

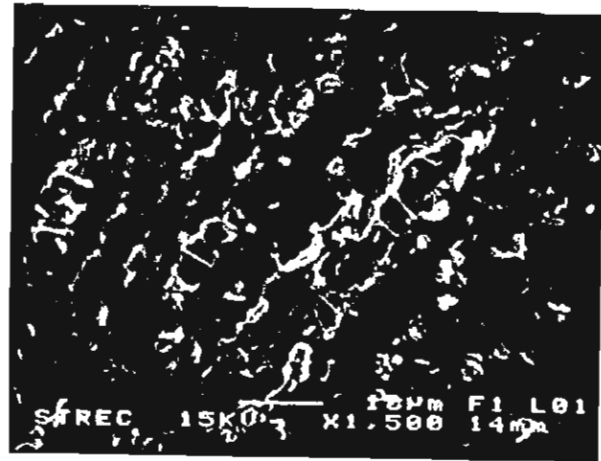
surface of virgin TPU after base immersion exhibits very small amount of fibrous characteristic and there are some small particles detached at the surface. In case of the blended TPU with 0.2% and 0.4% of PDMS after base immersion, it can be obviously seen that a lot of particles with various sizes seem to come off and detach on the fractured surface while some fibrous characteristic and craze can still be observed. In case of the blended TPU with 0.8% of PDMS, a difference in fractured surface is remarkably noticed, i.e. there are a lot of hollows occurred and less amount of particles detached at the surface. The hollows seem to be the result of the particles that come off and separate from the surface. A formation of craze can still be seen.

From the morphology observed and the results on the weight loss and the surface appearance of virgin TPU and blended TPU after base immersion, one can imagine an occurrence of a corrosive reaction between the sample surface and NaOH solution or the degradation of the soft domain of polyurethane in base solution. This seems to be stronger when PDMS contents in the blended TPU is increased. Furthermore, the fibrous characteristic on fracture surface of virgin TPU and blended TPU after base immersion, is obviously decreased comparing to those before immersion, as shown in Figure 13a-13d. This is consistent with the results of tensile test after base immersion that show the lowest ultimate tensile strength, the elongation at break and the energy to break, comparing to those before immersion and after immersion in other reagents. This indicates that base immersion, as well as the PDMS contents, has a strong effect on changing the morphology and tensile properties of virgin TPU and blended TPU after tensile testing.

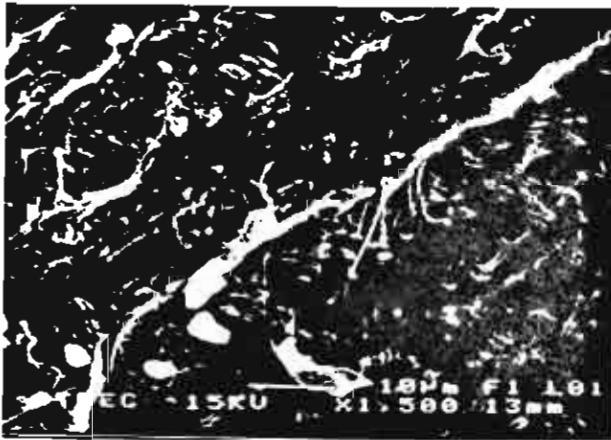
Nevertheless, which parts of TPU and blended TPU that react with NaOH solution is still to be confirmed in the further study.



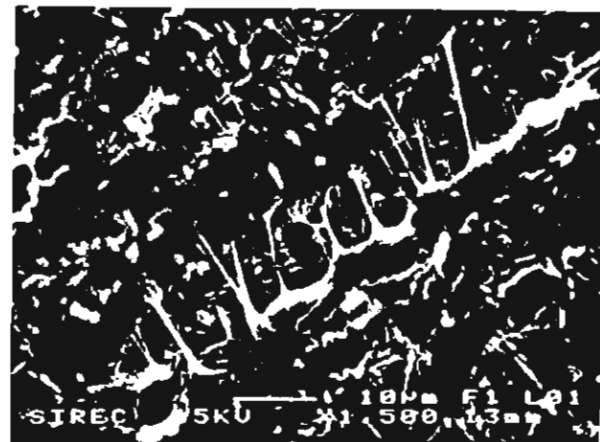
(a)



(b)

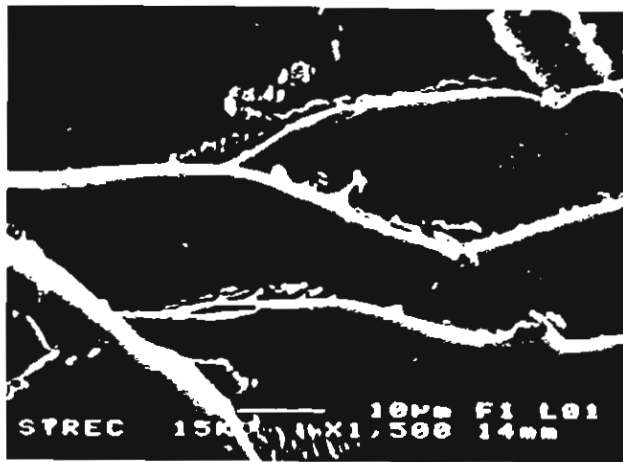


(c)

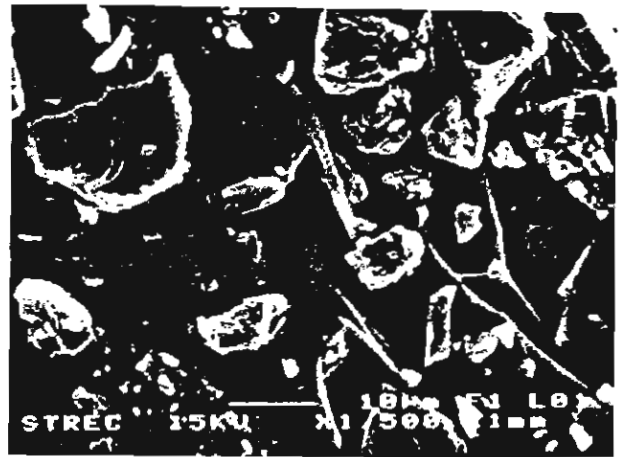


(d)

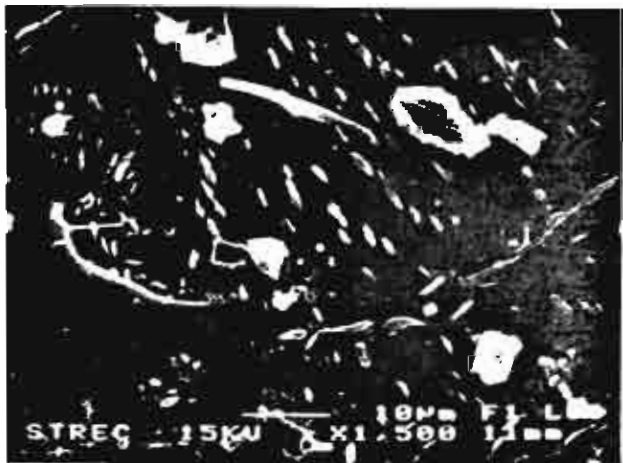
Figure 18. SEM photographic of fractured surface of the samples after acid immersion:
 (a) virgin TPU, (b) TPU/PDMS blends at 0.2% of PDMS, (c) TPU/PDMS blends at 0.4% of PDMS, (d) TPU/PDMS blends at 0.8% of PDMS.



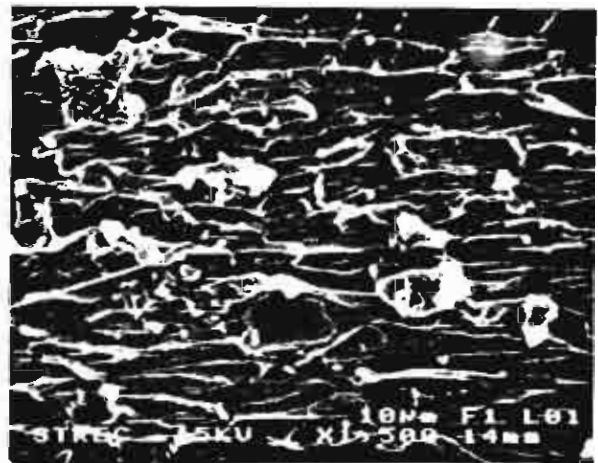
(a)



(b)



(c)



(d)

Figure 19. SEM photographic of fractured surface of the samples after base immersion:
 (b) virgin TPU, (b) TPU/PDMS blends at 0.2% of PDMS, (c) TPU/PDMS blends
 at 0.4% of PDMS, (d) TPU/PDMS blends at 0.8% of PDMS.

3.3 Heat Aging

3.3.1 Physical Appearance

The color of the TPU/PDMS blends changed from transparent or slightly cloudy to be yellow. The degree of the yellowness is compared in Table 3. It can be seen that the yellowness of the samples depends on the temperature and the heat aging period. The higher the temperature and the longer the heat aging period are, the more yellowness of the samples is noticed. This implies the thermal degradation occurred in the samples.

Table 3. Comparison of the degree of the yellowness of the samples after heat aging

Conditions		Heat aging period		
		1 day	3 days	5 days
Temperature	70 °C	1	2	3
	80 °C	1	4	4
	90 °C	2	5	5

Note: The degree of the yellowness starts from 1, 2, 3, 4 to 5. The lowest degree of 1 equals to the color of the samples before heat aging. The highest degree of 5 comparatively refers to the darkest yellow.

