

Preparation and Properties of Waterborne Polyurethane-Urea/Poly(vinyl alcohol) Blends for High Water Vapor Permeable Coating Materials

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Abstract: High water vapor permeable coating materials were prepared by blending aqueous poly(vinyl alcohol) (PVA) solution with waterborne polyurethane-urea (WBPU) dispersions synthesized by prepolymer mixing process. Stable WBPU/PVA dispersions were achieved at PVA content below 30 wt%. As the water soluble polymer PVA content increased, the number and density of total micro-pores (tunnel-like/isolated micro-pores) formed after the dissolution of PVA in water increased, and the water vapor permeability of coated Nylon fabric also increased significantly. Using WBPU/water soluble polymer PVA blends as a coating material and then dissolving PVA in water was confirmed to be an effective method to obtain prominent breathable fabrics.

Keywords: waterborne polyurethane, poly(vinyl alcohol), water vapor permeability, dissolution, micro-pore.

Introduction

Due to the thermodynamic incompatibility of most polymers, heterogeneous polymer blends are generally obtained with varied degrees of incompatibility. It is well known that nearly all polymer blends comprise one polymer domain dispersed in the matrices of the other polymer. One of the most direct ways to examine the morphology (i.e. how the phases are arranged in space) of blends is microscopic method.

Waterborne polyurethane-ureas (WBPU) are nontoxic, nonflammable and do not emit pollutants. In addition, they exhibit excellent adhesion to many surfaces including glass, rubber and polymeric fiber.¹⁻⁶ Most WBPU contain ionic groups in its molecular structure, and shows excellent mechanical properties due to the presence of inter-chain Coulombic forces and hydrogen bondings.⁷ The ionic groups lead to self-emulsification of WBPU in aqueous media. WBPU have been widely used in the textile industry for breathable coating, sueding, antistatic, and nonformaldehyde applications.⁸⁻¹² For resin-coated fabrics,^{13,14} characteristics such as softness, handle, permeability, and mechanical properties are required. In the applications of breathable coating fabrics, the water vapor permeability was the most important factor.

There are several methods by which breathable waterproof fabric can be prepared, such as microporous, hydrophilic, and the fabric based on microfilaments.¹⁵ Waterproof breathable fabrics which are used to construct sportswear and foul weather garments were grouped together according to their manufacturing methods irrespective of their brand-names: cotton ventiles, microfibre fabrics, PTFE laminated fabrics, poromeric polyurethane laminated fabrics, and hydrophilic laminated fabrics.

There are a lot of researches about how to use polyurethanes in making breathable products, such as porous polyurethane film¹⁶⁻¹⁸ and hydrophilic non-porous polyurethane products.¹⁹⁻²² The advantage of hydrophilic polyurethane coatings over laminating method of microporous polyurethane film is that the former has good adhesion on textile substrate and it is less expensive. However, it is almost impossible to produce high water vapor permeable fabric by direct coating of hydrophobic polyurethane. Incorporation process of micro-porous structure into the coated layer on the fabric is subsequently needed after coating process to improve the water vapor permeability of fabrics. Systematic studies on this method are rarely available in the open literature.

As mentioned above, micro-porous structure generally shows higher water vapor permeability. In this study, in order to make direct coated fabric to have micro-porous structure, WBPU/PVA were used as coating materials for fabrics, and then water soluble polymer PVA were removed by dissolution

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of PVA in water. Waterborne polyurethane-urea (WBPU) was synthesized by prepolymer mixing process using isophorone diisocyanate (IPDI)/2,2-bis(hydroxymethyl)propionic acid (DMPA)/poly (tetramethylene ether) glycol (PTMG)/ethylenediamine (EDA)/triethylamine (TEA) in an emulsion system. Coating materials were prepared by blending WBPU dispersion with aqueous PVA solution. The effect of PVA content on the viscosity of coating materials, and the effects of PVA content and dissolution conditions on the dissolution% of PVA and number/mean size of micro-pores of coating material films were examined. The changes of water vapor permeability of coated Nylon fabrics according to the changes of PVA content and dissolution condition were studied. In addition, the thermal degradation/dynamic mechanical thermal properties of coating material film samples were also investigated.

Experimental

Materials. Poly(tetramethylene oxide) glycol [PTMG, number-average molecular weight (M_n)=2,000, Aldrich Chemical Co.] was degassed at 70°C under vacuum overnight before use. Isophorone diisocyanate (IPDI, Aldrich Chemical Co.), methyl ethyl ketone (MEK, Aldrich Chemical Co.), ethylene diamine (EDA, Aldrich Chemical Co.), triethyl-amine (TEA, Aldrich Chemical Co.), and *N*-methyl-2-pyrrolidone (NMP, Aldrich Chemical Co.) were used after dehydration with 4 Å molecular sieves for one day. 2, 2-Bis(hydroxymethyl) propionic acid (DMPA, Aldrich Chemical Co.) were dried at 100°C under vacuum (1~2 mmHg) for 5 hrs before being used. Dibutyl tin diaurate (DBTDL, Aldrich Chemical Co.), thickener (L75N, Bayer, Germany) and hardener (ARF-30, main component: polyisocyanate, solid content: > 99, NCO%: 20, Dongsung, Busan, Korea) were used without further purification. Poly(vinyl alcohol) (PVA, 99+ hydrolyzed, M_w =89,000~98,000, Aldrich Chemical Co.) was dried at 100°C under vacuum for 3 hrs before use.

