CHAPTER V
DETERMINATION OF SERVICE LIFE TIME OF ENGINEERING PLASTIC CARDS

5.1 Abstract

This chapter shows the comparison between service life time of the commodity plastic card (PVC and PC) and new material (PC-Teslin and PC-DDI) in first and second cycle. The various conditions and accelerated aging were applied to plastic cards followed ISO/IEC 24789-1 and 10373-1 standard. According to the results of the observation of surface and functionality checking of plastic cards, they show insignificant changing in functionality checking (max. distance). In part of visual inspection, each material was changing in ΔE (color difference) and the decreasing of gloss retention. In case of mechanical properties, the modulus of each material was decreased. After two cycles, PC-STD was found to have a lifetime of 10 years. In term of PVC, it was found to have a lifetime 5 years, while PC-DDI and PC-Teslin were found to have a lifetime for 1 year.

5.2 Introduction

In the previous chapter, PETG was found the lifetime for 1 year which was not suitable for commercial plastic card. Therefore, PETG was neglected in this comparison. However, PC and PVC were retest for confirm the lifetime with new plastic card.

For this chapter, newly developed multilayers engineering plastic cards such as PC-Teslin and PC-DDI were used as raw material for manufacturing smart cards and the commercial plastics, PC and PVC, were also used as card body to compare with the new smart card. Then, their plastic cards were then passing through several standard testing and qualitative checking to confirm their actual service life time and durability.

The aim of this chapter is to evaluate the visual inspection, logical functionality, mechanical properties of card after testing in any conditions follow the standard tests. Finally, the service lifetime of PC-STD, PVC, PC-Teslin and PC-DDI cards were indicated.

5.3 Materials and Methods

5.3.1 Card Material

All of smart cards (PC-STD,PVC, PC-Teslin and PC-DDI) were supported by Smartrac Technology LTD.

5.3.2 Identify the Plastic Card

Identify the environment, storage, reader profile, and frequency in which the cards is used follow to ISO/IEC 24789-1

a) Select the possible environment, storage, reader profile and frequency with the lifetime 10 years in order to find the data of Usage (U), Age (A) and Coefficient (c) for 10 years testing.

b) Determine Uc and Ac to find the durability class and test sequence cycle. After get the summation of U and summation of A in each condition. Uc and Ac are checked against the table to determine the age class and durability class. From all information, we got 4 mission profiles which are C1,C2 and D1, D2 for testing

5.3.3 Test Cycles

a) Storage in short term contamination: follow ISO/IEC 10373-1
b) Storage in long term contamination:
   - Salt spray test: follow ISO 9227
   - Storage in acid solution: follow ISO/IEC 10373-1
   - Storage in alkaline solution:follow ISO/IEC 10373-1
c) Softener storage: follow to ISO/IEC 24789-2
d) UV light exposing: follow to ISO/IEC 24789-2
e) Thermal storage: follow to ISO/IEC 24789-2
f) Thermal cycling: follow to ISO/IEC 24789-2
g) Thermal and humidity ageing: follow to ISO/IEC 24789-2

h) Dynamic bending stress: follow to ISO/IEC 10373-1

i) US Postal test: follow to ISO/IEC 10373-3

5.3.4 Define the Test Method from Durability Class and Test Sequence Cycle for example, the test method for C1.

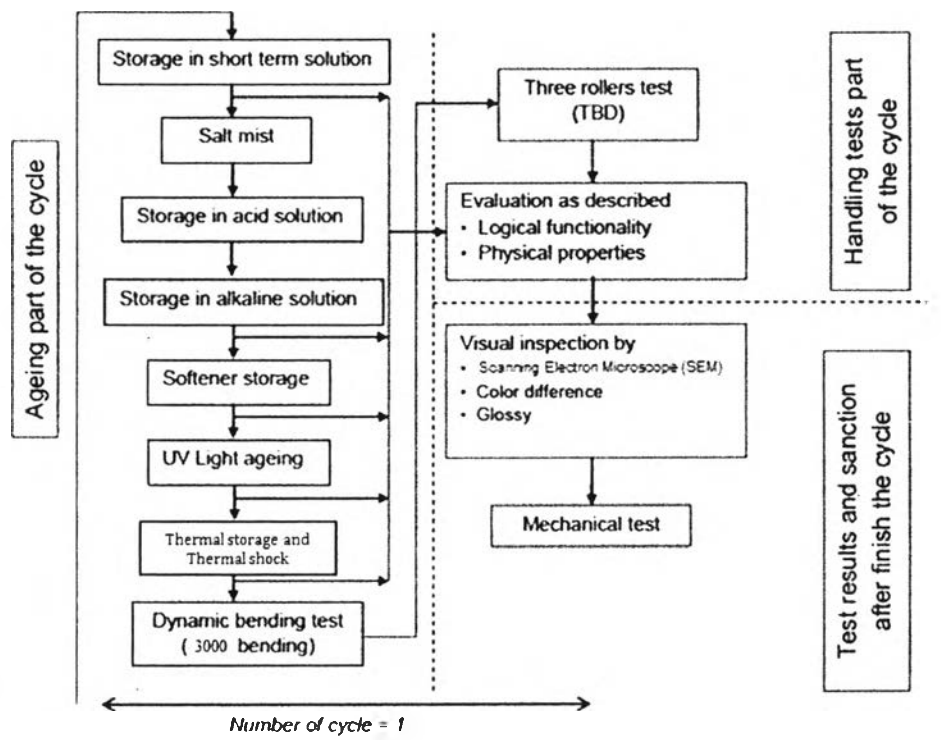


Figure 5.1 Test cycle for determining card service lifetime of plastic card.

5.3.5 Characterizations and Testing of Plastic Smart Card by Logical Functionality

Functionality of data storage devices, memories and microprocessors must be checked after each test and checked Max. distance after finish cycle testing.

5.3.6 Characterizations and Testing of Plastic Smart Card by Visual Inspection

The ΔE (Color difference) and surface of plastic card were observed by colorimetric spectrophotometer and scanning electron microscope (SEM), respectively.

5.4 Results and Discussion

5.4.1 Functionality Analysis

In this work, two types of commercial plastics (PC, PVC) and a novel multilayer engineering plastic such as PC-Teslin and PC-DDI were used to make smart cards. The 48 cards of each material were divided into tested samples and references as show in Table 5.1.

Table 5.1 The samples and references of smart card material

Materials	Tested sample (pieces)	Reference (pieces)	Total (pieces)
PC-STD	40	8	48
PVC	40	8	48
PC-Teslin	40	8	48
PC-DDI	40	8	48

48 cards of tested samples were divided into 4 groups for mission profile C1, D1, C2 and D2. All tested cards were checked for visual inspection and functionality before testing. The detail shows in Table 5.2-5.4.

Table 5.2 Visual inspection and functionality checking of cards before testing

Materials	Functionality checking, Max. distance as receives								
	Yellow-ness	Matted	Stain Scratch	Warpage	Crack/ Fracture	Distance (cm)			$\bar{X}$
PVC	NONE	NONE	NONE	NONE	NONE	4.9	5		4.932± 0.05
PC-STD	NONE	NONE	NONE	NONE	NONE	5	5.1		5.004± 0.05
PC-Teslin	NONE	NONE	NONE	NONE	NONE	4.7	4.8	5	4.816± 0.15
PC-DDI	NONE	NONE	NONE	NONE	NONE	Pass			

Table 5.3 Visual inspection and functionality checking after finished 1st cycle testing

Materials	Defects for visual inspection after 1st cycle testing					Functionality checking, Max. distance after 1st cycle (Mission profile;C1 and D1)				
	Yellowness	Matted	Stain Scratch	Warpage	Crack*/ Fracture**	Distance (cm)				
PVC	ALL	ALL	ALL	Few	NONE	4.8	4.9	5	5.1	4.923± 0.10
PC-STD	ALL	ALL	ALL	Few	NONE	5	5.1	5.2		5.080± 0.09
PC-Teslin	ALL	ALL	ALL	Few	3 pcs.*	4.7	4.8	4.9	5	4.878± 0.09
PC-DDI	ALL	ALL	ALL	Few	NONE	PC-DDI was measured the functionality by contact with chip which cannot measure the max. distance				

Table 5.4 Visual inspection and functionality checking after finished 2^{nd} cycle testing

Materials	Defects for visual inspection after 2^{nd} cycle testing					Functionality checking, Max. distance after 2^{nd} cycle (Mission profile;C2 and D2)				
	Yellowness	Matted	Stain Scratch	Warpage	Crack*/ Fracture**	Distance (cm)				
PVC	ALL	ALL	ALL	Few	1 pc.*	5.3	5.4	5.5		5.39± 0.08
PC-STD	ALL	ALL	ALL	Few	NONE	4.9	5.1	5.2	5.3	5.11± 0.09
PC-Teslin	ALL	ALL	ALL	Few	13 pcs.*	4.7	4.8	4.9	5	3.96± 0.08
PC-DDI	ALL	ALL	ALL	Few	NONE	PC-DDI was measured the functionality by contact with chip which cannot measure the max. distance				

The functionality was evaluated because of the application of smart card as a secure storage for data. The tested cards were checked for visual inspection and functionality after finished each step (pass or not pass). The detail was shown in Table 5.5. The steps start from chemicals resistance, softener storage, treatment with UV light, thermal storage, thermal shock, dynamic bending test and US postal (tensile test), respectively. After that, the visual inspection and functionality checking of plastic cards after first and second cycle testing were in Table 5.5.

