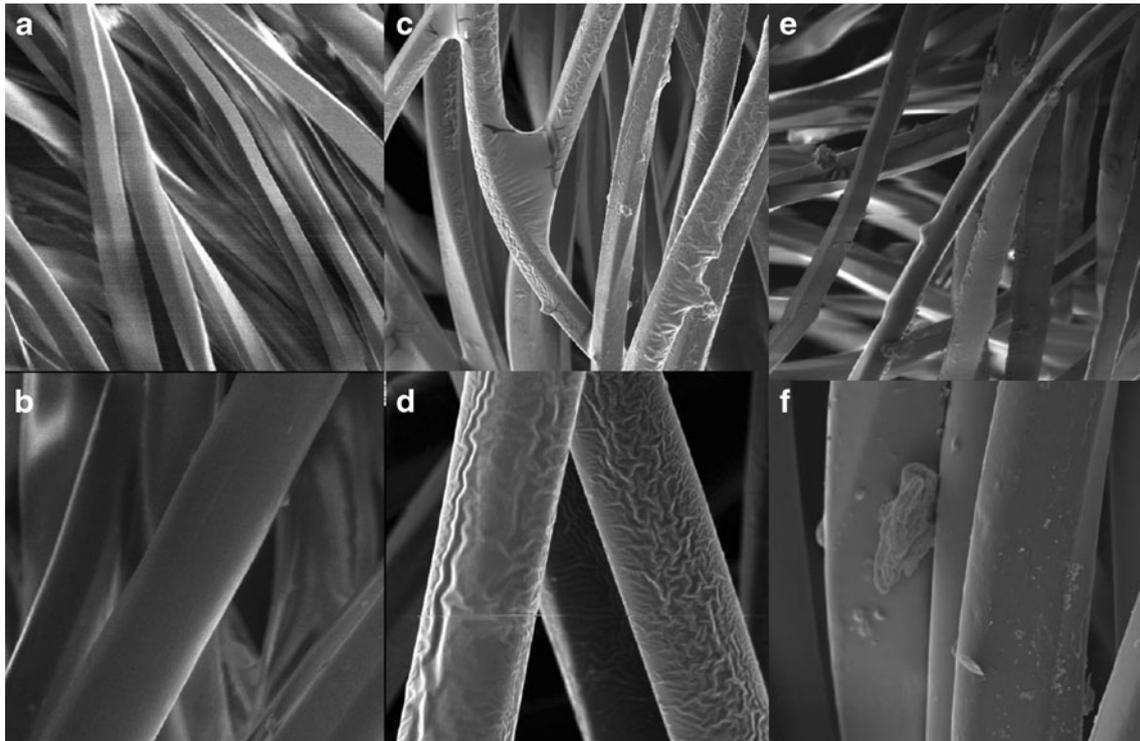


Fig. 10a–f SEM micrographs of treated textiles: **a** the original PET textile (1,000×); **b** the original PET textile (3,000×); **c** the UV-PU-coated textile (1,000×); **d** the UV-PU-coated textile (3,000×); **e** the UV-

PU-coated textile after 30 washing cycles (1,000×); **f** the UV-PU-coated textile after 30 washing cycles (3,000×);

(tripropylene glycol diacrylate) presented gel contents of 82.1 and 85.6%, respectively, while that of UV-PU without TPGDA was 76.8%. The sample weight loss in water decreased from 30.0% for the sample without the reactive diluent to 16.4% and 7.6% for samples derived from the systems with 3 and 5 phr TPGDA; the water absorption (hydrophilicity) also decreased from 71.2% to 49.4% and 30.7%, respectively. The contact angles of water drops on these UV-PU films increased from 40 to 51°. These results indicate that the hydrophilicity of UV-PU decreases as the dosage of the reactive diluent (TPGDA) increases, due to the resulting increase in crosslinking density. However, ethanol swollen and the weight losses of UV-PU with various dosages of TPGDA were in the ranges of 130.5–103.6% and 29.9–21.8%, respectively (Table 2).

Use of UV-PU as a textile treatment

When a PET textile was treated with the UV-PU curable system (with 3 phr TPGDA), it showed hydrophilic character, even after it had been washed in water for 30 cycles (Fig. 9). Therefore, this UV-PU system represents a new, long-lasting hydrophilic textile treatment. SEM micrographs (Fig. 10) of the treated textiles show that the hydrophilic UV-PU remained among the fibers after 30 wash cycles in water.

Conclusion

A new hydrophilic polyurethane (PU) was prepared by a nonisocyanate process. The product of each step in the sequence of reactions that produced the PU was observed in FT-IR and NMR spectra. In this sequence of steps, bis (cyclic carbonate) (BCC), the product of the insertion of CO₂ into an epoxy resin, is the key raw material that is used to synthesize an amino-terminated PU (NH₂-PU) oligomer through the ring-opening reaction of BCC with a diamine compound, Jeffamine D-2000. A UV-curable PU (UV-PU) prepolymer is then prepared through the Michael addition of the NH₂-PU to the acrylate end group of AHM (3-acryloyloxy-2-hydroxypropyl methacrylate). The gel contents of this UV-curable UV-PU system was found to range from 76.8 to 85.6%, depending on the amount of reactive diluent present. This UV-curing reaction enhances the water resistance of PU, and when the UV-curable UV-PU system is applied to a PET textile, the treated textile exhibits hydrophilic properties. SEM micrographs demonstrate that the hydrophilic treatment remains on the textile, even after the textile has been washed in water many times. Therefore, this new UV-PU obtained via a nonisocyanate process represents an alternative hydrophilic textile treatment.

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