Synthesis of Waterborne Polyurethane (WBPU). The WBPU was synthesized using the prepolymer mixing process.⁷ The PTMG was placed in a 4 necks round-bottom flask equipped with a thermometer, a stirrer, an inlet of dry nitrogen, a condenser, and a heat jacket, and was degassed under

vacuum at 90°C for 30 min. Then DMPA/NMP (1/1 wt ratio) was added to the flask, and the mixture was cooled until it reached a temperature of 40°C under moderate stirring. IPDI/MEK (2.15/1 wt ratio) was added to the flask, and was heated to 85°C under moderate stirring (175~200 rpm). The reaction mixture was allowed to react at 85°C until the theoretical NCO content was reached. The change of NCO content during reaction was determined by the standard dibutylamine back-titration method (ASTM D1638). Then, methyl ethyl ketone (MEK: about 20 wt%) was added to the NCO-terminated prepolymer mixture to adjust the viscosity of reaction mixture. TEA was added to the reaction mixture for neutralizing the carboxyl group of the NCO-terminated polyurethane prepolymer. After 30 min of neutralization reaction, distilled water (60 wt% per solid) was added to the reaction mixture under vigorous stirring (1,300~1,500 rpm). The neutralized prepolymer was chain-extended by dropping EDA at 40°C for 1 hr and the reaction continued until NCO peak (2270 cm^{-1}) in the IR spectrum had completely disappeared. All the aqueous dispersions (40 wt% solid content) were obtained by evaporating MEK and the subsequent addition of an adequate amount of water. The feed molar composition of WBPU is shown in Table I.

Preparations of WBPU/PVA Blends. The WBPU/PVA blends were prepared by solution blending using WBPU and aqueous PVA solution. The various WBPU/PVA blends prepared in this way are identified in Table I.

Viscosity. The viscosity of WBPU/PVA blends was measured with Brookfield viscometer (model LVTDV-II+) over the temperature range of 25~75°C and 10~100 rpm.

Preparation of WBPU/PVA Films. WBPU/PVA films were prepared by pouring the WBPU/PVA blend solutions into a Teflon disk at ambient conditions. The films (typically about 0.12 mm thickness) were dried in vacuum at 50°C for 2 days and stored in a desiccator at room temperature.

Coating to Nylon Fabrics. The coating materials were formulated from WBPU/PVA/thickener (L75N, Bayer)/hardener or WBPU/PVA/hardener. The WBPU/PVA blend containing high PVA content (30 wt%) showed a high viscosity (> 3,000 cps). So, it was directly used as coating materials. However, the thickener (0.5 wt%) was used for WBPU/PVA blends having lower PVA contents. The hardner

Table I. Composition, Particle Size, and Solid Content of Pure WBPU and WBPU/PVA Blends Dispersions

Sample Designation	Composition					WBPU/PVA	Particle Size (μm)	Solid Content (wt%)
	IPDI	PTMG ($M_n=2,000$)	DMPA	EDA	TEA			
WBPU/PVA-0						100/ 0	0.25	40
WBPU/PVA ^a -5						95/ 5		40
WBPU/PVA-15	2.5	1	0.7	1	0.7	85/15		40
WBPU/PVA-30						70/30		40

^aConcentration of PVA in aqueous PVA solution used : 40 wt%.

contents were 0, 3, 5, and 7 wt%. The formulated coating materials were coated onto Nylon fabrics using steel bar and filler, and then dried at 100 °C for 5 min. The thicknesses of coated layer on Nylon fabrics were about 0.127, 0.248, or 0.487 mm.

Dissolution Condition of Water-Soluble Polymer PVA.

Dissolution temperature and time were 25~90 °C and 1~5 hrs, respectively. Higher dissolution temperature and longer time proved more effective in dissolving PVA. Therefore, the water soluble polymer PVA in WBPU/PVA blend films and coated Nylon fabrics were dissolved in water using shaking water bath at 90 °C for 4 hrs. After dissolution of PVA in water, the remained films and coated Nylon fabrics were dried at 80 °C for 1 day.

Characterization. The dissolution % was determined as follows: $\text{dissolution \%} = [\text{weight of dissolved PVA (dried weight of un-dissolved sample - dried weight of dissolved sample)} / \text{PVA weight determined from the blend ratio of WBPU/PVA blend coating material}] \times 100$. Infrared spectra of pure WBPU was measured using a FTIR spectrometer (Impact 400D, Nicolet) in the wavenumber of 400~4000 cm^{-1} at room temperature. For each IR spectro-meter sample, 32 scans at a 4 cm^{-1} resolution were collected in the transmittance mode. The viscosity of WBPU/PVA blends was measured in the temperature of 25~75 °C using a Brookfield viscometer (Model LVDV II+, spindle No. 6). Thermal gravimetric analysis of about 5 mg of blend WBPU/PVA films were made with Perkin Elimer LTD (TGA7, U.S.A) under nitrogen atmosphere at the heating rate of 5 °C/min from room temperature to 600 °C. The thermal dynamic mechanical behaviors of WBPU/PVA were measured at 4 Hz using DMTA (DMA Q800 V7.1 Build 116) with the heating rate 3 °C/min. The dimension of specimens was 5 × 5 × 0.2 (mm) for DMTA measurement. Stress-strain (S-S) curves for dumbbell shaped WBPU/PVA blends were obtained with mechanical tensile tester (Tinius Olsen 1000, USA) at the speed of 20 mm/min according to ASTM D-412. Morphology of thin films of coating material was studied by scanning electron microscopy (SEM, Hitachi S-4200). The samples were coated in conventional manner with a thin layer of gold palladium to prevent changing. The water vapor permeability was determined using an evaporation method described in ASTM E9663-T. The mouth of the test dish is covered with test specimen, and the edges are sealed with sealing material. The whole assembly is weighed and placed in an air circulated, temperature and humidity controlled chamber. The condition of the chamber is temperature of 40 ± 2 °C, 50 ± 5% of relative humidity and 0.8 m/sec of air movement. WVP% was determined as follows: $\text{WVP \%} = (\text{WVP of coated Nylon fabric} / \text{WVP of Nylon fabric}) \times 100$.