Table 5.5 Visual inspection and functionality checking after finished of each step

Experimental	Functional checking : Contact less (after finish each step)												Contact (after finish each step)			
	PVC				PC-STD				PC-Teslin				PC-DDI			
Mission profile	C1	D1	C2	D2	C1	D1	C2	D2	C1	D1	C2	D2	C1	D1	C2	D2
Storage in short term solution	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass** 100%	Pass** 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%
Salt spray	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass** 100%	Pass** 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%
Storage in long term solution	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass** 100%	Pass** 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%
Softener storage	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass** 100%	Pass** 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%
UV treatment	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass** 100%	Pass 100%	Pass** 100%	Pass** 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%
Thermal storage	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass** 100%	Pass 100%	Pass** 100%	Pass** 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%
Thermal shock	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass** 100%	Pass 100%	Pass** 100%	Pass** 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%
Dynamic bending test	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass** 100%	Pass 100%	Pass** 100%	Pass** 100%	Pass 100%	Pass 90%	Pass 75%	Pass 56%
Three roller test	Pass 100%	Pass 100%	Pass 100%	Pass** 100%	Pass 100%	Pass 100%	Pass 100%	Pass 100%	Pass** 100%	Pass 100%	Pass** 100%	Pass** 100%	Pass 100%	Pass 90%	Pass 75%	Pass 56%

* Sample was fracture   ** Sample was observed crack

5.4.2 Visual Inspection Analysis

The optical properties were evaluated because of the widespread application of plastic card as a less color changing and smoot surface material. In such applications, appearance are fundamental. The appearance is influenced by factors such as colour, the gloss retention the roughness on the sample surface.

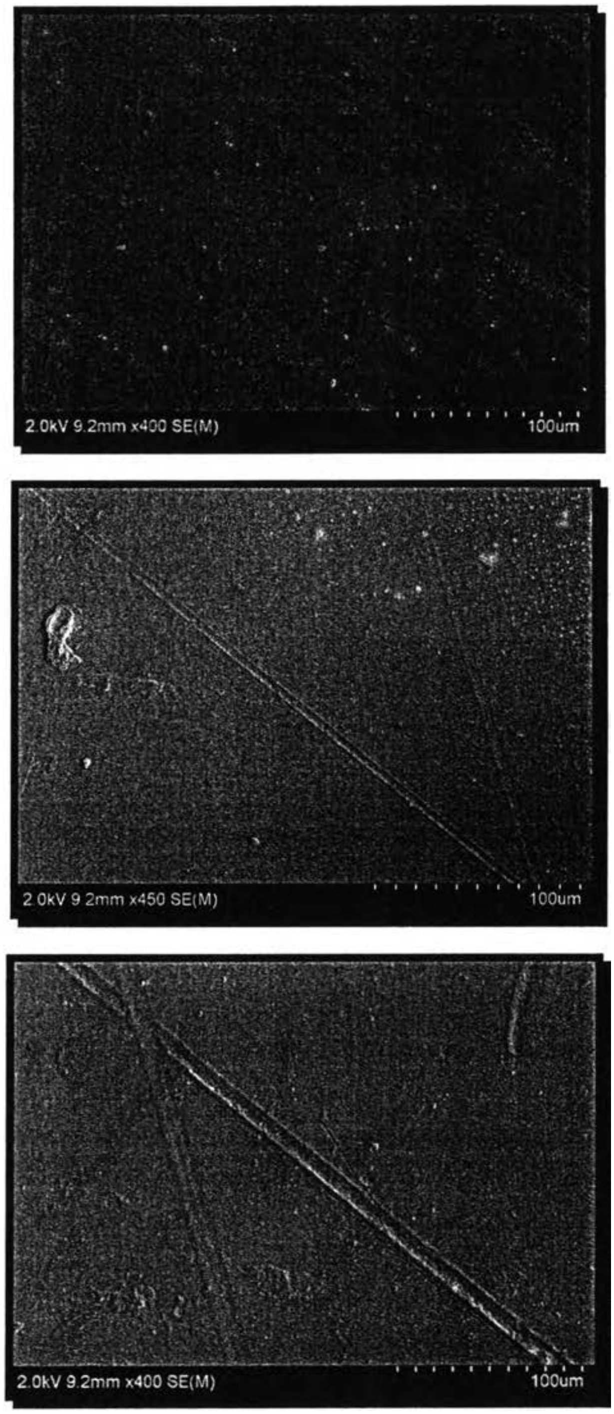
5.4.2.1 *Surface Observation of Plastic Cards After Testing*

The microstructure of the surfaces of each plastic card after the 1st and 2nd cycle testing was characterized using FE-SEM. The plastic specimens were then coated with platinum. The coated specimens were then observed on the SEM using an accelerating voltage of 2 kV with 100x to observe the microstructure and characterize their fracture behavior.

The results of surface observation of plastic cards are shown in Fig. 5.2-5.9. As it can be seen, each plastic material (mission profile C1 and D1) has a scratch appearance on the surface after the first cycle testing, whilst the reference of each sample card shows a more uniform and smooth surface.

After pass the second cycle testing, roughness of PC-STD (mission profile C2 and D2) was slightly increased with enhancement of cycle testing (Fig 5.3). The SEM images of PVC show the crack propagation in mission profile C2 and cracks deflection in mission D2 (Fig 5.5). In term of PC-Teslin micrographs, the mission profile C2 and D2 presents the cracking on the surface (Fig 5.7). Lastly, PC-DDI no cracking was found on the surface however some roughness was observe (Fig 5.9).

From the surface micrograph of plastic card, it can be concluded that the changing in polymer surface due to UV exposure, physical testing or storage in chemical are contributed to increase the surface roughness of the card sample.

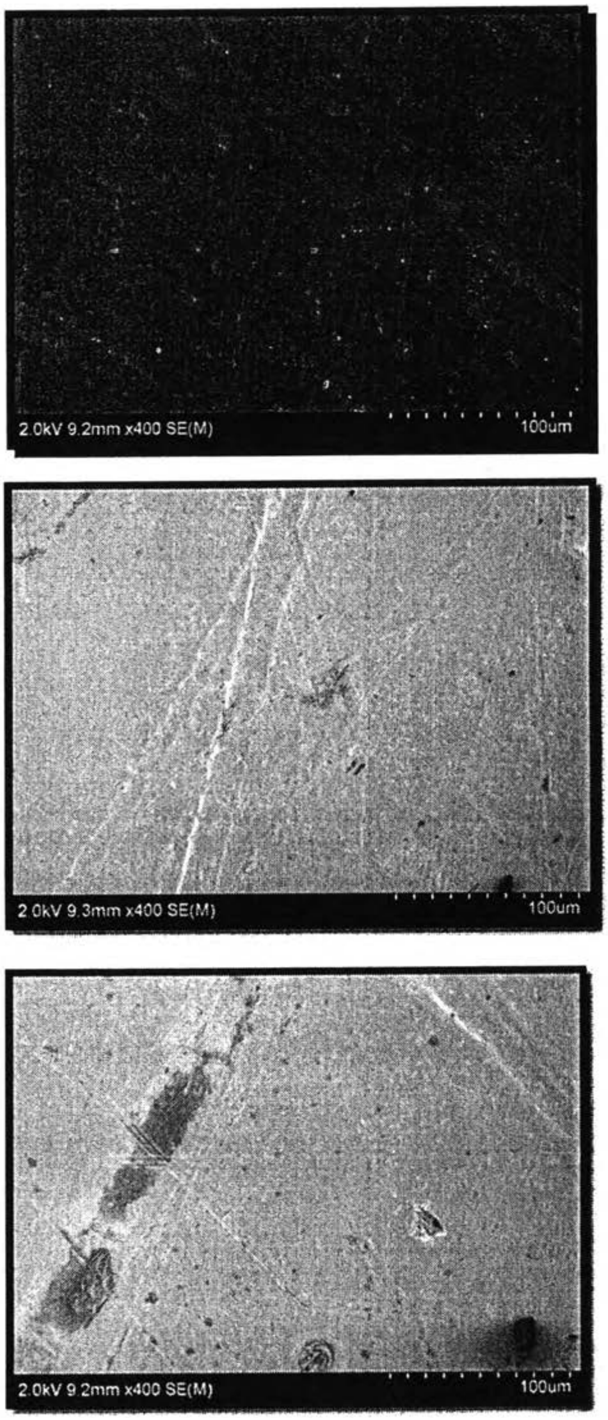


a)

b)

c)