3.3.2 Tensile properties

Tensile properties of the TPU and the TPU/PDMS blends after heat aging tend to show an insignificant change from those of the samples before heat aging except the samples after the heat aging at 90 °C for 5 days. At this condition, the samples have faced the maximum heat for the longest time period. The ultimate tensile strength, elongation at break, Young's modulus and energy to break of the TPU and TPU/PDMS blends after the heat aging at 90 °C for 5 days are compared with the samples before heat aging in Figure 20, 21, 22, and 23, respectively. The ultimate tensile strength of the samples after heat aging tends to be slightly lower than those before heat aging. The elongation at break and energy to break of the samples after heat aging gradually increase from those before heat aging when the PDMS concentration in the blend is increased more than 0.4%. The Young's modulus of the samples after heat aging is

slightly higher than those before heat aging at all PDMS compositions. In addition, the heat aging of the blends is further tested at 90 °C for a longer period up to 7 and 14 days but no significant change comparing to the case of heat aging at 90 °C for 5 days is observed.

It can be suggested that the heat aging process does not significantly change the tensile properties of TPU and TPU/PDMS blends.

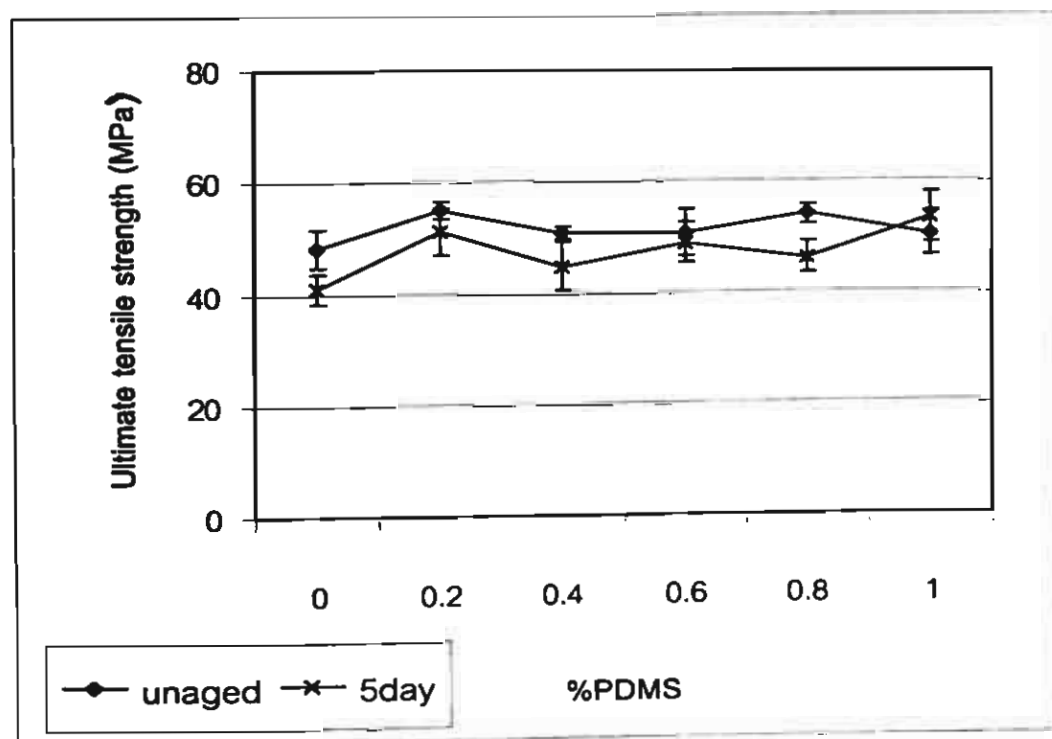


Figure 20. Ultimate tensile strength of TPU and blended TPU before and after heat aging at 90°C for 5 days.

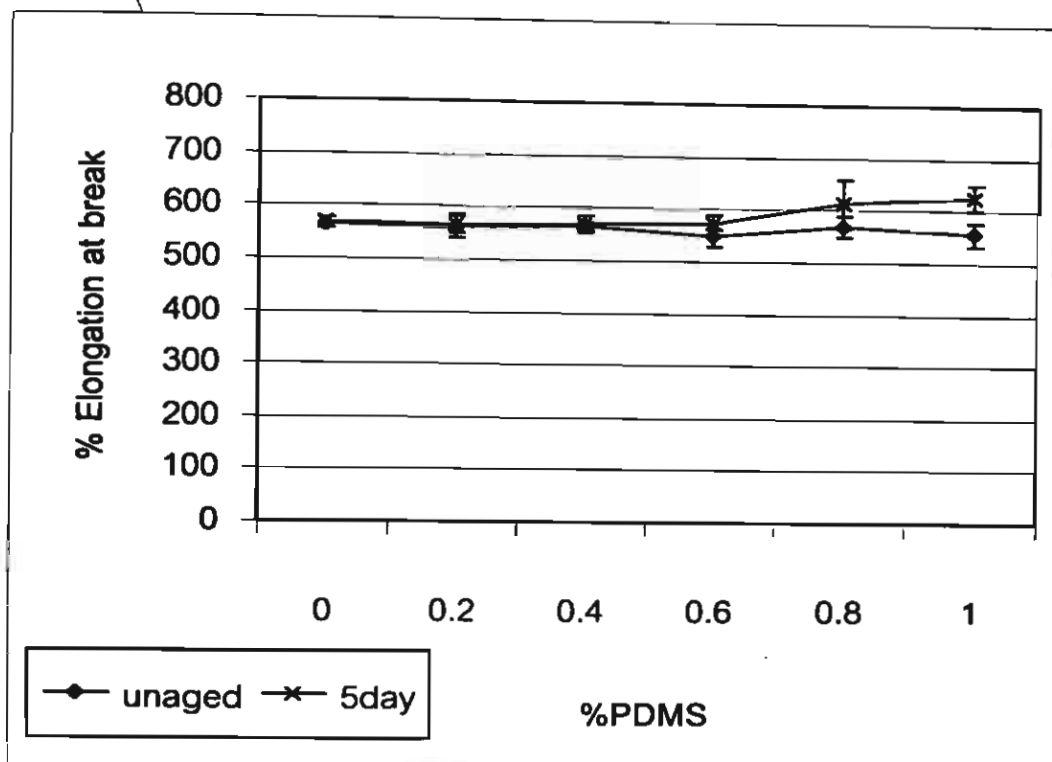


Figure 21. Elongation at break of TPU and blended TPU before and after heat aging at 90°C for 5 days.

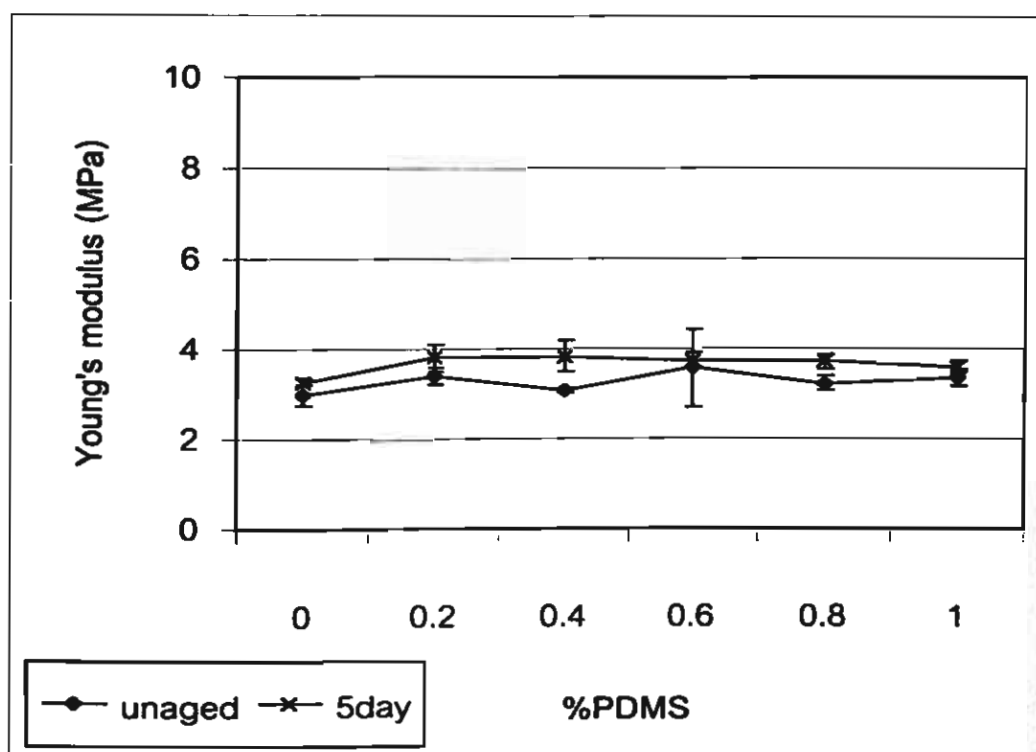


Figure 22. Young's modulus of TPU and blended TPU before and after heat aging at 90°C for 5 days.