Results and Discussion

Particle Size and Identification of WBPU. The compo-

sition, particle size and solid content of pure WBPU dispersion prepared in this study are shown in Table I. Generally, it is known that the average particle size of WBPU is not directly related to the physical properties of the emulsion cast films.²³ However, control of particle size is important with regard to the particular application of WBPU. For example, relatively bigger particles are preferred in surface coating for rapid drying, and smaller ones are desirable when the deep penetration of dispersion into a substrate is an essential step. In general, it is desirable to have a particle size at least smaller than 10 μm for textile coatings. The average particle size and solid content of WBPU dispersion prepared in this study were found to be about 0.25 μm and 40 wt%, respectively. Figure 1 shows the FTIR spectrum of WBPU film prepared here. The WBPU was identified by the characteristic IR peaks, such as N-H stretching vibration peak near 3340 cm^{-1} , -CH₂- stretching band at 1460 and 770 cm^{-1} , C-N-H stretching band at 1540 cm^{-1} , and the C=O group near 1730 cm^{-1} .

Viscosity. The aqueous dispersion of WBPU/PVA blends prepared in this study is a colloidal system in which larger amount of PU particles are dispersed in a continuous water soluble polymer (PVA) matrix. Figure 2 shows the viscosity vs. revolutions per minute (rpm) of aqueous WBPU/PVA blends dispersions having various PVA contents at various temperatures. It was found that the viscosity was very sensitive to rpm and temperature. The viscosity decreased with increasing rpm of spindle, indicating that the rheological property of aqueous WBPU/PVA dispersion showed non-Newtonian behavior. Figure 3 shows the effect of PVA content on the viscosity of WBPU/PVA dispersion at 25 °C and 10 rpm. The viscosity of pure WBPU without PVA was 9.4 cps at 25 °C. The viscosity of WBPU/PVA increased up to 8,100 cps with increasing PVA content up to 30 wt%. It was found that high viscosity above 3,000 cps is required for use in fabric coating, since coating material of low viscosity

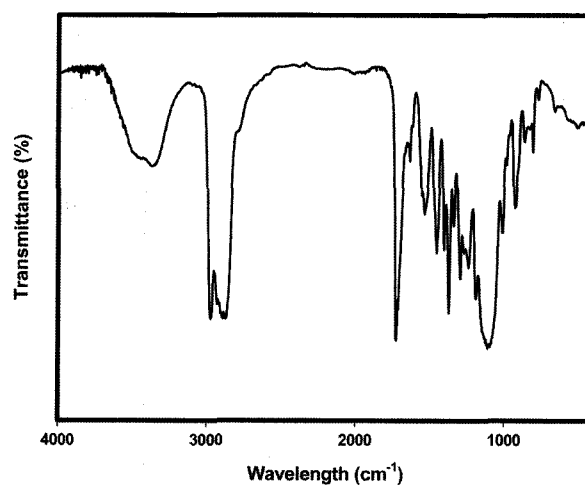


Figure 1. FTIR spectrum of pure WBPU film.

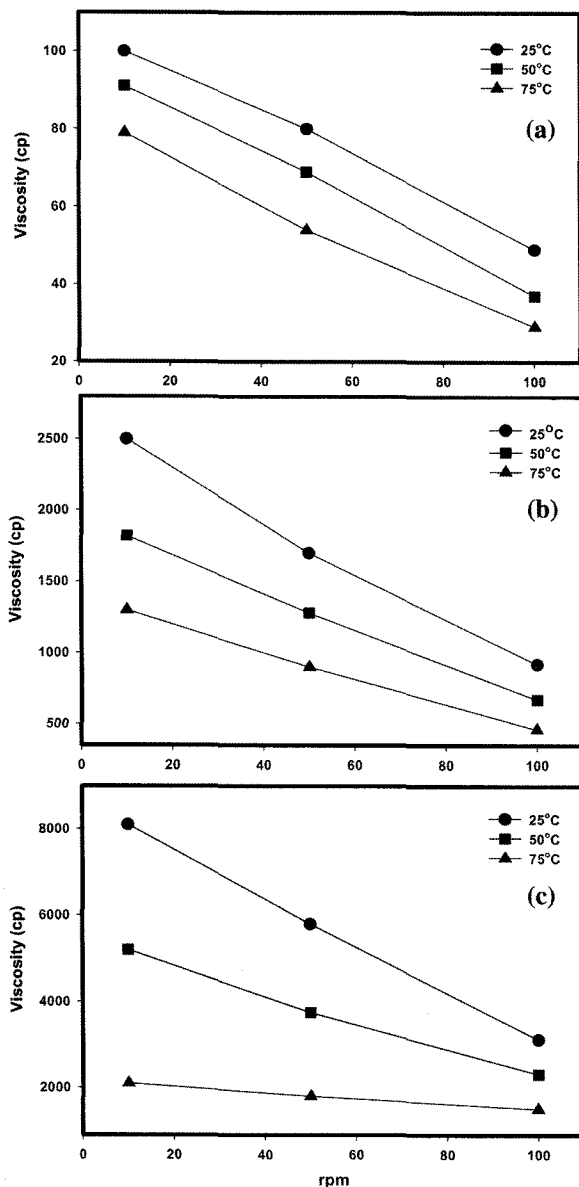


Figure 2. Viscosity vs. rpm for (a) WBPU/PVA-5, (b) WBPU/PVA-15, and (c) WBPU/PVA-30 at various temperatures.

penetrated into the fabrics and leaked out to the backside of coated fabrics. The WBPU/PVA-30 samples could be used as a coating material without thickener. However, small amount of thickener (L75N, Bayer) was used for samples WBPU/PVA-5 and WBPU/PVA-15 to increase the viscosity.