Figure 5.2 The surface micrograph of PC-STD card after 1st cycle a) PC-STD as received, b) PC-STD of mission profile C1 and c) PC-STD of mission profile D1.



a)

b)

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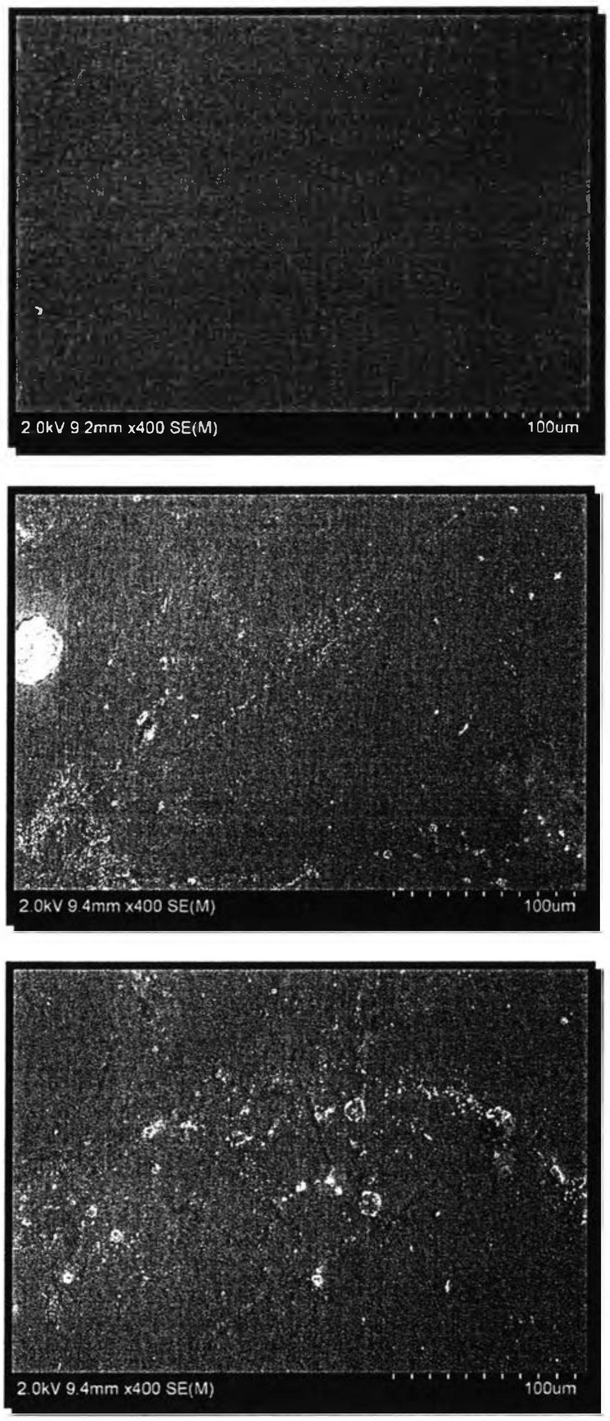
Figure 5.3 The surface micrograph of PC-STD card after 2nd cycle a) PC-STD as received, b) PC-STD of mission profile C2 and c) PC-STD of mission profile D2.



a)

b)

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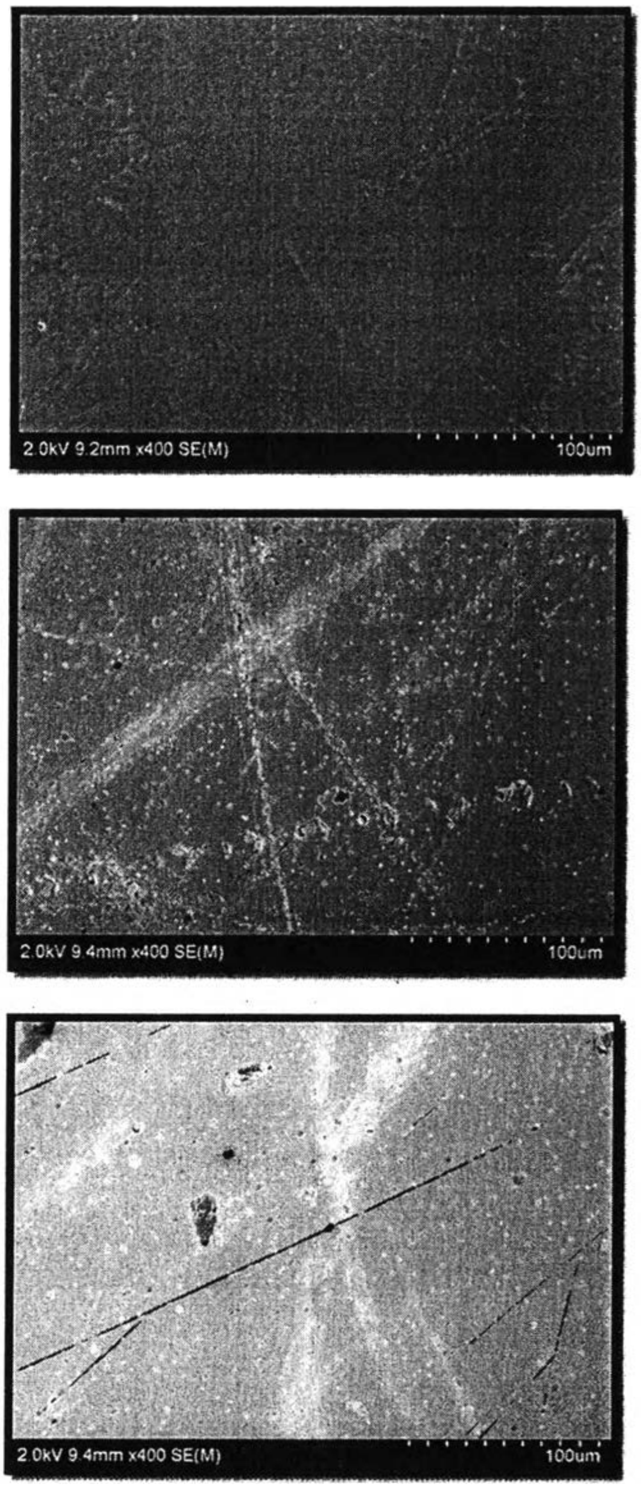
Figure 5.4 The surface micrograph of PVC card after 1st cycle a) PVC as received, b) PVC of mission profile C1 and c) PVC of mission profile D1.

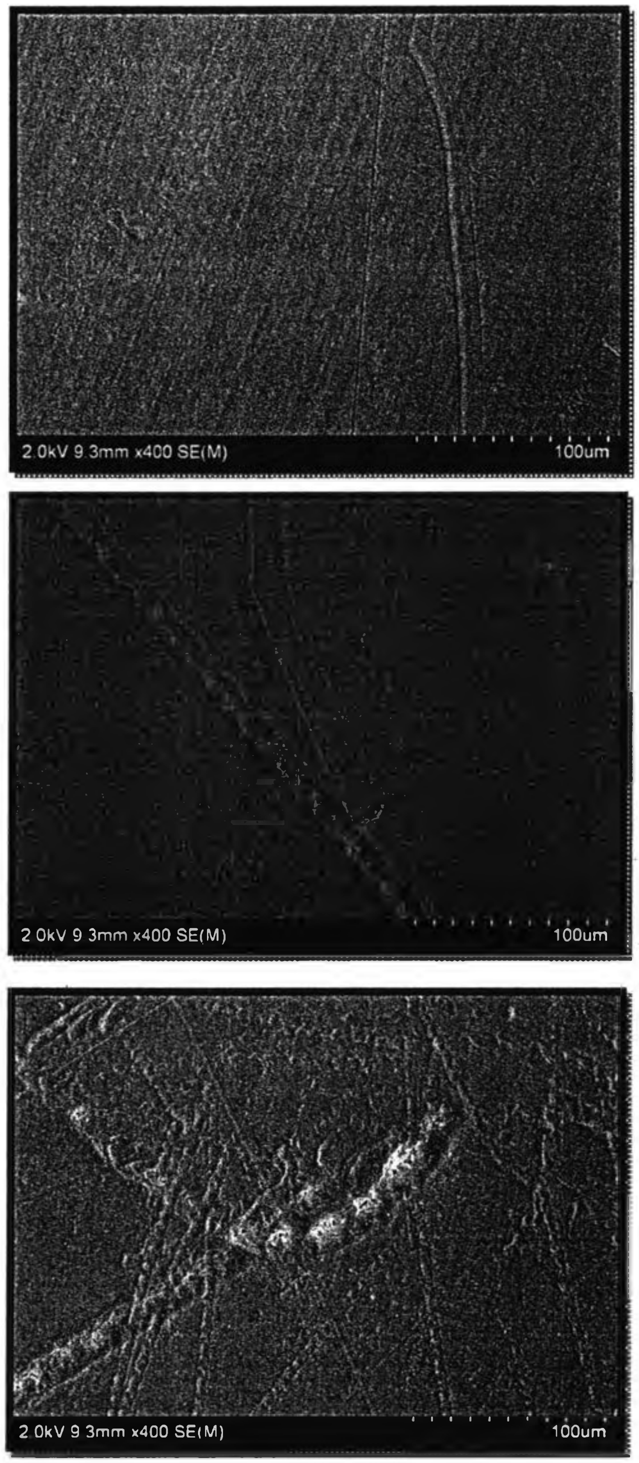


a)

b)

c)

Figure 5.5 The surface micrograph of PVC card after 2nd cycle a) PVC as received, b) PVC of mission profile C2 and c) PVC of mission profile D2.