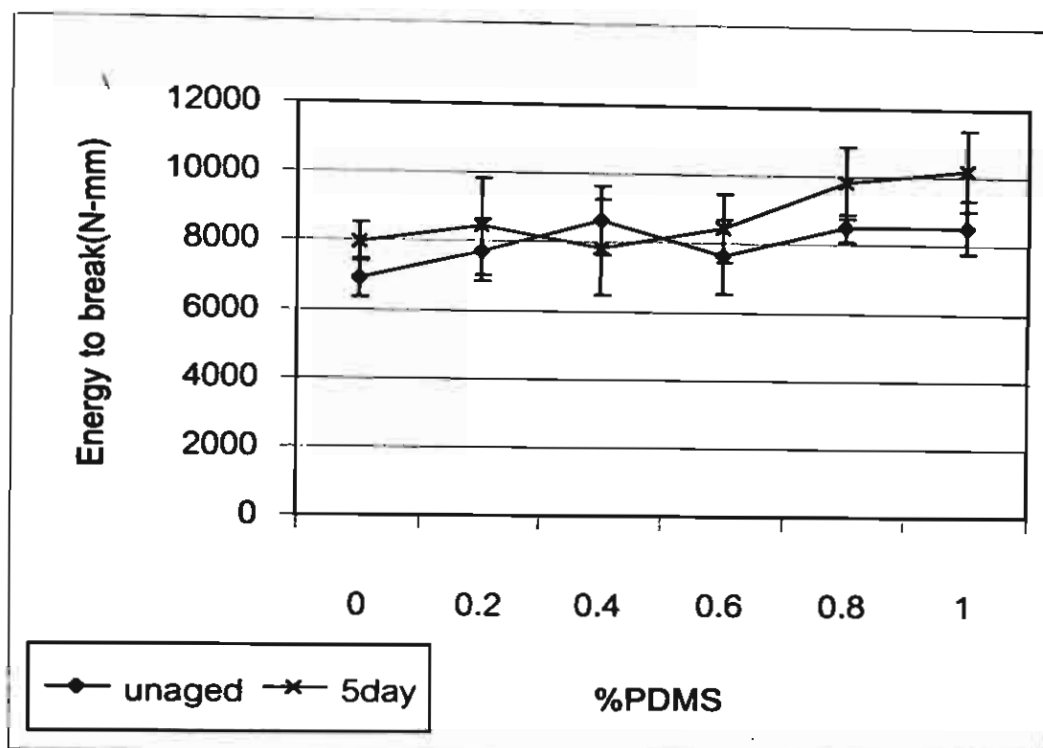


Figure 23. Energy to break of TPU and blended TPU before and after heat aging at 90 °C for 5 days.

3.3.3 Morphology

SEM photomicrographs of the fractured surface from tensile test of blended TPU after heat aging at 90 °C for 5 days are similar to those before heat aging, i.e. the less amount of fibrous characteristic in the blends is observed when the PDMS concentration in the blend is increased. (See Figure 24 for the TPU/PDMS blend at 0.8% of PDMS.) The only difference noticed is the holes distributed throughout the sample. This might be caused by the movement of dispersed PDMS in the blend gathering together and evaporating during the heat aging process since PDMS has a very low glass transition temperature.

From the heat aging (up to 90 °C for 5 days) of the TPU/PDMS blends, it can be concluded that the strongest effect of heat aging is obviously noticed on the yellowness of the blends, likely due to the thermal degradation of the polymers. No remarkable effect is noticed on the tensile properties and the morphology of TPU and TPU/PDMS blends.

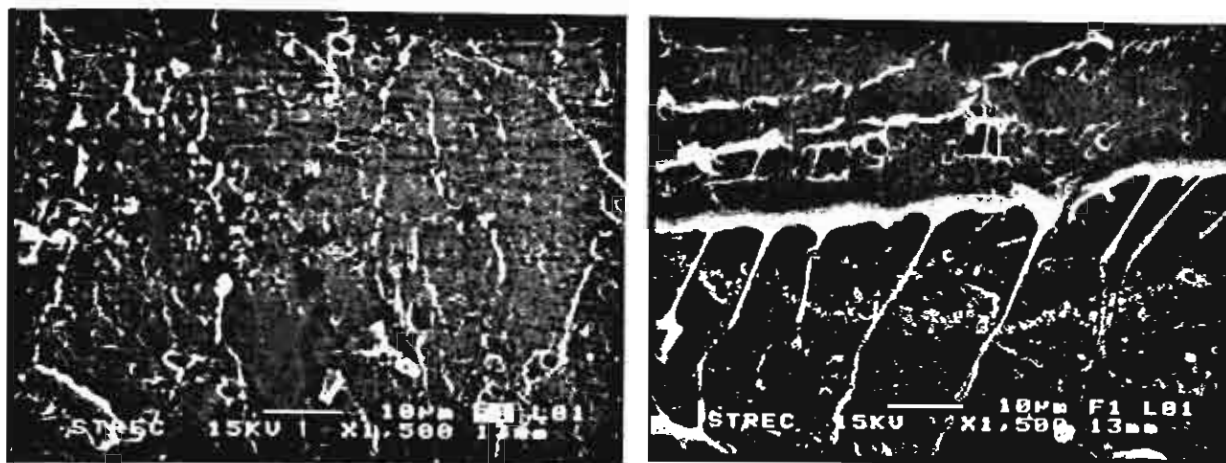


Figure 24. SEM photographic of fractured surface of TPU/PDMS blends at 0.8% of PDMS after heat aging at 90°C for 5 days.

4. CONCLUSION

4.1 TPU/PDMS blends

From the results of the tensile properties of blended TPU, it can be concluded that the ultimate tensile strength of the blended TPU is decreased about 20% while the elongation at break of blended TPU is gradually increased about 30% with increasing PDMS content in the blends from 0.2%-0.8%. Young's modulus of the blended TPU is increased about 40% with increasing PDMS content up to about 0.6% of PDMS. Energy to break of virgin TPU and blended TPU with 0.2% to 0.4% of PDMS is consistent but those with 0.6% to 1.0% of PDMS tend to decrease about 10%.

The morphology of the blends shows that TPU/PDMS blends exhibit dispersed phase morphology. PDMS is evident as the dispersed phase in TPU matrix with the average domain size of PDMS at around 0.1-0.7 μm . The domain size of PDMS in the blends becomes smaller for higher PDMS concentration. In case of the fractured surface, there are three different fractured mechanism occurred. The first mechanism of fibrous characteristic occurred with the virgin TPU. The second mechanism of craze formation with some fibrous characteristic can be observed in the blended TPU at 0.2% and 0.4% of PDMS. The third mechanism of chunky formation without any fibrous characteristic of TPU occurred in the blended TPU with 0.8% of PDMS. It can be concluded that there is an optimum PDMS contents at around 0.6% to 0.8% that has an

effect on the tensile properties and a change in the phase morphology of TPU/PDMS blends.

4.2 Chemical resistance of TPU/PDMS blends

In the study of tensile properties and morphology of TPU/PDMS blends after chemical immersion, it can be concluded that the water immersion has no effect on the tensile properties of the virgin TPU and blended TPU while a slight effect of PDMS contents on the acid resistance to the tensile properties can be noticed. The fractured structures of blended TPU at all PDMS compositions after acid immersion show fibrous characteristic and craze formation similar to before acid immersion. While the fractured surface of blended TPU at 0.8% of PDMS after acid immersion does not show the mechanism of chunky formation. Thus, difference of morphology before and after acid immersion of blended TPU at 0.8% of PDMS content may support that acid immersion has changed the fractured mechanism of the sample.

For the base immersion, as well as the PDMS contents, has a strong effect on changing the morphology and tensile properties of virgin TPU and blended TPU. The results of the tensile properties of virgin TPU after base immersion comparing to before base immersion can be concluded that the ultimate tensile strength and energy at break is decreased, the Young's modulus is increased while the elongation at break is rather consistent. For blended TPU after base immersion comparing to before base immersion, similar trends for each property are noticed when PDMS content in the blend is not more than 0.8%. The resulting phase morphology of the all blends after immersion in NaOH exhibits very small amount of fibrous characteristic and a large amount of craze formation while there are some small particles detached at the surface. In case of the blended TPU with 0.8% of PDMS, there are a lot of hollows occurred. The hollows seem to be the result of the particles that come off and separate from the surface. From the morphology observed and the results on the weight loss and the surface appearance of virgin TPU and blended TPU after base immersion, it is suggested that there is an occurrence of a corrosive reaction between the sample surface and NaOH solution or the degradation of the soft domain of polyurethane in base solution. This seems to be stronger when PDMS contents in the blended TPU is increased.

4.3 Heat aging of TPU/PDMS blends

The heat aging of TPU and TPU/PDMS blends, from 70°C to 90°C for 1 to 5 days, has an influence on the yellowness of the samples. The higher the temperature and the longer the heat aging period are, the more yellowness of the samples is noticed. This implies the thermal degradation occurred in the samples. No remarkable effect of heat aging is noticed on the tensile properties and the morphology of TPU and TPU/PDMS blends.