Dissolution Percentage. WBPU is weak in chemical resistance, thermal resistance, and mechanical property because the films of WBPU are linear thermoplastic polymers which are resolvable in solvents. Therefore, crosslinking is used in many industrial coatings and adhesive applications to improve solvent and chemical resistance, hardness, and mechanical properties of WBPU. Hardner ARF-30 (polyisocyanate crosslinking agent) was used to improve these

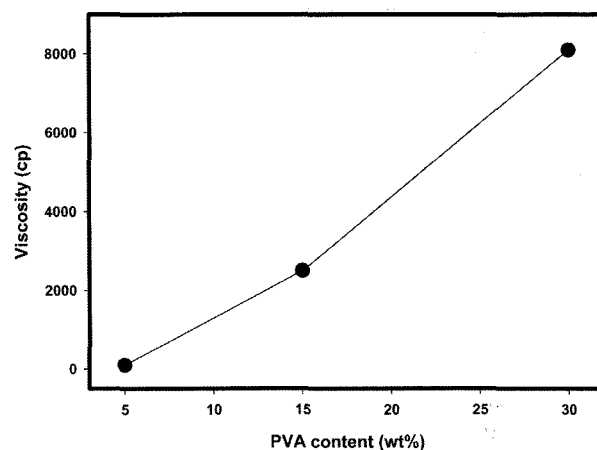


Figure 3. Relationship between viscosity and PVA content at 25°C and 10 rpm.

properties. Figure 4 shows the relation between dissolution % and hardner content for WBPU/PVA blends films with various dissolution temperatures in 4 hrs of dissolution time. The dissolution % increased with increasing dissolution temperature up to 90°C. The dissolution % decreased slightly with increasing hardner content up to 3 wt%, and then decreased sharply. The hardner content that optimizes the dissolution of PVA was found to be about 3 wt%. Figure 5 shows the effect of PVA content on the dissolution % of WBPU/PVA blends films. The dissolution % in the range of 85–96% increased with increasing PVA content. This indicates that higher portion of PVA domain in WBPU matrix makes the dissolution easier.

Morphology. Generally, it is possible to give new functions to polymer blends by controlling the morphology of blend. Polymer blends vary greatly in morphological complexity. The morphology of polymer blend films can be controlled by many factors, such as the blending sequence, chemical characteristics, viscosity, blending conditions, and interfacial tension of each component. Two types of morphology can be achieved; the first is encapsulation type, in which the domain polymer particles are surrounded by matrix polymer, and the second is interpenetrating type. The WBPU/PVA blend dispersion prepared in this study showed possibly two-phase system consisting of major component WBPU polymer (70 wt% <) particles dispersed in a continuous aqueous phase containing smaller amount component PVA (~30 wt%). The SEM micrographs of surfaces of WBPU/PVA blends films before and after dissolution of PVA in water at 90°C for 4 hrs are shown in Figure 6. The un-dissolved WBPU/PVA-30 coated layer had a fairly smooth surface as shown in Figure 6(a). However, it appeared that solvent water attacked the entire surface of dissolved samples and caused its porous/tunnel-like micro-pores structure [see Figures 6(b), (c), and (d)]. As the PVA content increased, the density (number/m²) of micro-pores formed after removal

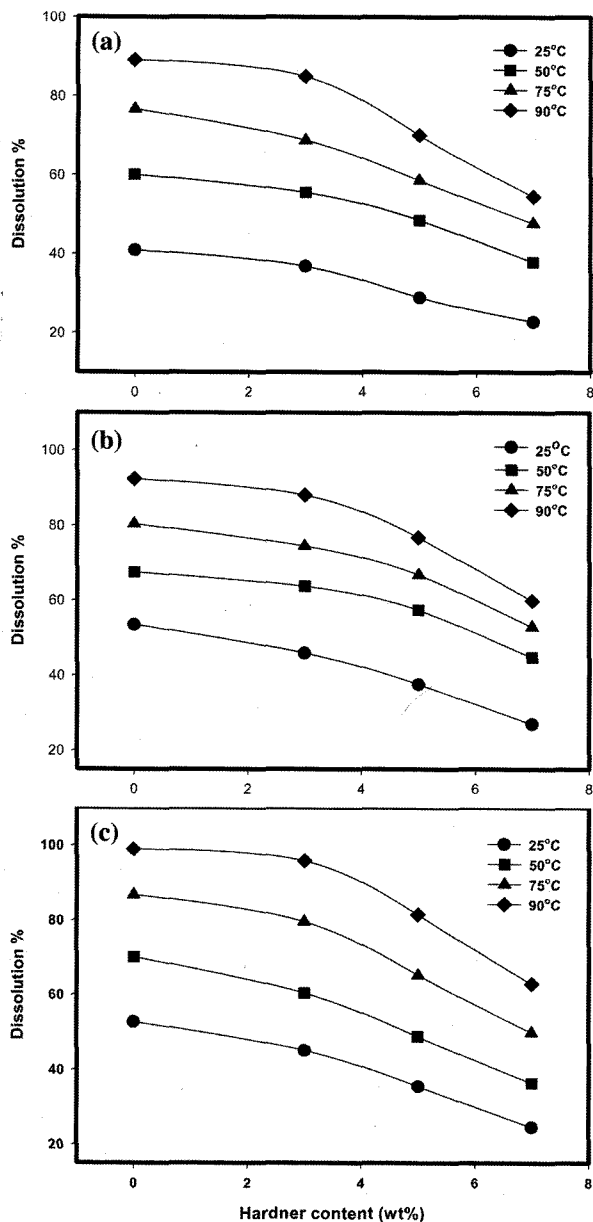


Figure 4. Dissolution % vs. hardener content for (a) WBPU/PVA-5, (b) WBPU/PVA-15, and (c) WBPU/PVA-30 with various dissolution temperatures (at a fixed dissolution time: 4 hrs).