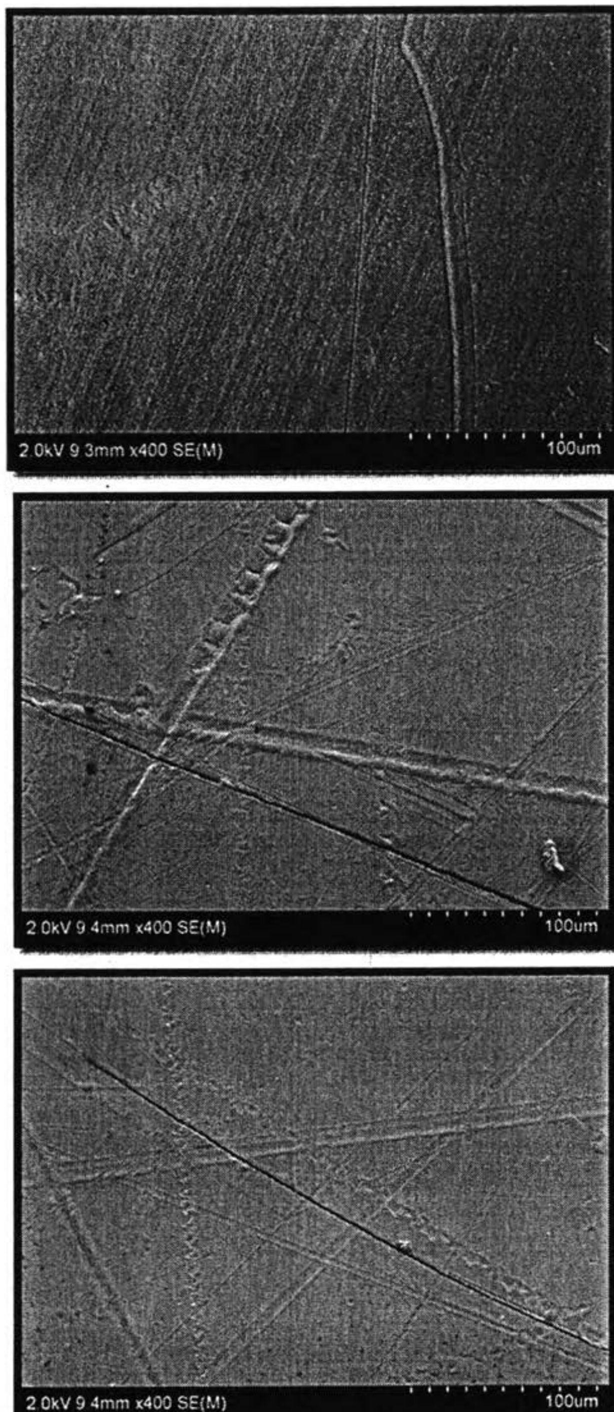


a)

b)

c)

Figure 5.6 The surface micrograph of PC-Teslin card after 1st cycle a) PC-Teslin as received, b) PC-Teslin of mission profile C1 and c) PC-Teslin of mission profile D1.

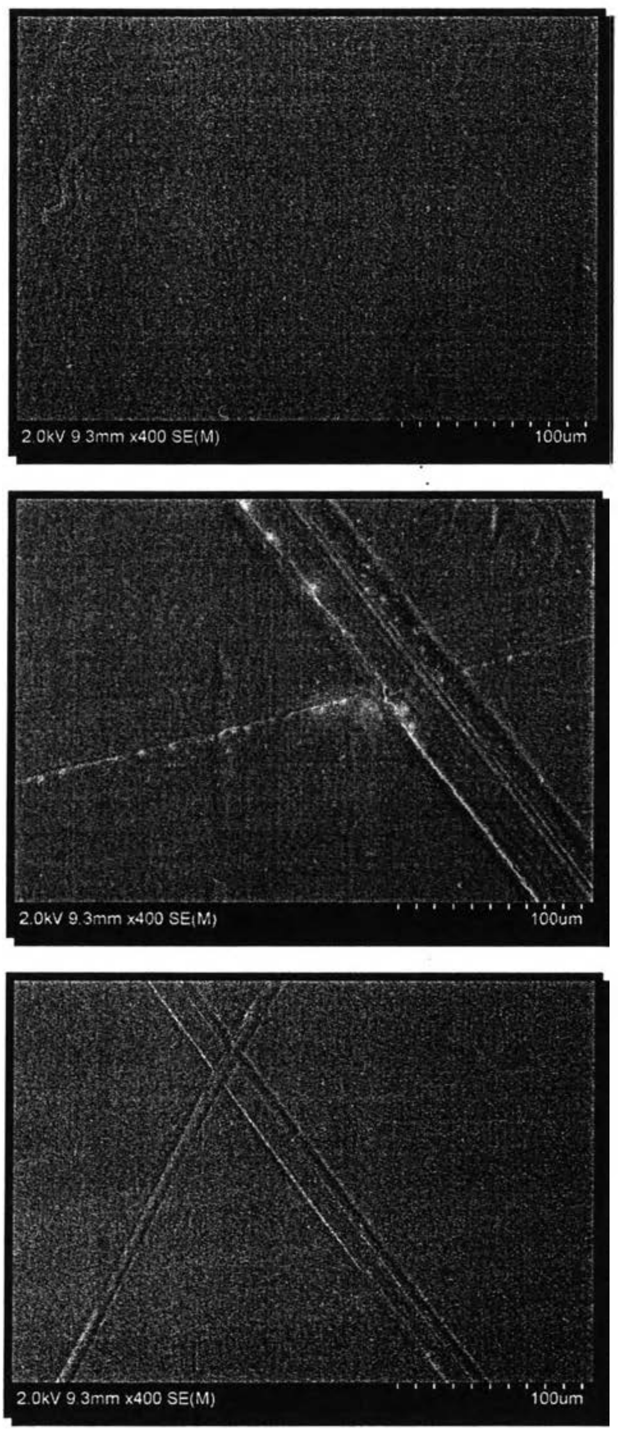


a)

b)

c)

Figure 5.7 The surface micrograph of PC-Teslin card after 2nd cycle a) PC-Teslin as received, b) PC-Teslin of mission profile C2 and c) PC-Teslin of mission profile D2.

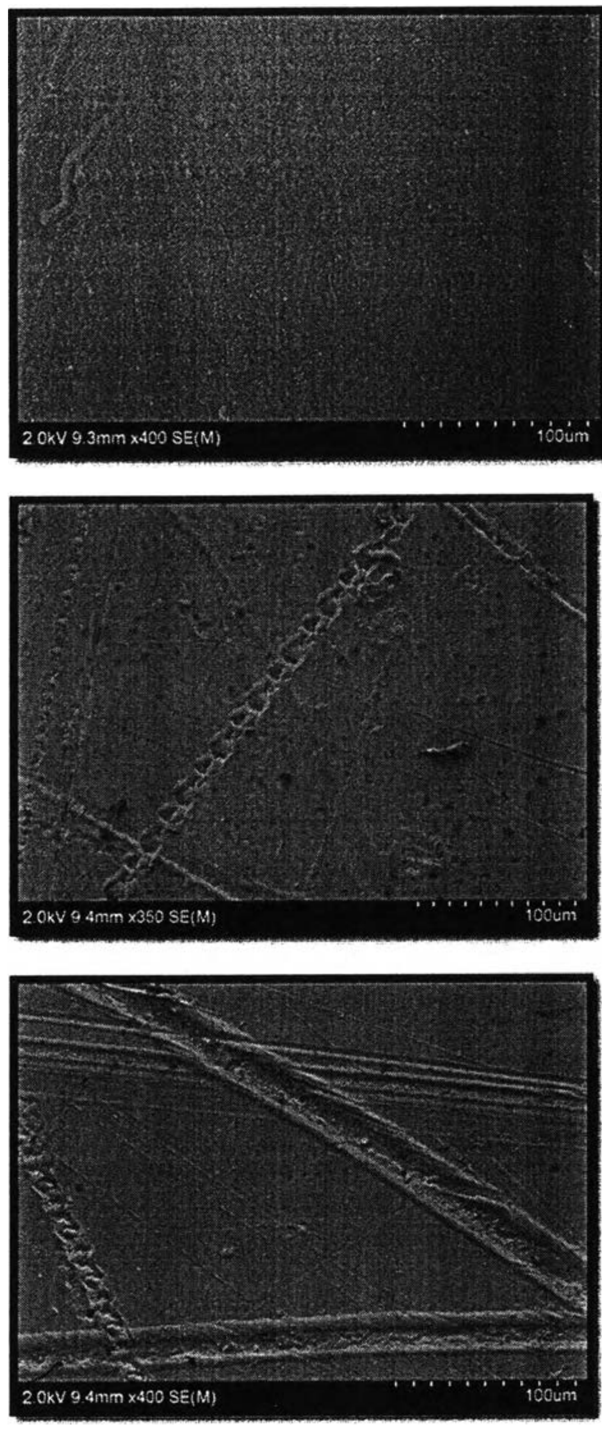


a)

b)

c)