5. BIBLIOGRAPHY

- [1] Paul D.R., C.B. Bucknall, "*Polymer Blends volume 1 :Formulation*", J. Wiley & Sons, New York 2000.
- [2] L.A. Utracki, "*Polymer Alloys and Blends*", Hanser Publishers, New York 1990.
- [3] D.J. Walsh, J.S. Higgins, A. Maconnachie, "*Polymer Blends and Mixtures*", Martinus Nijhoff, Dordrecht 1985.
- [4] G. Oertel, "*Polyurethane Handbook*", Hanser Publishers, Germany 1985.
- [5] D.J.T. Hill, M.I. Killeen, J.H. O'Donnell, P.J. Pomery, D.S.T. John, A.K. Whittaker, *Journal of Applied Polymer Science*, 1996, 61, 1757-1766.
- [6] S.N. Jaisankar, G. Radhakrishnan, *Polymer Engineering and Science*, 2000, 40, 621-626.
- [7] Y. Kim, W.J. Cho, C.S. Ha, *Journal of Applied Polymer Science*, 1999, 71, 451-422.
- [8] P. Potschke, K. Wallheinke, H. Fritsche, H. Stutz, *Journal of Applied Polymer Science*, 1997, 64, 749-762.
- [9] A. Stanciu, A. Airinei, D. Timpu, A. Ioanid, C. Ioan , V. Bulacovschi, *European Polymer Journal*, 1999, 35, 1959-1965.
- [10] C. Hepburn, "*Polyurethane Elastomers*", Applied Science Publication, England 1982.
- [11] Z. Wirpaza, "*Polyurethanes (Chemistry, Technology and Applications)*", Ellis Horwood, Great Britain 1993.
- [12] M.Z. Yue, K.S. Chian, *Journal of Applied Polymer Science*, 1996, 60, 597-603.
- [13] M. Furukawa, T. Yokoyama, *Journal of Polymer Science: Polymer Letters Edition*, 1979, 17, 175-180

6. OUTPUT

6.1 International Publication

- 1) S. DAMRONGSAKKUL, R. SINWEERUTHAI, J.S.HIGGINS, "Processability and Chemical Resistance of the Polymer Blend of Thermoplastic Polyurethane and Polydimethylsiloxane" *Macromolecular Symposium*, to be published (2003) [Appendix A]

6.2 International Conference

- 1) S. DAMRONGSAKKUL, R. SINWEERUTHAI, J.S.HIGGINS, "Processability and Chemical Resistance of the Polymer Blend of Thermoplastic Polyurethane and Polydimethylsiloxane" 7th European Symposium on Polymer Blends, Lyon-Villeurbanne, France, May 27-29, 2002, E1 (poster presentation) [Appendix B]

APPENDIX A

- **Accepted letter for publication**
- **Referee report**
- **Revised manuscript submitted to Macromolecular Symposium journal**

Siriporn Damrongsakkul

From: Jean-Pierre Pascault <Jean-Pierre.Pascault@insa-lyon.fr>
To: <siriporn.d@chula.ac.th>
Sent: 9 พฤศจิกายน 2545 1:13
Attach: SiripornRw2.doc
Subject: Polymer Blends

Dear Colleague,

On May 27-29th, 2002, the "7th European Symposium on Polymer Blends" took place in Lyon-Villeurbanne, France. As for the previous symposia of this series, lectures and selected papers are going to be collected in a single Macromol. Symp. Volume, before the end of this year.

57 papers have been received and sent to two, eventually three referees. After discussions with Wiley-VCH the optimum length of the volume will be 400-450 pages. It requires to reject ~ 17 papers. For this difficult stage only the referees comments have been taken into account.

In conclusion of this stage and in agreement with the opinion of our referees, I am glad to inform you that your article has been accepted for publication. However, the referees did make suggestions for the improvement of the article which I ask you to take into account when revising the manuscript. If you have some remarks concerning the length of the manuscript, I would like you to be informed that we will be very careful with the respect of referees recommendations. Please return two complete hard copies of the revised manuscript, a completed copyright form, and a disk version of your manuscript.

We look forward to receiving your revised manuscript before the 1st of December.

Best regards,

JP. Pascault

Chairman Polymer Blends

Jean-Pierre Pascault

LMM / INSA - Bat Jules Verne

20 avenue Albert Einstein

69621 Villeurbanne Cedex

tel (33) (0)4 72 43 82 25

fax (33) (0)4 72 43 85 27

<http://www.insa-lyon.fr/Laboratoires/LMM/index.htm>

http://www.insa-lyon.fr/Laboratoires/LMM/trombino/Chercheurs_fichiers/frame.htm

<http://www.gfp.fr.fm>

Referee Report for Macromolecular Symposia

Referee's name:

Referee's email:

Do you wish to remain anonymous: Yes

Manuscript no.: 52-Siriporn

Abbreviated title: Processability and chemical resistance of the polymer blend...

Correspondence author(s): Siriporn Damrongsakkul

Title of symposium: Polymer Blends

Place and date of symposium: Lyon-Villeurbanne May 27-29, 2002

1) How important do you consider the results reported?

very important

important

less important

unimportant

2) Do the data obtained by experiment or calculation verify the hypotheses and conclusions?

Yes

No

3) Is the length of the manuscript appropriate to its contents?

Yes

No, the manuscript is too long

No, the manuscript is too short

4) Do you recommend acceptance of the article?

Yes, without alterations

Yes, after minor alterations

Yes, but only after major alterations

No

5) If you are of the opinion that the contribution is not suitable for publication in Macromolecular Symposia, please state your reasons why?

Other comments:*

1) the English in some sentences should be improved (for example, p.4, 5th paragraph, one should probably read "The ultimate tensile strength... are not significantly ALTERED" ?)

2) pp.4&5, the authors comment on a sharp decrease in various properties after base immersion. This does not seem very surprising since the TPU is based on a polyester soft segment, i.e. very sensitive to base hydrolysis. The method is well-known to degrade the soft domains of polyurethane networks in order to study their structure (see for example Furukawa et al. *J. Polym. Sci. Polym. Lett. Ed.* **17**, 175 (1979); *Angew. Makromol. Chem.* **240**, 205 (1996).

*For further comments please use separate sheet.

Processability and Chemical Resistance of the Polymer Blend of Thermoplastic Polyurethane and Polydimethylsiloxane

Siriporn Damrongsakkul^{1,*}, Ratirat Sinweeruthai¹, Julia S. Higgins²

¹Polymer Engineering Laboratory, Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand

²Imperial College, University of London, London SW7 2BY, UK

Summary: This work is aimed to develop the melt blend of thermoplastic polyurethane (TPU) and polydimethylsiloxane (PDMS) and to study the effect of the chemical resistance on the tensile properties and morphology of the blends. The master batch blends at 2% of PDMS with 98% of TPU were firstly prepared by an internal mixer and then the blends of TPU/PDMS were prepared by melt mixing using a twin screw extruder. The maximum PDMS content that can be mixed with TPU was found to be no higher than 1%. Higher PDMS content leaves an unmelted TPU fraction in the blends due to the short residence time in the twin screw extruder. The resultant blends show an increase in the elongation at break up to 30% and in Young's modulus up to 40% at the optimum PDMS concentration of around 0.6%-0.8%, beyond which these properties diminish. The ultimate tensile strength and the energy to break are decreased by about 20% and 10%, respectively. The Scanning Electron Micrographs of the blends show dispersed phases of PDMS in a TPU matrix. The domain size of the PDMS phase becomes smaller when increasing PDMS content from 0.2% to 0.8%. The morphology of the fractured surface of TPU/PDMS blends shows less fibrous characteristics with increasing PDMS content in the blends.

For the study of the effects of chemical resistance on the tensile properties and morphology of TPU/PDMS blends, two chemical reagents, sulfuric acid (H_2SO_4 , 3% v/v) and sodium hydroxide (NaOH, 10% w/v) are selected. The results on the relationship of chemical resistance to tensile properties and morphology of the blends show that NaOH solution has a stronger effect on the tensile properties and morphology of virgin TPU and the blends than H_2SO_4 solution. The ultimate tensile strength and the energy to break of virgin TPU after base immersion was found to be strongly decreased, which could be caused by the base hydrolysis of the polyester soft segment of polyurethane. The effect of PDMS content in the blends on the base resistance and tensile properties is similar to results before immersion, i.e. the effective PDMS content in the blends that can generally improve tensile properties of the blends after immersion in NaOH does not exceed 0.8%. The results are in agreement with the weight loss of TPU/PDMS blends after base immersion and the morphology of the fractured surface of TPU/PDMS blends after base immersion that exhibit very small amounts of a fibrous character. There are also some small particles detached at the surface. This could be the result of an occurrence of a corrosive reaction between the sample surface and NaOH solution.

Keywords: Polymer blends, thermoplastic polyurethane, polydimethylsiloxane, tensile properties, morphology

Introduction

Polymer blends have emerged as an important group of polymeric materials since the late 1970s and have experienced substantial growth since the 1980s. Interests in polymer blending are reflected in the numbers of patent and research publications by both industry and academia.^[1-9] Blending of polymeric materials has been shown to be a useful and cost effective route, in comparison with the synthesis of new polymers, for enhancing material properties and developing materials with desired performance.

During the past decades, thermoplastic polyurethane (TPU) has received considerable attention from both the scientific and industrial communities.^[10-11] Applications of TPU include automotive exterior body panels, medical implants such as the artificial heart, membranes, ski boots and flexible tubing. TPU features the best physical properties of all elastomers exhibiting high modulus and abrasion resistance, with excellent resistance to aging (ozone), atmospheric factors, typical solvents and oils. Moreover, TPU is capable of bearing greater loads than other rubbers. But the properties of TPU can be changed by the environment in that a physical or chemical process may occur. There are three environmental effects considered particularly important for polyurethane elastomers: the effect of heat, swelling by immersion in certain fluids and hydrolytic resistance. In certain fluids such as alcohols, acids, bases, ketones and esters, polyurethanes tend to show swelling, degradation and changes in some mechanical properties.