of PVA in WBPU/PVA films increased, however, the size of the pore decreased. The decrease of pore size might be attributable to the collapse of matrix WBPU polymer. The size and density of micro-pores were in the range of $5.16\sim 12.9\ \mu\text{m}$ and $6.50\times 10^8\sim 14.7\times 10^8$ number/ m^2 , respectively. These porous/tunnel-like structures will promote the water vapor permeability. Figure 7 shows SEM micrographs of cross sections cut perpendicular to the surface for WBPU/PVA blend film samples. The structure of cross sections of film samples was almost the same as the surface structure of coated layer. The ratio of tunnel-like micro-pores to isolated

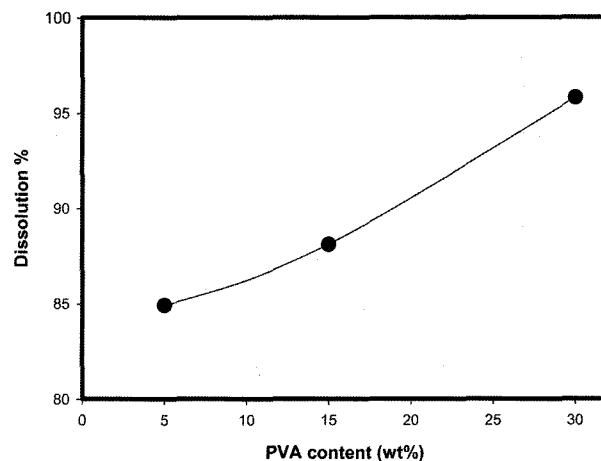


Figure 5. The effect of PVA content on the dissolution % of WBPU/PVA blend films.

micro-pores increased with increasing PVA content. The WBPU/PVA-30 blend sample showed larger amount of tunnel-like structure (open cell structure) resulted from higher amount of dissolved PVA (30 wt%).

TGA Behavior. TGA curves of pure WBPU, pure PVA, and WBPU/PVA-30 blend films samples before and after dissolution of PVA are shown in Figure 8. The temperatures at 10 wt% weight loss of pure WBPU, WBPU/PVA-30 blend samples before and after dissolution of PVA, and pure PVA are 303, 269, 292, and 250 °C, respectively. The degradation onset temperature of pure WBPU and dissolved WBPU/PVA-30 (dissolution %: 96%) was almost the same, and the temperatures at 10 wt% weight loss of these samples didn't present any notable contrast. This indicated that the qualitative analysis of dissolution was possible by TGA characterization. The temperature at 10 wt% weight loss decreased with increasing PVA content. This should be due to the higher thermal degradable behavior of PVA.

DMTA Behavior. Figures 9 shows the temperature dependence of the tensile storage modulus (E'), loss modulus (E'') and $\tan \delta$ of pure WBPU, WBPU/PVA-15, and WBPU/PVA-30 and dissolved WBPU/PVA-30 films, respectively. The DMTA results were summarized in Table II. The E' of WBPU/PVA blends films increased with increasing PVA content significantly. This was probably due to the higher stiffening effect of the rigid polymer PVA. Two loss modulus peaks were observed because of two glass-transition temperatures of the amorphous soft segments (T_{gs}) at a lower temperature and the amorphous hard segments (T_{gh}) at a higher temperature. However, the T_{gh} peak (near 57 °C) of pure WBPU in E'' and $\tan \delta$ curves was very weak. The distinct T_{gs} peak was attributed to the higher content of soft segments (70 wt%) of WBPU prepared in this study. With increasing PVA content from 0 to 30 wt%, the T_{gs} shifted slightly from -64 to -69 °C, but the T_{gh} increased a little from 57 to 60 °C. The increase of T_{gh} peak intensity was significant

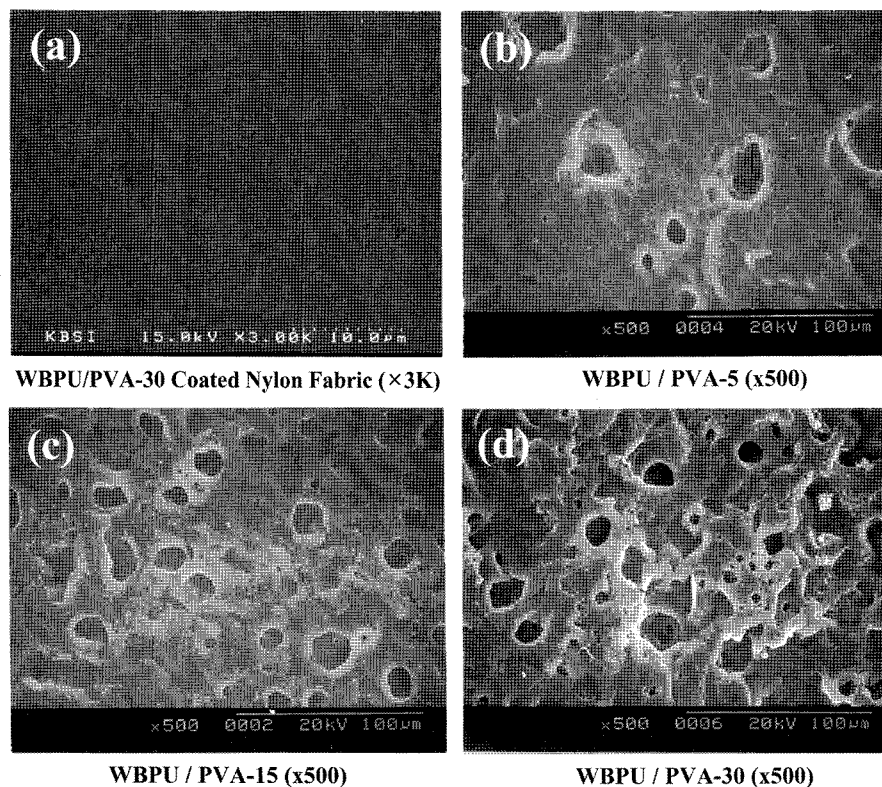


Figure 6. SEM micrographs of (a) WBPU/PVA-30 coated Nylon fabric surface before dissolution of PVA, (b) WBPU/PVA-5, (c) WBPU/PVA-15, and (d) WBPU/PVA-30 blends coated Nylon fabric surface after dissolution of PVA in water.