Figure 5.8 The surface micrograph of PC-DDI card after 1st cycle a) PC-DDI as received, b) PC-DDI of mission profile C1 and c) PC-DDI of mission profile D1.



a)

b)

c)

Figure 5.9 The surface micrograph of PC-DDI card after 2nd cycle a) PC-DDI as received, b) PC-DDI of mission profile C2 and c) PC-DDI of mission profile D2.

5.4.2.2 *Color difference Analysis*

The surface degradation of plastic card was also characterized by the measurement of color which determines the change of sample card color upon the testing operation. The color difference was measured after exposed to accelerated weathering conditions. The results of color measurements are listed in Table 5.6 and shown in Figure 5.10 and 5.11.

Table 5.6 The color changes of plastic card before and after testing

Materials	**Cycle**	**Average color value**			**Total color difference**
		ΔL*	**Δa***	**Δb***	**ΔE**
PVC reference	-	0	0	0	0
PVC mission profile C1	1	-0.641	1.532	-4.881	5.156
PVC mission profile C2	2	-1.016	2.913	-8.489	9.032
PVC mission profile D1	1	-0.458	1.492	-4.620	4.876
PVC mission profile D2	2	-0.805	2.913	-8.489	9.010
PC-STD reference	-	0	0	0	0
PC-STD mission profile C1	1	0.249	0.476	-2.340	2.405
PC-STD mission profile C2	2	-0.050	1.491	-4.528	4.767
PC-STD mission profile D1	1	0.622	0.436	-2.650	2.757
PC-STD mission profile D2	2	0.291	1.491	-4.528	4.776
PC-Teslin reference	-	0	0	0	0
PC-Teslin mission profile C1	1	-1.022	-0.576	-3.079	3.294
PC-Teslin mission profile C2	2	-2.79	0.332	-4.377	5.201
PC-Teslin mission profile D1	1	-0.906	-0.582	-2.780	2.981
PC-Teslin mission profile D2	2	-2.75	0.332	-4.377	5.180

Table 5.6 The color changes of plastic card before and after testing (continue)

Materials	Cycle	Average color value			Total color difference
		ΔL^*	Δa^*	Δb^*	ΔE
PC-DDI reference	-	0	0	0	0
PC-DDI mission profile C1	1	0.252	0.357	-1.885	1.935
PC-DDI mission profile C2	2	-0.814	1.147	-3.595	3.860
PC-DDI mission profile D1	1	0.290	0.339	-1.818	1.872
PC-DDI mission profile D2	2	-0.901	1.147	-3.595	3.882

According to the results, Table 5.6 presents the color changes of plastic card before and after testing. As it can see that, the mission profile C1 and D1 of each material was observed similarly the average color value after pass the first cycle. Likewise, after pass the second cycle testing also shows the equally the average color value.

For Figure 5.11a, PVC and PC-Teslin plastic card, L* values decreased a bit during the first cycle. The small L* raising was found in the case PC-STD and PC-DDI material. But after second cycle testing PC-STD, PC-Teslin, PVC and PC-DDI are decreasing in L* values, perhaps due to more degradation of material. (S.M. Mirabedini *et al.*, 2011)

Next, The redness (a*) of all plastic card is increase in the first cycle except the PC-Teslin. However, the redness (a*) trend to increase with testing cycle increasing (Fig. 11b). Then, Figure. 5.11c shows that the changing in b* values were observed for all plastic card. The highest decreasing in the b* value indicates growing of yellowing, which is the sign of gradation of polymer material (G. Luciano *et al.*, 2009). Meanwhile, the lowest Δb^* and yellowness were found in PC-STD and PC-DDI which is indicated more stability of card body against weathering conditions. However, higher degradation was observed in PVC and PC-Teslin.

The total color changes (ΔE) of various plastic cards are shown Fig. 5.10. As it can be seen, a significant increasing in ΔE is observed the second cycle testing. The PVC card body showed maximum color changes ($\Delta E \sim 8.9$) after second cycle testing, while the ΔE of PC-STD and PC-Teslin were about 4.8 and 5.1, respectively. The PC-DDI revealed the lowest color change ($\Delta E \sim 3.5$) after the second cycle testing

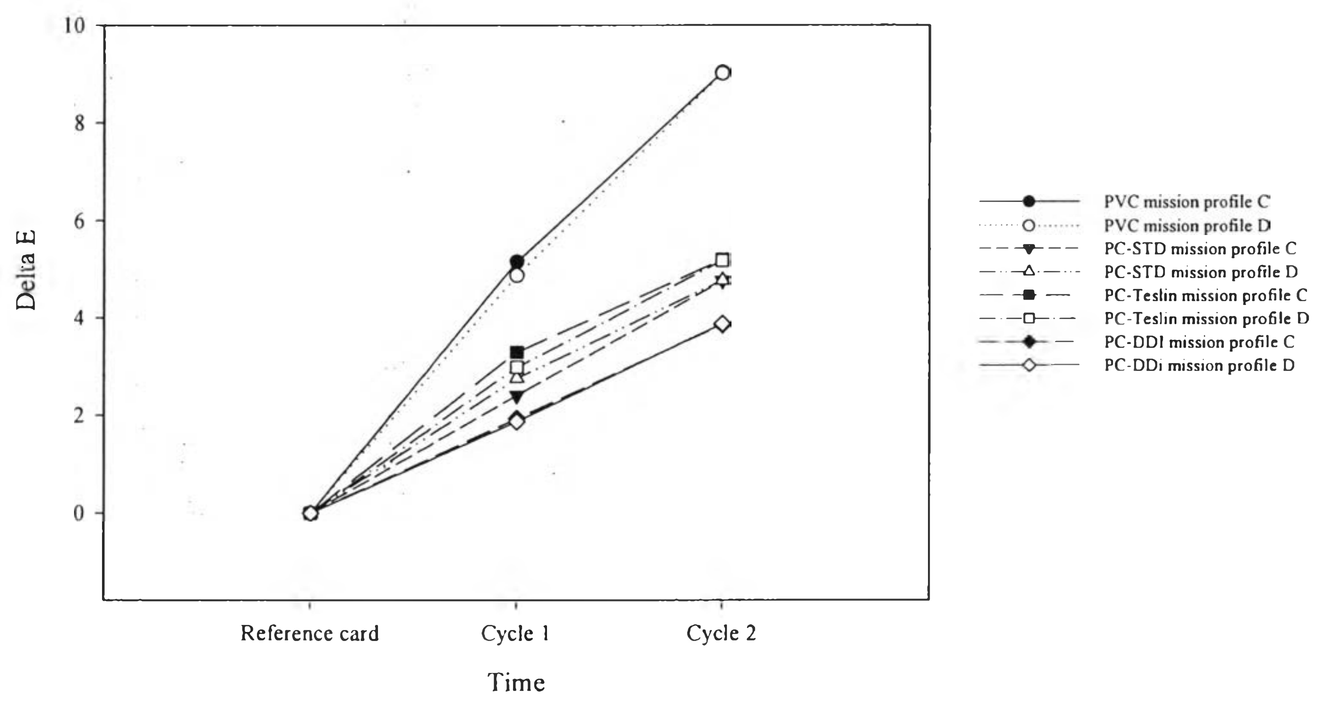


Figure 5.10 The total color difference (ΔE) versus the cycle testing.