From the discussion above, it is interesting to study polymer blends of TPU with other polymers. Polydimethylsiloxane (PDMS) was chosen to blend with TPU because PDMS is a polymer with a unique combination of properties resulting from the presence of an inorganic siloxane backbone with organic methyl groups attached to the silicon. This chemical configuration produces polymers which have good chemical stability, in particular good oxidative resistance. Thus, this research is aimed to study the tensile properties and the morphology of TPU/PDMS blends. The effects of chemical reagents on the tensile properties and the morphology of TPU/PDMS blends are investigated.

Materials and experiments

Materials: Thermoplastic polyurethane used in this study is S385A series with the trade name of Skythane, obtained from SK Chemicals Co, Ltd. S385A is a polyester-based thermoplastic polyurethane of which the hard segment is 4,4'-diphenylmethane diisocyanate (MDI) extended with 1,4-butanediol (BO). The soft segment is polyester polyol and 1,4-butanediol.

Polydimethylsiloxane used in this study was obtained from Dow Corning Co, Ltd; it is transparent fluid with a viscosity of 60,000 centistoke.

Sample preparation: The master batch of TPU/PDMS at 2% by weight of PDMS was prepared using the internal mixer of Haake "Rheomix3000p" at 190C for 10 min with a rotor speed of 30 rpm. After that the master TPU/PDMS batch was compressed and cut into pieces. The master batch was used to blend with the virgin TPU, using the counter-rotating twin screw extruder of Haake, to obtain the blends with the final PDMS concentration of 0.2%-1% in 0.2% increments. The extruded blends were cooled and finally cut into pellet form. The virgin TPU sample was treated by the same procedure for use as a reference sample.

Measurements: Tensile properties were measured following ISO 527-1 of the British Standards Institution (BSI) with "Lloyd LR 5K". Chemical resistance of all samples was tested following ASTM D543-95. Chemical reagents used were distilled water, sulfuric acid (H_2SO_4 , 3% v/v) and sodium hydroxide (NaOH, 10% w/v). Samples were immersed in chosen chemical reagents at 25C for 168 hr, after which they were dried and tested for tensile strength. Scanning electron microscopy (SEM), using a JEOL JSM-6400 instrument, was used to study sample morphology.

Results and discussion

Since PDMS is a liquid, the internal mixer is first employed for preparation of the master batch before final blending of the master batch with virgin TPU in the twin screw extruder. Using this procedure, the maximum concentration of PDMS in the TPU/PDMS blend is found to be 1% of PDMS; more than 1% excess PDMS resulted in unmelted TPU due to the short residence time in the twin screw extruder.

Comparison of the ultimate tensile strength, the elongation at break, Young's modulus and the energy to break, of the blended TPU at all compositions before and after immersion in various chemical reagents are shown in Figures 1-4.

Comparing to the virgin TPU, the prepared blends, before immersion, show an increase in the elongation at break up to 30% and in Young's modulus up to 40% at the optimum PDMS concentration of around 0.6-0.8%, beyond which these properties diminish. The ultimate tensile strength and the energy to break are decreased by about 20% and 10%, respectively. The optimum PDMS concentration on a similar system was also reported by Hill *et al*^[5] but at higher values than our results. This could arise from differences in the structure and characteristics of the polymer components. The dependence of tensile properties on PDMS

concentration in the blends can be preliminary explained by the change of the morphology and the fractured mechanism of the blends, as observed by SEM (Figures 5-8).

Fractured surface of blended TPU at 0.2% and 0.4% PDMS concentrations in Figure 6 and Figure 7 is different from that of virgin TPU (Figure 5), with less fibrous characteristic in the blends and with, in addition, areas of craze structure. In contrast, the fibrous characteristic and craze formation in blended TPU at 0.8% PDMS concentration, shown in Figure 8, is not visible. In this case the fractured structure appears in a chunky crack form. It is evident that there are three different fracture characteristics. The first, of a fibrous nature, occurs with the virgin TPU. The second, craze formation with some fibrous characteristics, is observed in the blended TPU at 0.2% and 0.4% of PDMS. The third, the chunky formation without any of the fibrous characteristics observed in virgin TPU, occurs in the blended TPU with 0.8% of PDMS. A change in the phase morphology of the TPU blend at the optimum PDMS concentration corresponds to the results on tensile properties, where the reduced effect of PDMS content on the tensile properties of TPU blends occurred at around 0.6%-0.8% PDMS concentration.

The ultimate tensile strength, Young's modulus and the energy at break of the blends at all compositions after immersion in water and acid (3% H_2SO_4), comparing to those before immersion, are not significantly different. In the case of acid immersion, a slight effect of PDMS contents on the acid resistance to the tensile properties is noticed.

In the case of base immersion (10% NaOH), the results on tensile properties show that base immersion has a significant effect on tensile properties. The effect of PDMS concentrations on the base resistance to the tensile properties is marked, i.e. the effective PDMS contents in blended TPU does, more or less, not exceed 0.8%. At 1% PDMS concentration, the effect on each property diminishes, with the value of each property being close to that of pure TPU. This is similar to the results found in the case of TPU/PDMS blends before immersion.

Comparing immersion in different chemical reagents, NaOH (10% w/v) has the strongest influence on the tensile properties of virgin TPU and blended TPU. For virgin TPU after base immersion comparing to before base immersion the ultimate tensile strength and energy at break is strongly decreased by 42% and 55%, respectively. This could be caused by the base hydrolysis of the polyester soft segment of polyurethane^[12]. The effect of PDMS concentration on the base resistance to tensile properties is similar to results before immersion, i.e. the effective PDMS contents in the blends that can generally improve tensile properties of the blends after immersion in NaOH does not excess 0.8%. The results are in agreement with the weight loss of TPU/PDMS blends after base immersion and the

morphology of the fractured surface of TPU/PDMS blends after base immersion that exhibits very small amount of fibrous characteristic and there are some small particles detached at the surface (Figure 9). This could be the result of a corrosive reaction between the sample surface and NaOH solution or the degradation of the soft domain of polyurethane in base solution as mentioned previously. Further study will be performed to clarify this point.

Acknowledgements

S.D. gratefully acknowledges the financial support from the Thailand Research Fund (TRF).

- [1] D.R. Paul, C.B. Bucknall, *"Polymer Blends volume 1 :Formulation"*, J. Wiley & Sons, New York 2000.
- [2] L.A. Utracki, *"Polymer Alloys and Blends"*, Hanser Publishers, New York 1990.
- [3] D.J. Walsh, J.S. Higgins, A. Maconnachie, *"Polymer Blends and Mixtures"*, Martinus Nijhoff, Dordrecht 1985.
- [4] G. Oertel, *"Polyurethane Handbook"*, Hanser Publishers, Germany 1985.
- [5] D.J.T. Hill, M.I. Killeen, J.H. O'Donnell, P.J. Pomery, D.S.T. John, A.K. Whittaker, *Journal of Applied Polymer Science*, 1996, 61, 1757-1766.
- [6] S.N. Jaisankar, G. Radhakrishnan, *Polymer Engineering and Science*, 2000, 40, 621-626.
- [7] Y. Kim, W.J. Cho, C.S. Ha, *Journal of Applied Polymer Science*, 1999, 71, 451-422.
- [8] P. Potschke, K. Wallheinke, H. Fritsche, H. Stutz, *Journal of Applied Polymer Science*, 1997, 64, 749-762.
- [9] A. Stanciu, A. Airinei, D. Timpu, A. Ioanid, C. Ioan , V. Bulacovschi, *European Polymer Journal*, 1999, 35, 1959-1965.
- [10] C. Hepburn, *"Polyurethane Elastomers"*, Applied Science Publication, England 1982.
- [11] Z. Wirpaza, *"Polyurethanes (Chemistry, Technology and Applications)"*, Ellis Horwood, Great Britain 1993.
- [12] M. Furukawa, T. Yokoyama, *Journal of Polymer Science: Polymer Letters Edition*, 1979, 17, 175-180.