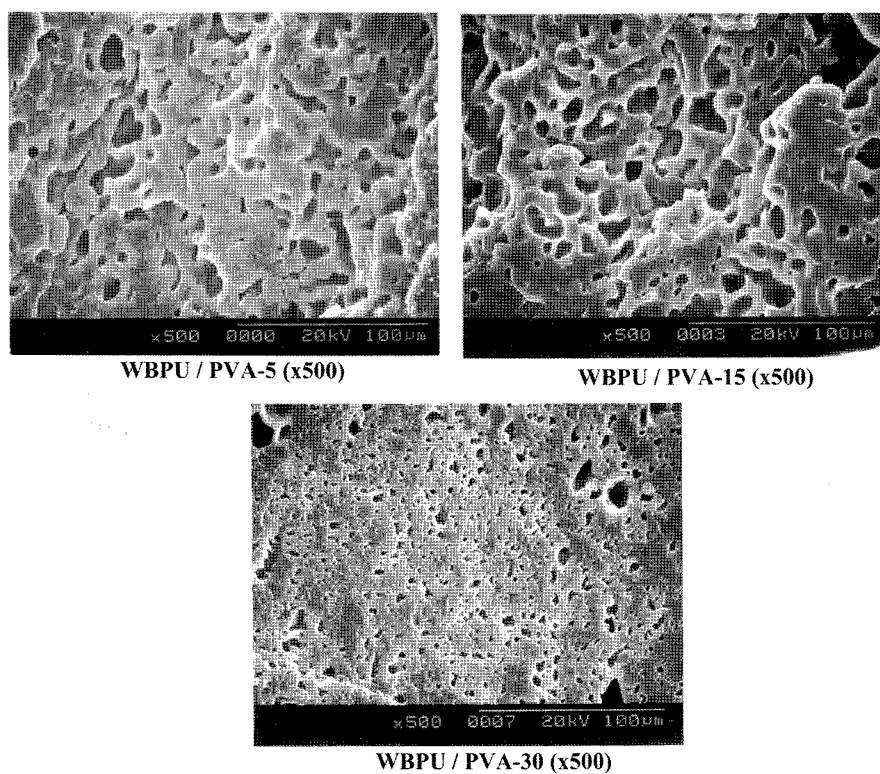


Figure 7. Cross-sectional SEM micrographs for WBPU/PVA blends films after dissolution.

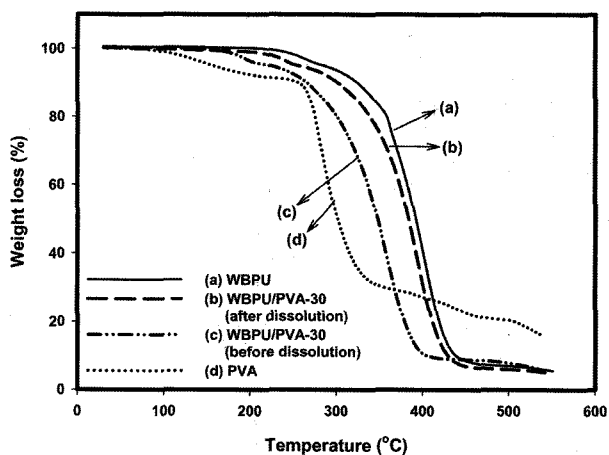


Figure 8. TGA curves of pure WBPU film, WBPU/PVA-30 film before dissolution, WBPU/PVA-30 film after dissolution, and PVA film.

indicating that PVA molecule interacted with amorphous hard segment. However, the peak intensity of T_{gs} was apparently not changed. The slight changes of T_{gs} and T_{gh} should be attributed to the lower compatibility of WBPU and PVA. The peaks of tensile storage modulus (E'), loss modulus (E'') and $\tan \delta$ of pure WBPU film were almost the same as those of dissolved WBPU/PVA-30 (dissolution %: 96%) film. This also indicated that the qualitative analysis of dissolution was possible by DMTA characterization.

Tensile Properties. The stress-strain curves of the WBPU/PVA films samples and their extracted films samples are shown in Figure 10 and the tensile properties are summarized in Table II. The tensile strength and elongation at break of pure WBPU film were 8.3 MPa and 1468%, respectively. As the PVA content increased, the tensile strength and the elongation at break decreased but the initial modulus increased. The tensile strength of dissolved film samples decreased a little compared to un-dissolved samples. However, the elongation at break of dissolved samples increased significantly. The initial modulus of dissolved samples came close to the modulus of pure WBPU.

Water Vapor Permeability. Figure 11 showed the relationship between water vapor permeability (WVP) and coat-