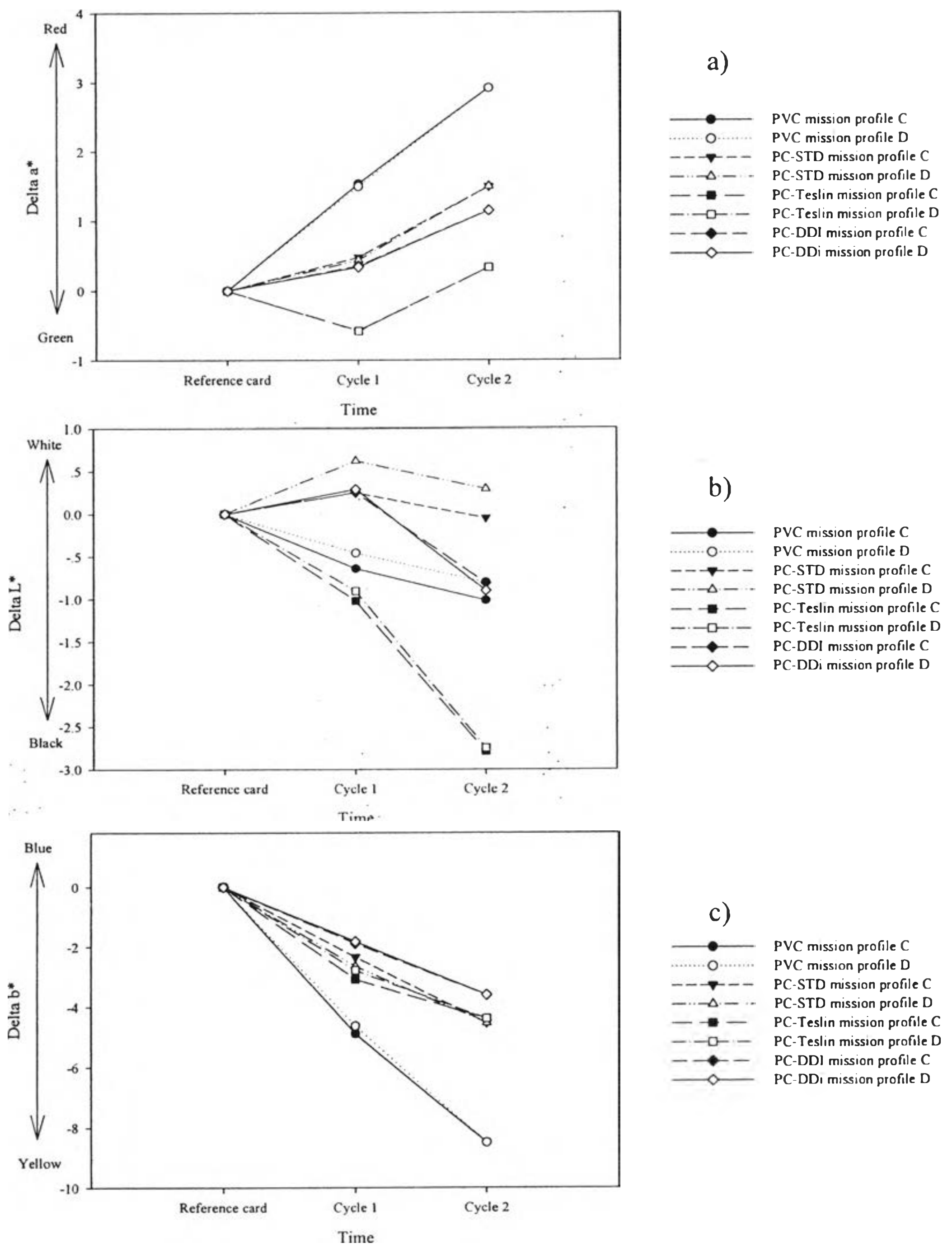


Figure 5.11 a) Variations of L*, b) Variation of the redness index and c) Variations of the yellowness index with the different plastic card material.

5.4.2.3 *Gloss Analysis*

The gloss was evaluated before and after testing. The surface gloss was measured using a gloss meter which measured at a 60° angle of incidence and reflection. The gloss meter measures the intensity of a reflected light beam after striking the surface and compares it to the reference value (Adilson Y. Furuse *et al.*, 2008)

Table 5.7 The gloss retention of plastic card before and after testing

Materials (mission profile)	Cycle	Gloss value
PVC reference	-	101.8200
PVC mission profile C1	1	80.1688
PVC mission profile C2	2	80.0899
PVC mission profile D1	1	80.8575
PVC mission profile D2	2	80.3750
PC-STD reference	-	105.0250
PC-STD mission profile C1	1	88.9388
PC-STD mission profile C2	2	83.6525
PC-STD mission profile D1	1	89.7350
PC-STD mission profile D2	2	81.8300
PC-Teslin reference	-	93.4400
PC-Teslin mission profile C1	1	84.0263
PC-Teslin mission profile C2	2	78.6125
PC-Teslin mission profile D1	1	85.2200
PC-Teslin mission profile D2	2	79.2975
PC-DDI reference	-	104.7000
PC-DDI mission profile C1	1	90.6270
PC-DDI mission profile D1	1	78.0975
PC-DDI mission profile C2	2	88.4788
PC-DDI mission profile D2	2	75.4825

From Table 5.7 and Figure 5.12, the level of surface gloss of the plastic cards showed a downward trend, the reduction being approximately 15-20% after first cycle testing and 5-10% after pass the second cycle testing. As it can see that the PVC card was sharply dropped after pass the first cycle and constant value after second cycle. The PC-STD has decreased the gloss value from 105 to 90 after the first cycle while the gloss retention drops to 82 after second cycle testing. Moreover, The PC-Teslin shows the decreasing gloss value from 92 to 85 after the first cycle testing and drops to 78 after second cycle testing. In term of PC-DDI, they show minimum gloss retention value after second cycle testing. Gloss is the ability of the surface to reflect light. According to the results, the loss in gloss is associated with an increase in diffuse light scattering on the sample surface (Heintze SD *et al.*, 2006) and correlates with features on the SEM micrographs, shown in Figs. 5.2 – 5.9. The exposed sample had a rougher appearance, whilst the control sample exhibited a more uniform and smooth surface.

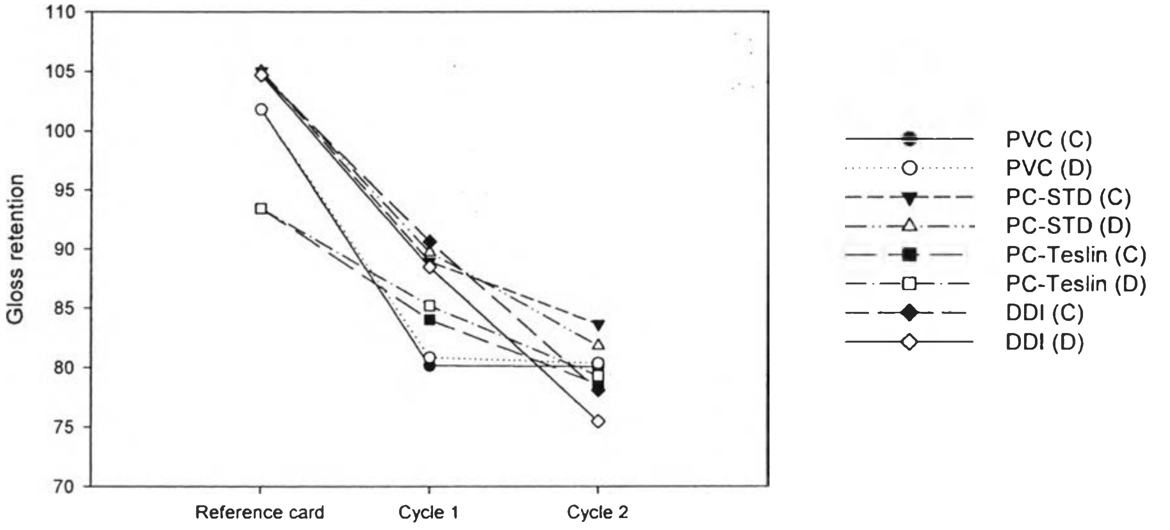


Figure 5.12 The gloss measurement at 60° of each plastic card after testing.

In summary of gloss, the changes in polymer morphology due to UV exposure and chemial storage also contributed to increase the surface roughness of the samples decreasing their gloss.

5.4.3 Mechanical Properties

The mechanical properties were performed on a universal testing machine (Lloyd Instruments), at 25°C. The tensile strength, elongation at break and modulus were measured by using a 50 mm/min of cross-head speed. Next, the rectangular specimens were prepared by ASTM D822. Then, the data were an average of 5 specimens from each sample, following the method.

The results of mechanical properties such as tensile strength, elongation at break and modulus of samples are presented in Figure 5.13-5.15. As it can see that, from Figure 5.13-5.15 can be deduced that the modulus, elongation at yield and the tensile strength were not significantly affected by the testing in the first cycle. The tensile strength of each card has properties similar to that of virgin material which shows in Figure 5.13. However, tensile strength of all plastic cards were not significantly affected. However, the elongation at yield of the PC-STD and PC-PC-DDI increases irregularly with increase in the cycle testing (Fig 5.14). The elongation at yield increased drastically during the second cycle testing and mission profile because the difference between mission profile C and D is the number of bending (C = 3000 round/min and D = 4000 round/min). The materials of mission profile D have more number of bending, it will have higher possibility to deform and crack. Therefore, the elongation is higher than the virgin and mission profile material.