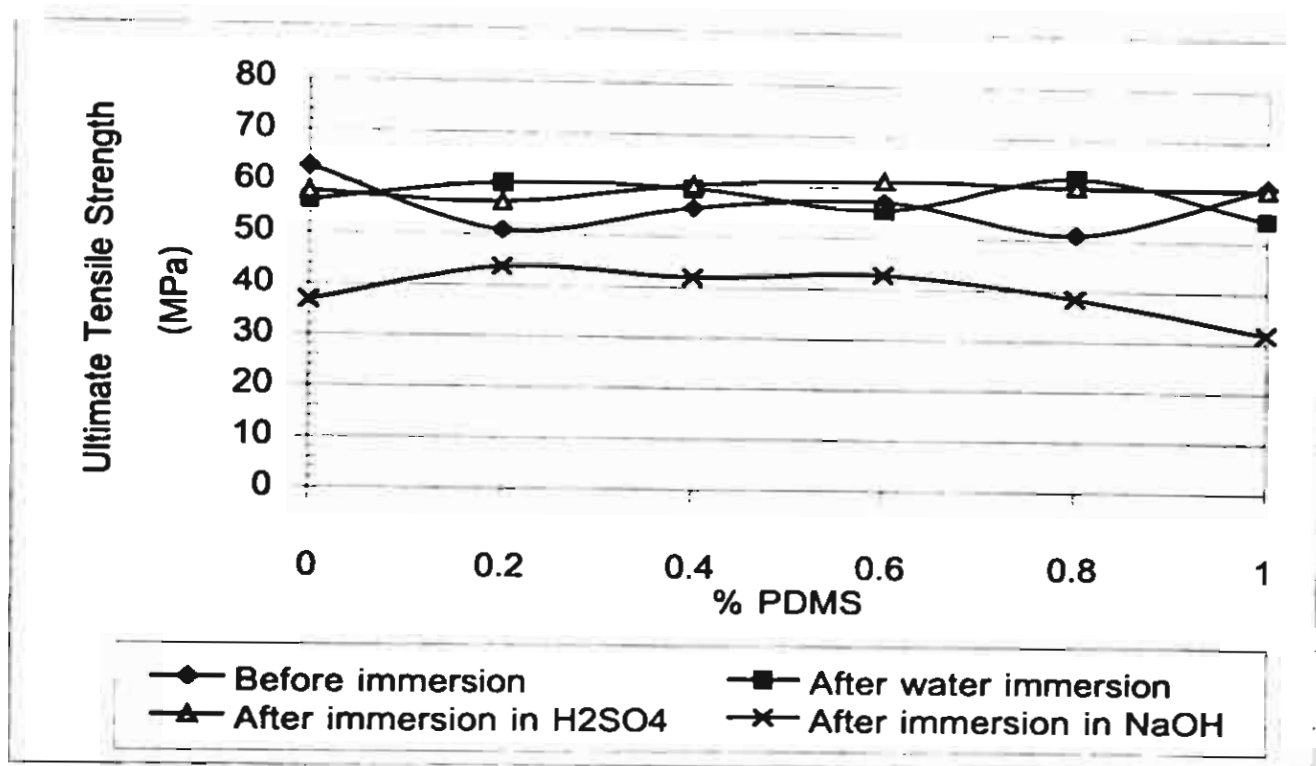


Figure 1. Comparison on the ultimate tensile strength of the virgin TPU and blended TPU before and after immersion in various chemical reagents

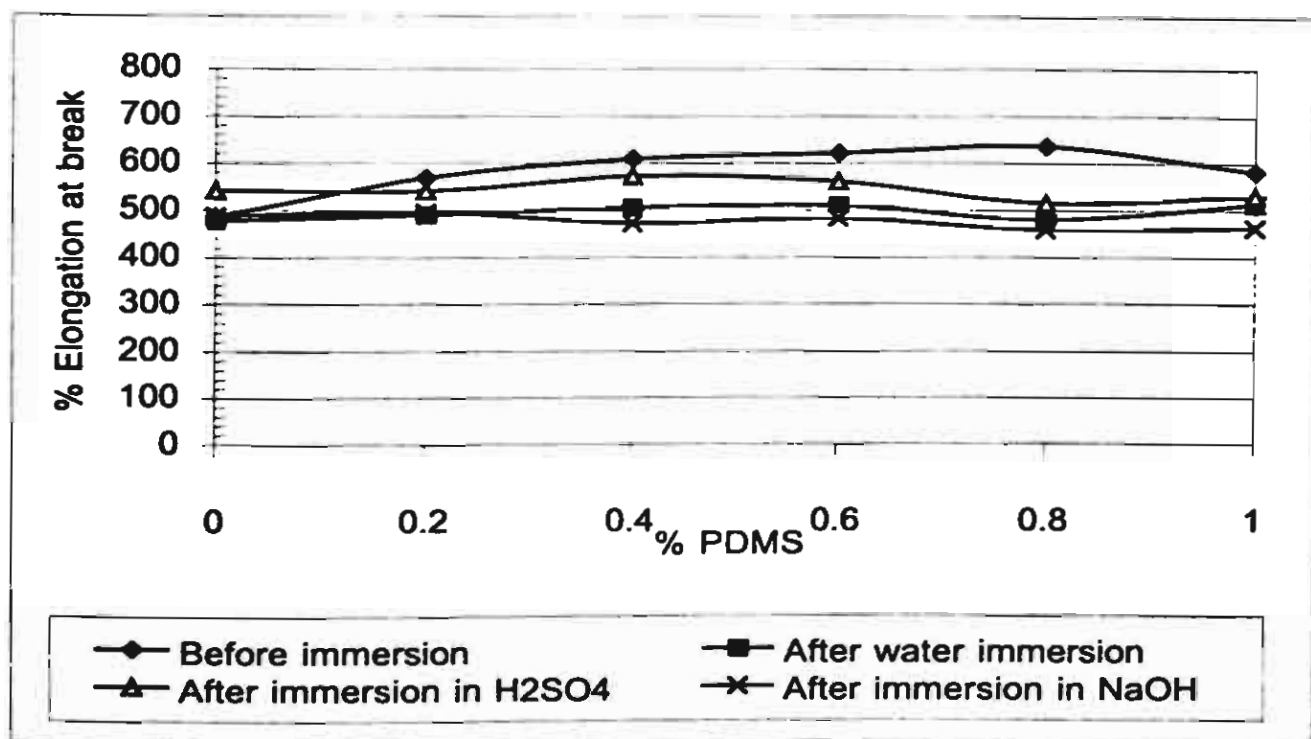


Figure 2. Comparison on the elongation at break of the virgin TPU and blended TPU before and after immersion in various chemical reagents.

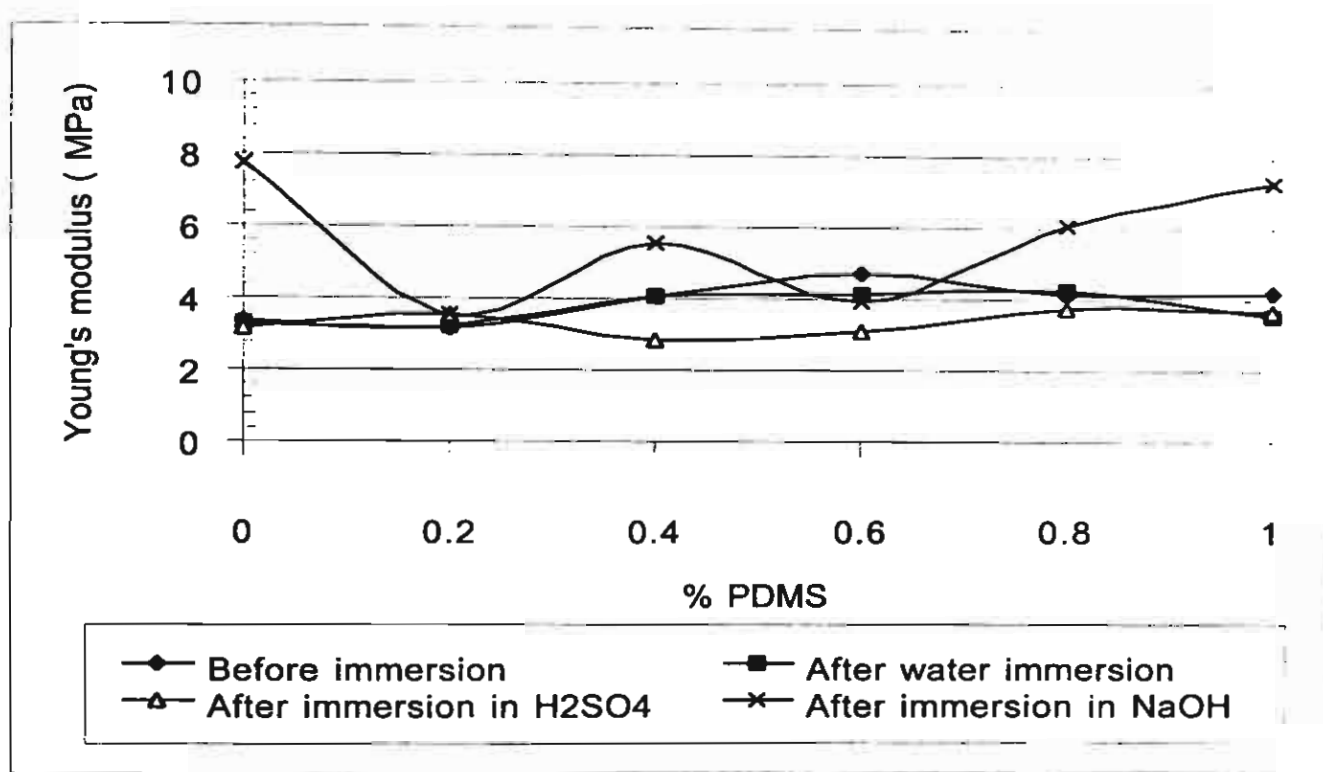


Figure 3. Comparison on Young's modulus of the virgin TPU and blended TPU before and after immersion in various chemical reagents.