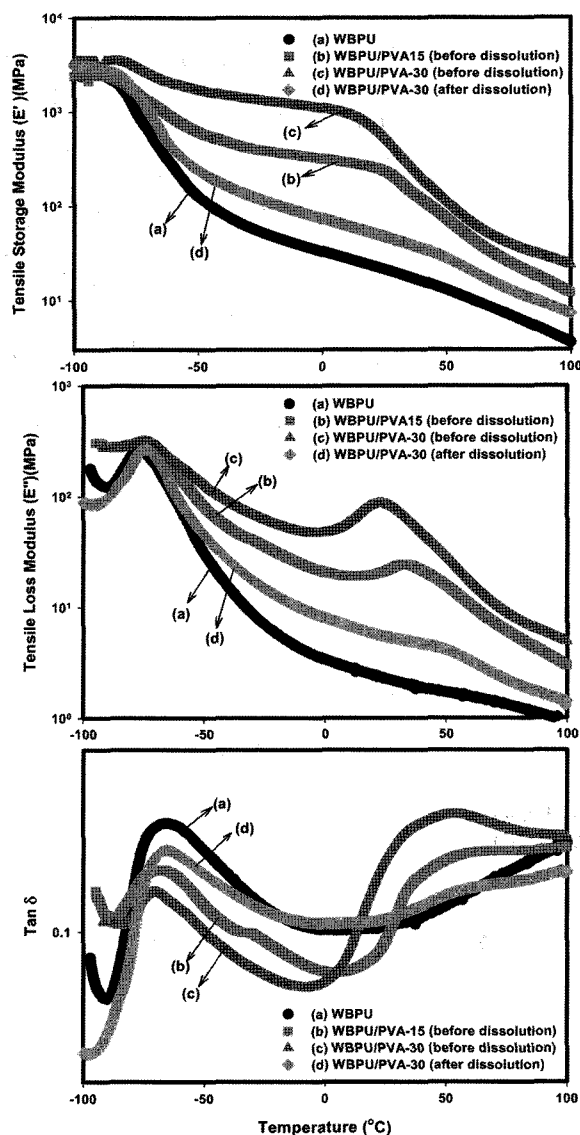


Figure 9. Dynamic storage modulus (E'), loss modulus (E''), and $\tan \delta$ for WBPU/PVA blends films.

ing layer thickness for the typical WBPU/PVA-15 coated Nylon fabric sample. The WVP of pure Nylon fabric were 3,234 g/m²/day. The WVP of WBPU/PVA-15 coated Nylon

Table II. T_{gs} , T_{gh} , and Tensile Properties for WBPU/PVA Blends Films

Sample Designation	T_g (°C) by DMTA		Sample Designation	Before Dissolution		After Dissolution	
	T_{gs}	T_{gh}		Tensile Strength (MPa)	Elongation at Break(%)	Tensile Strength (MPa)	Elongation at Break(%)
WBPU	-65	57	WBPU	8.3	1,468	8.0	1,460
WBPU/PVA-15	-68	59	WBPU/PVA-5	6.5	1,139	6.0	1,140
WBPU/PVA-30	-69	60	WBPU/PVA-15	5.1	810	5.1	943
WBPU/PVA-30 ^a	-64	57	WBPU/PVA-30	4.0	632	4.1	730

^aAfter dissolution.

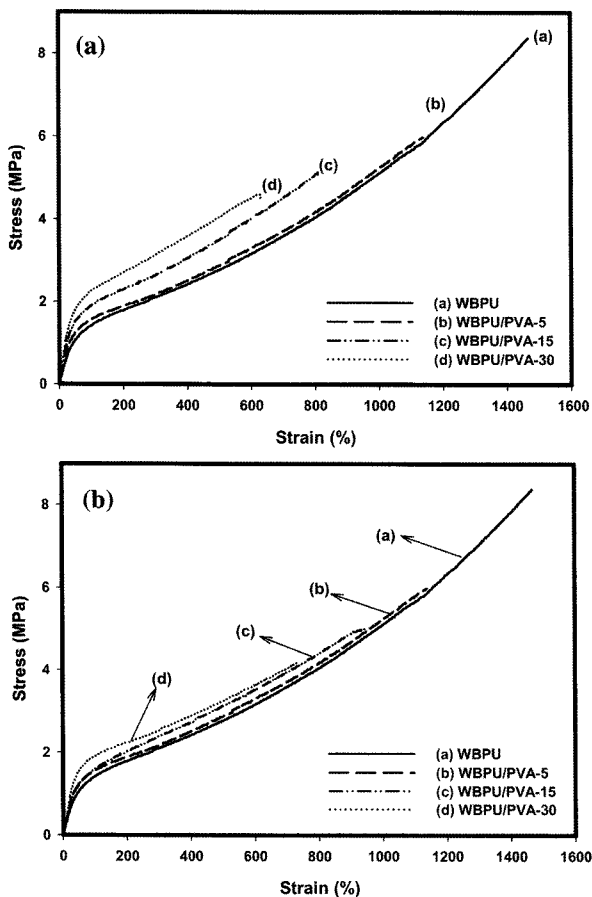


Figure 10. Stress-strain curves for WBPU/PVA blends films (a) before dissolution and (b) after dissolution.

fabric sample decreased from 2,374 to 1,400 g/m²/day with increasing thickness of coated layer from 0.127 to 0.487 mm. The effect of dissolution time on the WVP was shown in Figure 12. The WVP increased significantly with increasing dissolution time up to 4 hrs, and then decreased a little. From these results, the thickness layer, dissolution time and dissolution temperature were fixed at 0.127 mm, 4 hrs, and 90°C respectively, which were regarded optimum for obtaining higher water permeability in Nylon fabrics coated with various WBPU/PVA coating materials.

The WVP of pure Nylon fabric, pure WBPU coated Nylon fabric, and WBPU/PVA (5~30 wt%) coated Nylon fabrics before and after dissolution of PVA in water are shown in Figure 13 and Table III. The WVP of coated Nylon fabric was found to increase with increasing PVA content. This might be due to the increase of hydrophilic component PVA. The WVP of coated Nylon fabrics before and after dissolution were in the range of 1,646~2,135 and 1,998~2,698 g/m²/day, respectively. The WVP of coated Nylon fabrics after removal of PVA showed higher values than those of un-dissolved samples. WVP % [(WVP of coated Nylon fabrics/WVP of pure Nylon fabrics) × 100] also increased signifi-

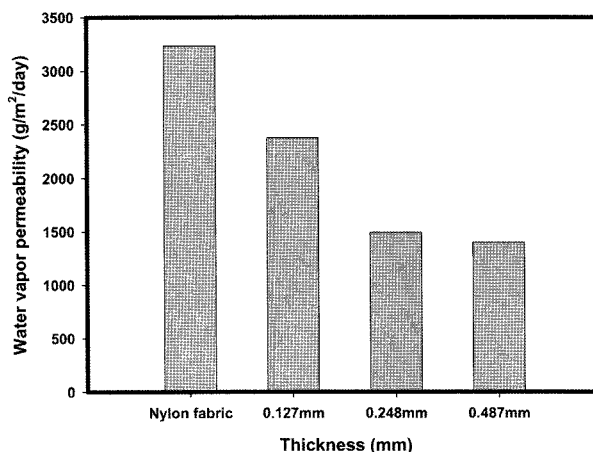


Figure 11. Effects of coating layer thickness on the water vapor permeability of WBPU/PVA-15 blend coated Nylon fabrics.