Nevertheless, for plastic card retested second times, the modulus (Fig 5.15) decreased slightly (approximately 20-25% of its initial value). These studies reveal that, after one cycle testing the mechanical properties of samples were reduced only slightly. Conversely, after the second cycle testing the decrease could reach 25%. Therefore, from the point of view of the mechanical properties, plastic cards were seriously degraded after second cycle testing.

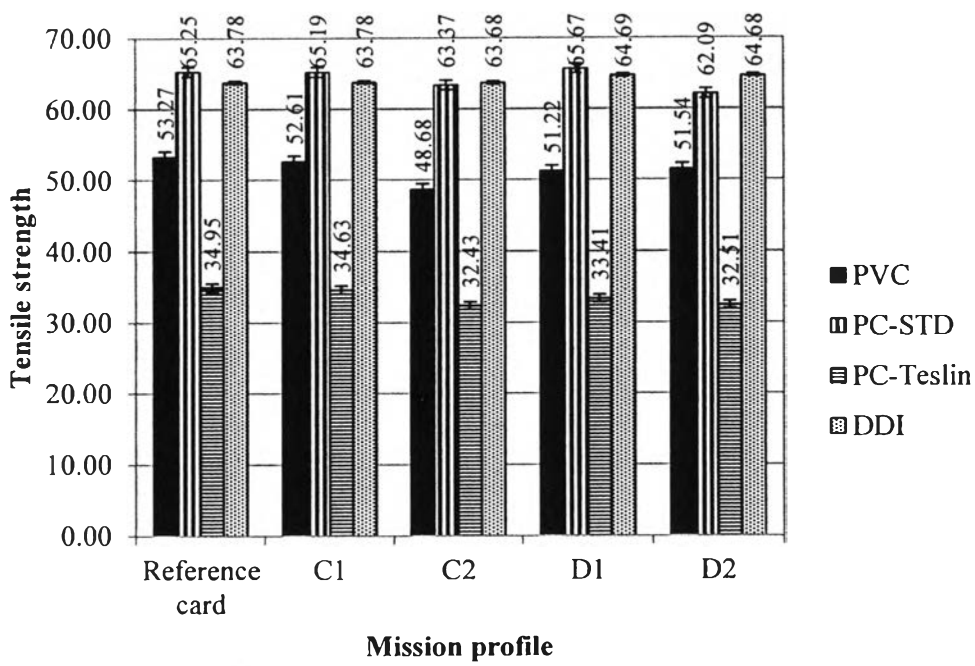


Figure 5.13 The tensile strength of each plastic card before and after testing.

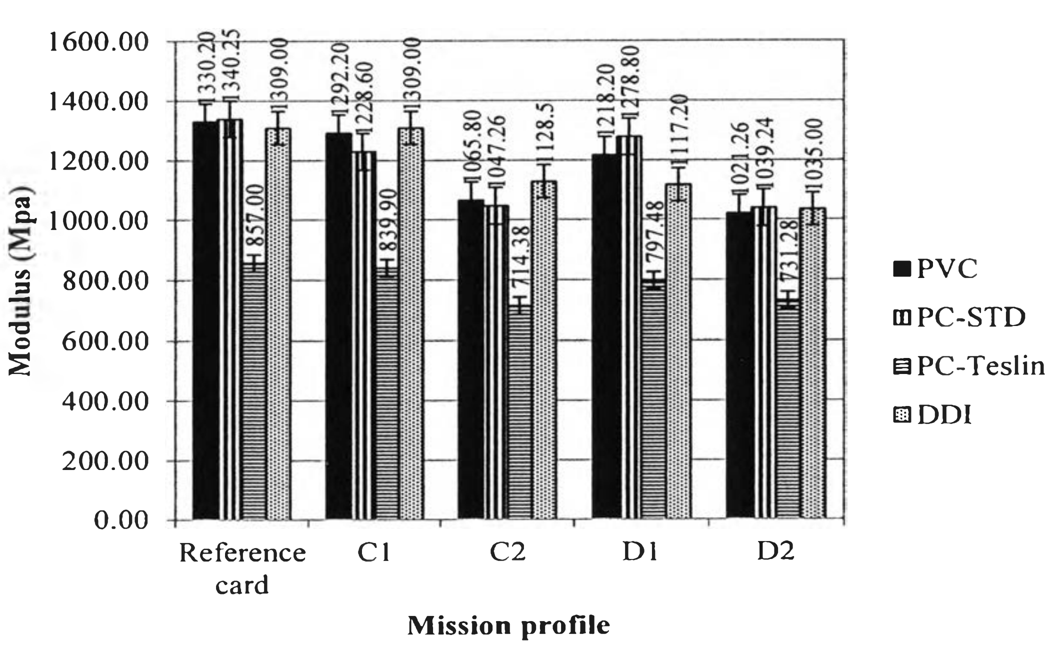
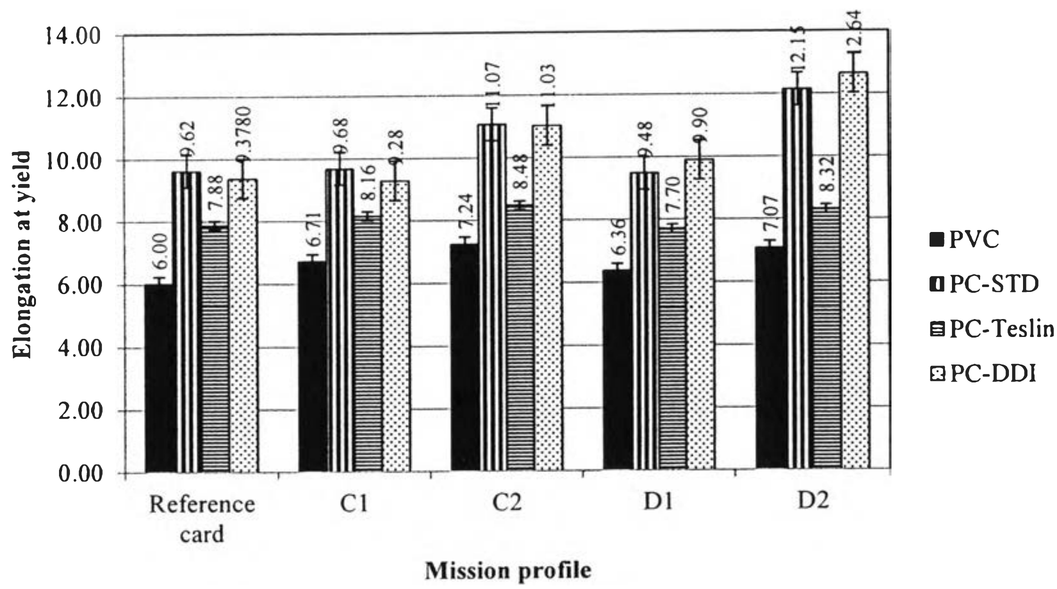
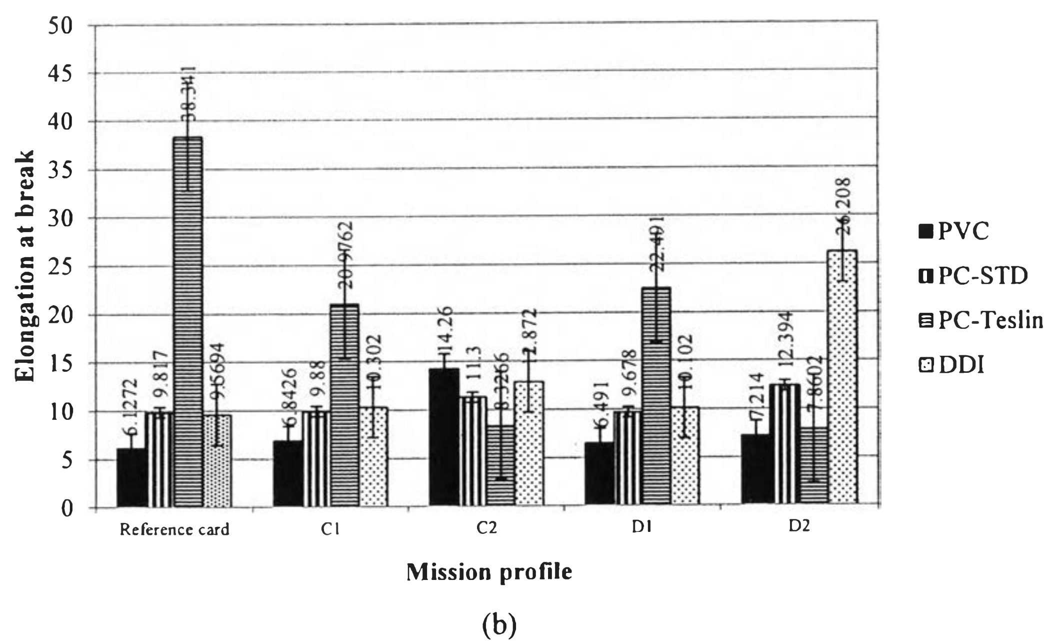


Figure 5.14 The modulus of each plastic card before and after testing.