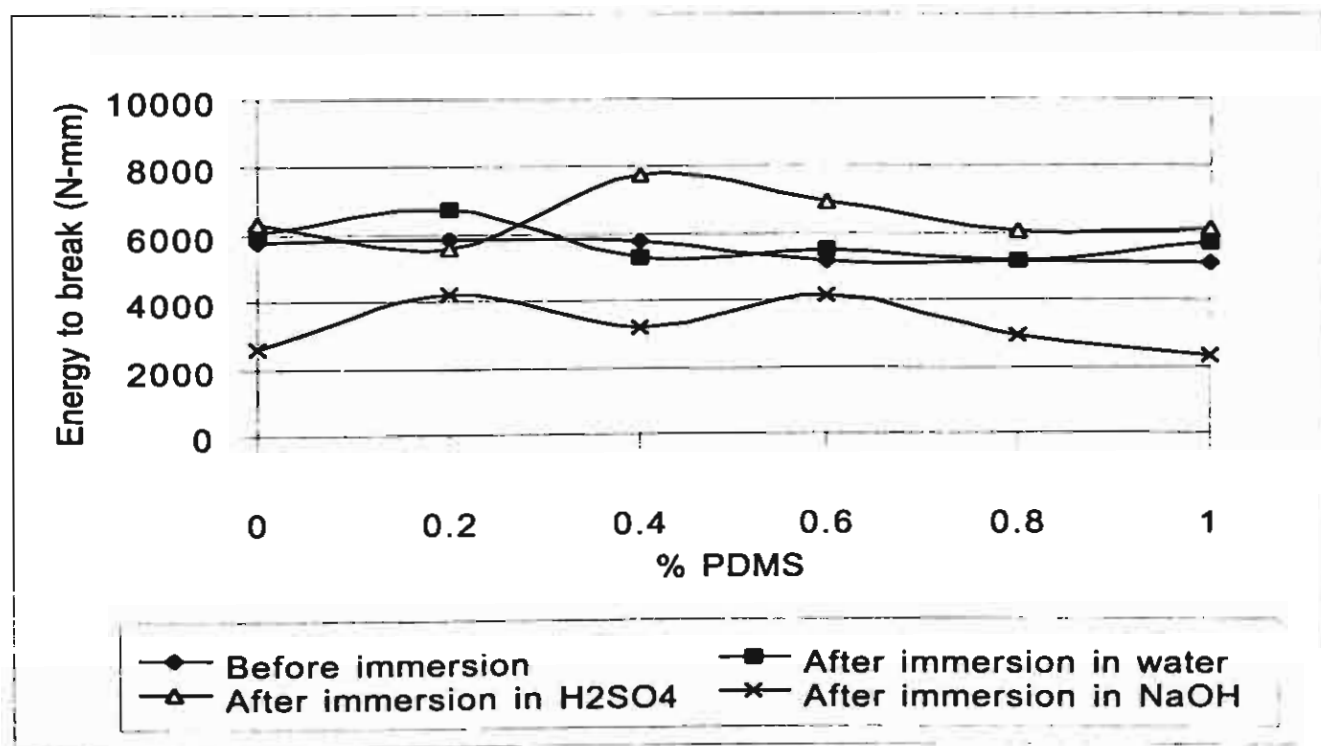


Figure 4. Comparison on the energy to break of the virgin TPU and blended TPU before and after immersion in various chemical reagents.

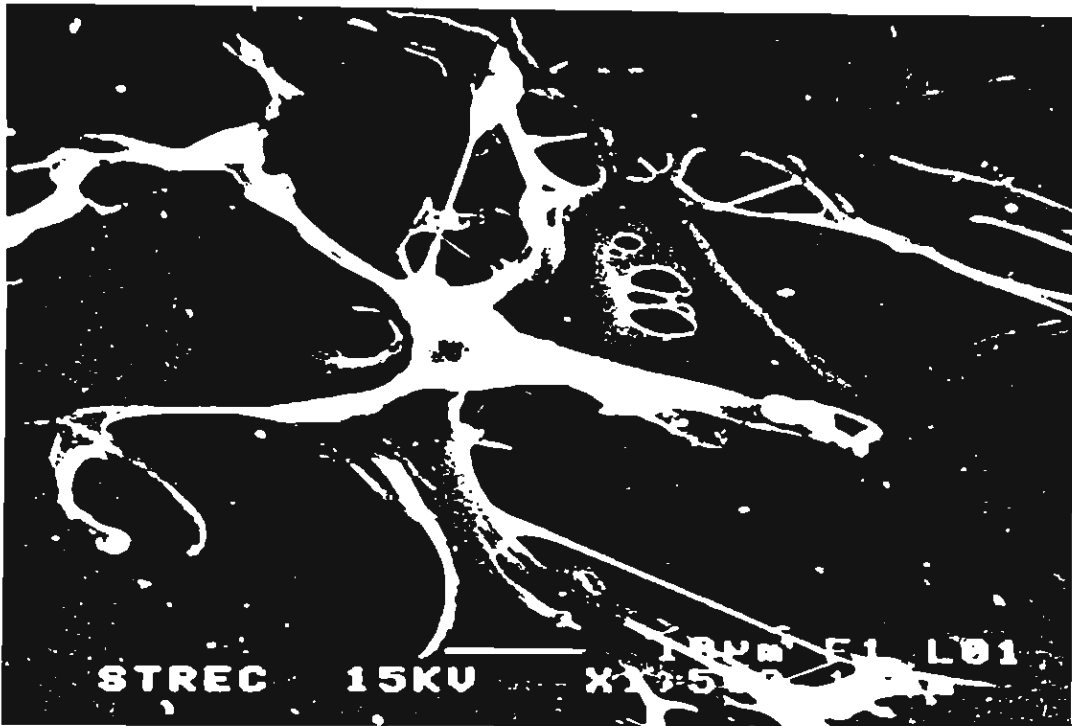


Figure 5. SEM photographic of fractured surface of virgin TPU.

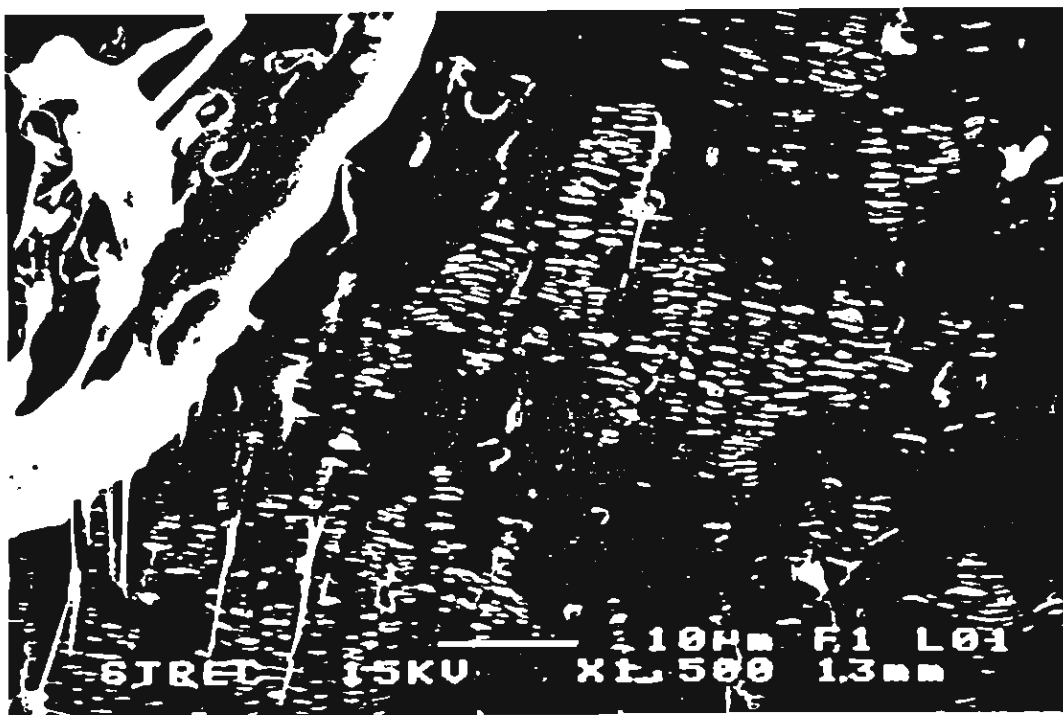


Figure 6. SEM photographic of fractured surface of TPU/PDMS blends at 0.2% of PDMS.

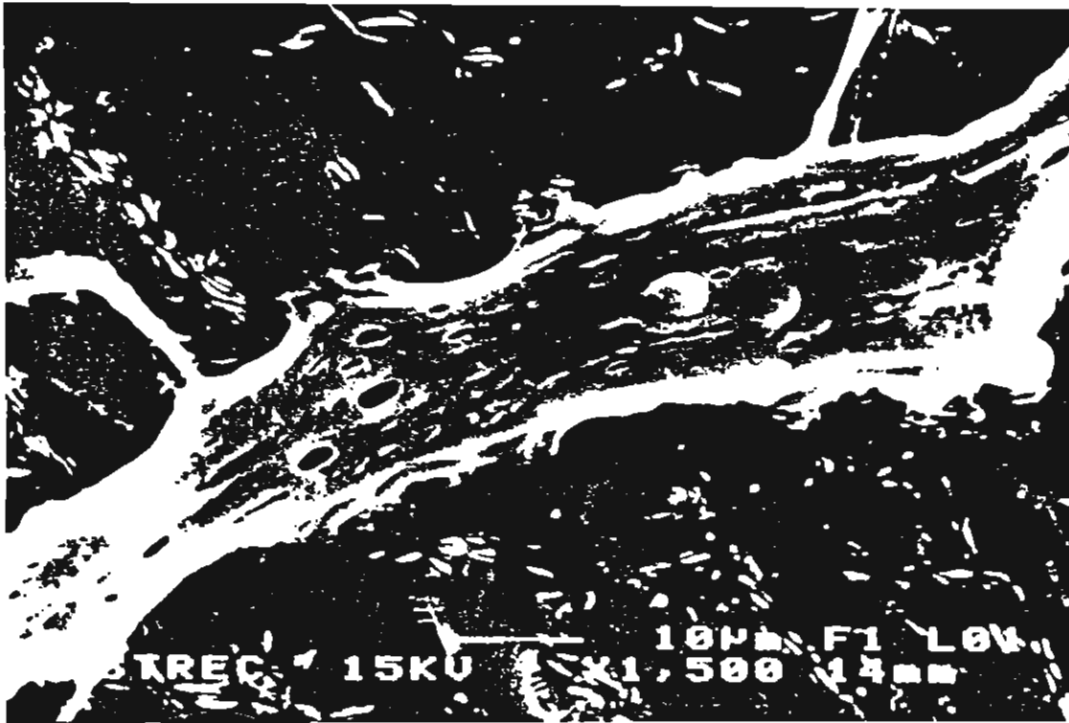


Figure 7. SEM photographic of fractured surface of TPU/PDMS blends at 0.4% of PDMS.