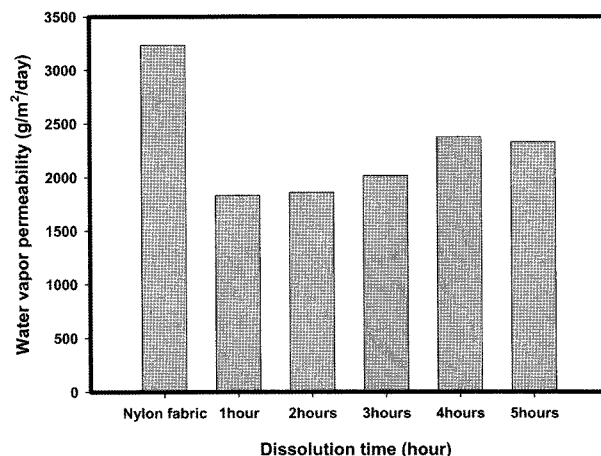


Figure 12. Effects of dissolution time on the water vapor permeability for WBPU/PVA-15 blend coated Nylon fabric.

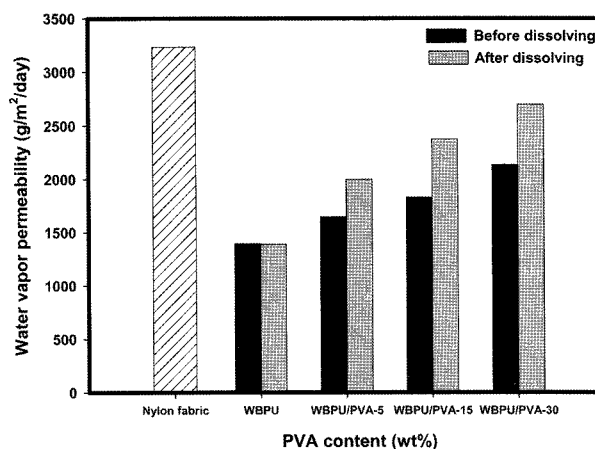


Figure 13. Water vapor permeability before and after dissolution for pure Nylon fabric, WBPU/PVA blends coated Nylon fabrics.

Table III. Water Vapor Permeability (WVP), WVP%, and Water Resistance of WBPU/PVA Blends Coated Nylon Fabrics

Sample Designation	Water Vapor Permeability (g/m ² day)		WVP %		Water Resistance (mmH ₂ O)	
	Before Dissolution	After Dissolution	Before Dissolution	After Dissolution	Before Dissolution	After Dissolution
WBPU	1,395	1,395	44	44	10,000	10,000
WBPU/PVA-5	1,646	1,998	51	62	5,000<	5,000
WBPU/PVA-15	1,829	2,374	56	73	5,000<	5,000
WBPU/PVA-30	2,135	2,698	66	83	5,000<	5,000

$$\text{WVP \%} = \frac{\text{WVP of coated Nylon fabric}}{\text{WVP of Nylon fabric}} \times 100. \text{ WVP of original Nylon fabric : } 3,234 \text{ g/m}^2\text{/day.}$$

cantly with increasing PVA content. WVP % for the WBPU/PVA-coated Nylon fabrics before and after dissolution of PVA in water were in the range of 51~66 and 62~83%, respectively. The higher WVP and WVP% of dissolved samples compared with un-dissolved samples should be attributed to the formed micro-pores in coated layer after dissolution of PVA in water. The water resistances of dissolved and un-dissolved fabric samples were shown in Table III. Water resistance of WBPU coated Nylon fabric was about 10,000 mmH₂O. Water resistance of WBPU/PVA coated Nylon fabrics before removal of PVA were above 5,000 mmH₂O, however, those of coated Nylon fabrics after removal of PVA were near 5,000 mmH₂O. These results suggested that using WBPU/water soluble polymer PVA blends as coating materials and then dissolving PVA in water was an effective method to obtain prominent breathable fabrics.

Conclusions

Waterborne polyurethane-urea (WBPU) was synthesized by prepolymer mixing process using isophorone diisocyanate (IPDI)/2,2-bis(hydroxymethyl)propionic acid (DMPA)/poly(tetramethylene ether) glycol (PTMG)/ethylenediamine (EDA)/triethylamine (TEA) in an emulsion system. WBPU/water soluble polymer PVA (5, 15, and 30 wt%) blends as coating materials were prepared by blending WBPU dispersion with PVA solution. The coating materials were coated to Nylon fabrics. It was found that the maximum/optimum contents of PVA for stable emulsions were about 30 wt%. The viscosity of WBPU/water soluble polymer aqueous dispersions (emulsion) remarkably increased with increasing PVA content. However, the tensile strength of film samples after removal of PVA was decreased a little with increasing PVA content in WBPU/PVA blends. The number and size of micro-pore formed on film samples increased with increasing PVA content. The water vapor permeability of coated Nylon fabrics was found to increase with increasing PVA content. WVP % also increased significantly with increasing PVA content. WVP % for the WBPU/PVA-coated Nylon fabrics before and after dissolution of PVA in water were in the range of

51~66 and 62~83%, respectively. These results clearly demonstrates that utilizing WBPU/water soluble polymer PVA blends as coating materials and then dissolving PVA in water surely facilitate obtaining prominent breathable fabrics.

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