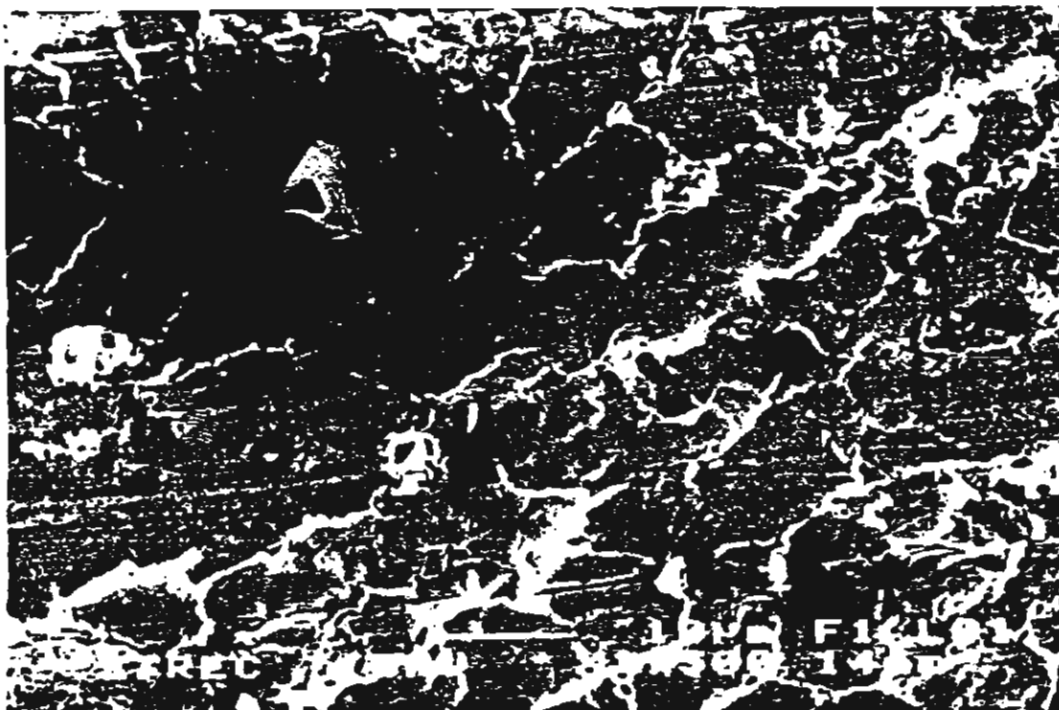


Figure 8. SEM photographic of fractured surface of TPU/PDMS blends at 0.8% of PDMS.



Figure 9. SEM photographic of fractured surface of TPU/PDMS blends at 0.8% of PDMS after base immersion.

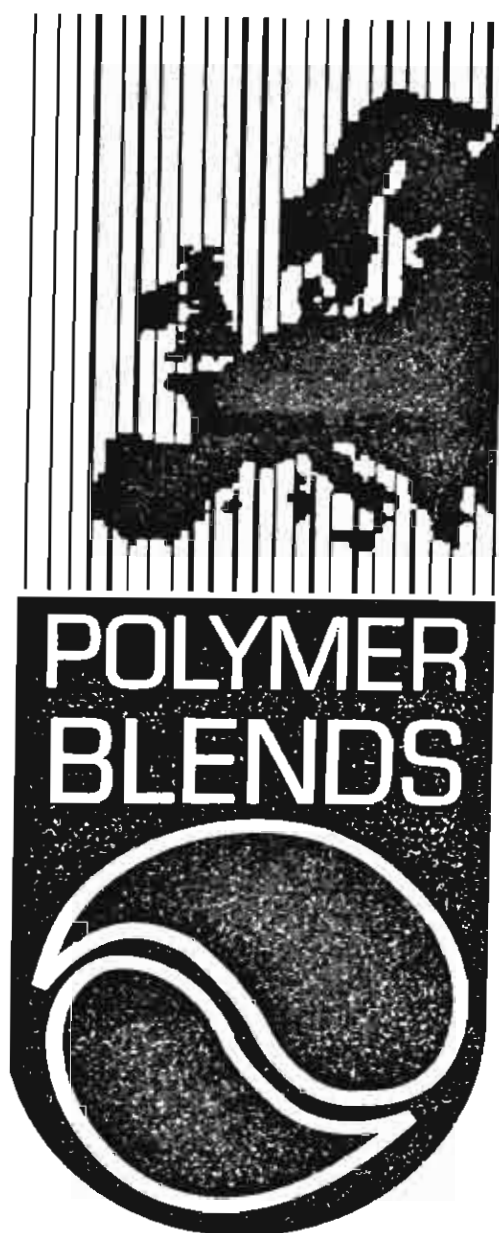
APPENDIX B

**Paper E1 in the conference proceeding "7th European Symposium on Polymer Blends"
May 27-29, 2002 at Lyon-Villeurbanne, France**

7th European Symposium



SE FRANCAIS D'ETUDES
D'APPLICATIONS DES
POLYMERES



CENTRE NATIONAL
DE LA RECHERCHE
SCIENTIFIQUE

May 27-29, 2002
Lyon-Villeurbanne, France

Information

7th European Symposium on Polymer Blends, Laboratoire des Matériaux Macromoléculaires,
Jules Verne, INSA Lyon 20, Avenue Albert Einstein 69621, Villeurbanne Cedex, France

Website : www.insa-lyon.fr/polymer_blends/index.htm

Congress E-mail: polymerblends@insa-lyon.fr Fax: 33 (0)4 72 43 85 27

DAMRONGSAKKUL	Siriporn		E 1	Poster
---------------	----------	--	-----	--------

PROCESSABILITY AND CHEMICAL RESISTANCE OF THE POLYMER BLEND OF THERMOPLASTIC POLYURETHANE AND POLYDIMETHYLSILOXANE

Authors : S.Damrongsakkul*, R.Sinweeruthai*, J.S.Higgins**

Lab: * Polymer Engineering Laboratory, Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand

** Imperial College, University of London, London SW7 2BY, England

This work is aimed to develop the melt blend of thermoplastic polyurethane (TPU) and polydimethylsiloxane (PDMS) and to study the effect of the chemical resistance on the tensile properties and morphology of the blends. The master batch blends at 2% of PDMS with 98% of TPU were firstly prepared by an internal mixer and then the blends of TPU/PDMS were prepared by melt mixing using a twin screw extruder. The maximum PDMS content that can be mixed with TPU was found to be no higher than 1%. Higher PDMS content leaves an unmelted TPU fraction in the blends due to the short residence time in the twin screw extruder. The resultant blends show an increase in the elongation at break up to 30% and in Young's modulus up to 40% at the optimum PDMS concentration of around 0.6%-0.8%, beyond which these properties diminish. The ultimate tensile strength and the energy to break are decreased by about 20% and 10%, respectively. The Scanning Electron Micrographs of the blends show dispersed phases of PDMS in a TPU matrix. The domain size of the PDMS phase becomes smaller when increasing PDMS content from 0.2% to 0.8%. The morphology of the fractured surface of TPU/PDMS blends shows less fibrous characteristics when increasing PDMS content in the blends.

For the study of the effects of chemical resistance on the tensile properties and morphology of TPU/PDMS blends, two chemical reagents, sulfuric acid (H_2SO_4 , 3% v/v) and sodium hydroxide (NaOH, 10% w/v) are selected. The results on the relationship of chemical resistance to tensile properties and morphology of the blends show that NaOH solution has a stronger effect on the tensile properties and morphology of virgin TPU and the blends than H_2SO_4 solution. The ultimate tensile strength and the energy to break of virgin TPU after base immersion was found to be strongly decreased by 42% and 55%, respectively. The effect of PDMS content in the blends on the base resistance and tensile properties is similar to results before immersion, i.e. the effective PDMS content in the blends that can generally improve tensile properties of the blends after immersion in NaOH does not excess 0.8%. The results are in agreement with the weight loss of TPU/PDMS blends after base immersion and the morphology of the fractured surface of TPU/PDMS blends after base immersion that exhibit very small amounts of a fibrous characteristic and there are some small particles detached at the surface caused by a corrosive reaction between the sample surface and NaOH solution.