(a)



(b)

Figure 5.15 (a) The elongation at yield of each plastic card before and after testing and (b) The elongation at break of each plastic card before and after testing.

5.4.4 Thermal Stability as Received Card

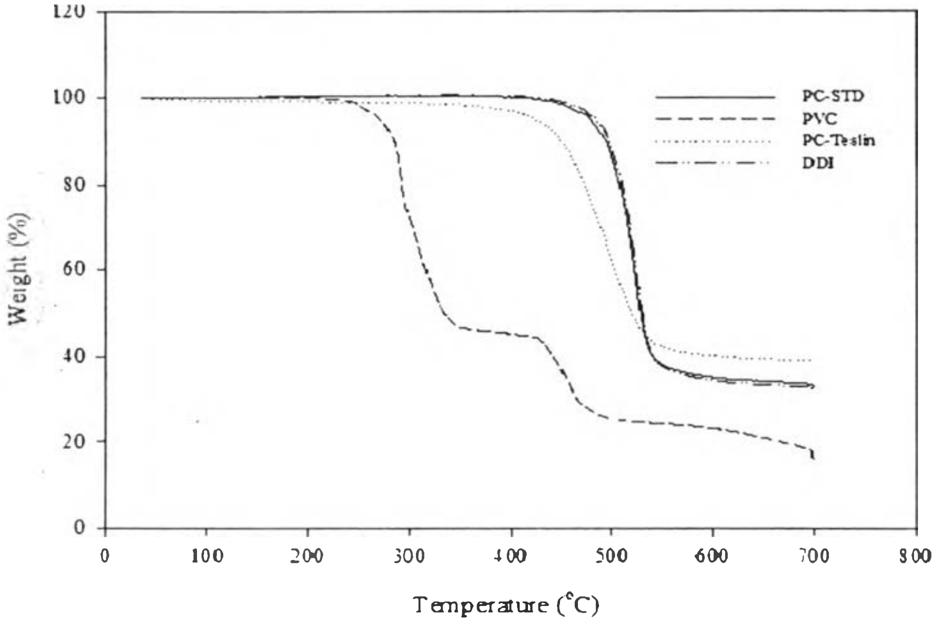


Figure 5.16 Thermogravimetric analysis of virgin commercial plastic card and virgin engineering plastic.

The thermogravimetric analysis was used to investigate the degradation temperature (T_d) and % weight loss. The plastic cards were analyzed at temperature of 50-700°C with the heating rate of 10°C/min under the nitrogen gas atmosphere.

Figure 5.16 and Table 5.8 showed the degradation temperature of virgin commercial plastic card (PC-STD and PVC) and virgin engineering plastic (PC-Teslin and PC-PC-DDI). According to the results, PC-STD and PC-PC-DDI had already started degradation temperature about 500°C while for the PC-Teslin degradation temperature was only 428.8°C. In case of PVC, it showed two well-defined degradation steps at 281.8 and 437.6°C.

It can be concluded that the degradation temperature of virgin PC-STD and PC -DDI plastic card was higher than those of cards and the PC-Teslin has the lower thermal stability than other.

Table 5.8 T_d degradation content (weight loss) of each virgin plastic card

	T_d (°C)	**Weight loss (%)**
PC STD	500.1	65.9
PVC	281.8 and 437.6	53.9 and 21.9
PC-Teslin	428.8	60.2
PC-DDI	501.6	67.2

5.4.4.1 *Thermal Stability After Testing*

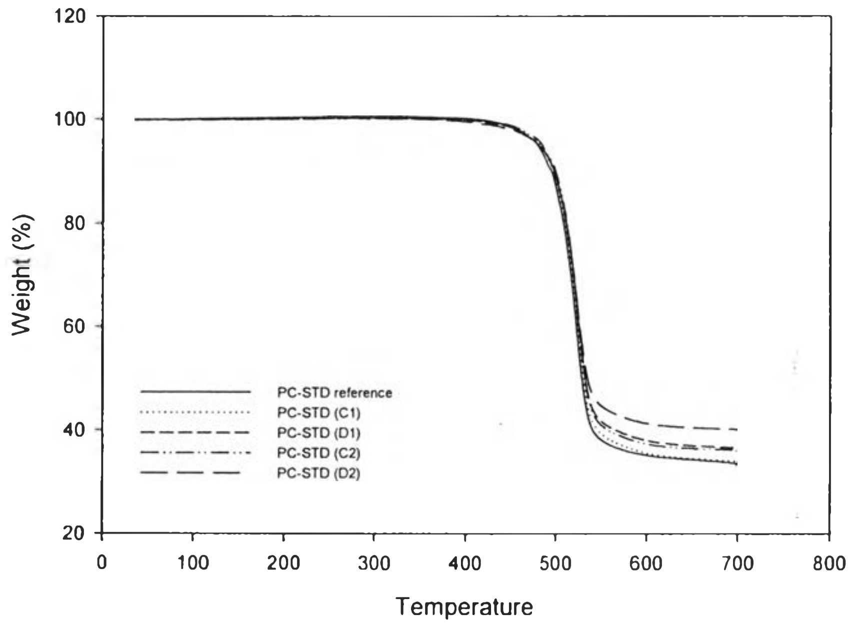


Figure 5.17 Thermogravimetric analysis of PC-STD.

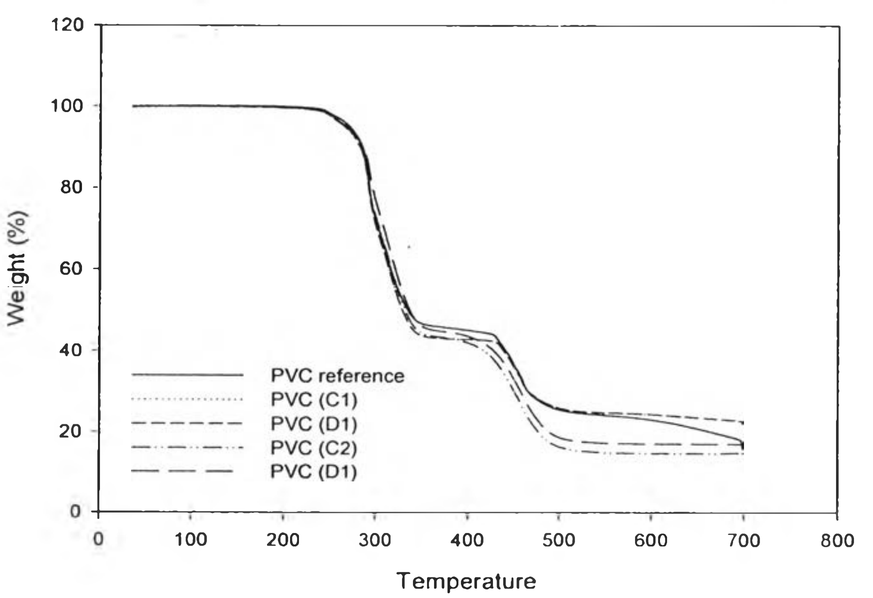


Figure 5.18 Thermogravimetric analysis of PVC.

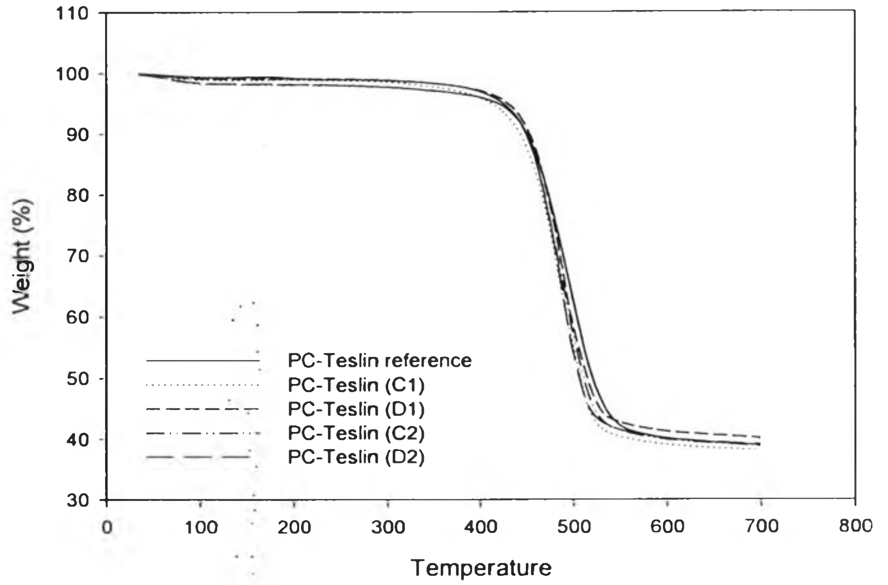


Figure 5.19 Thermogravimetric analysis of PC-Teslin.

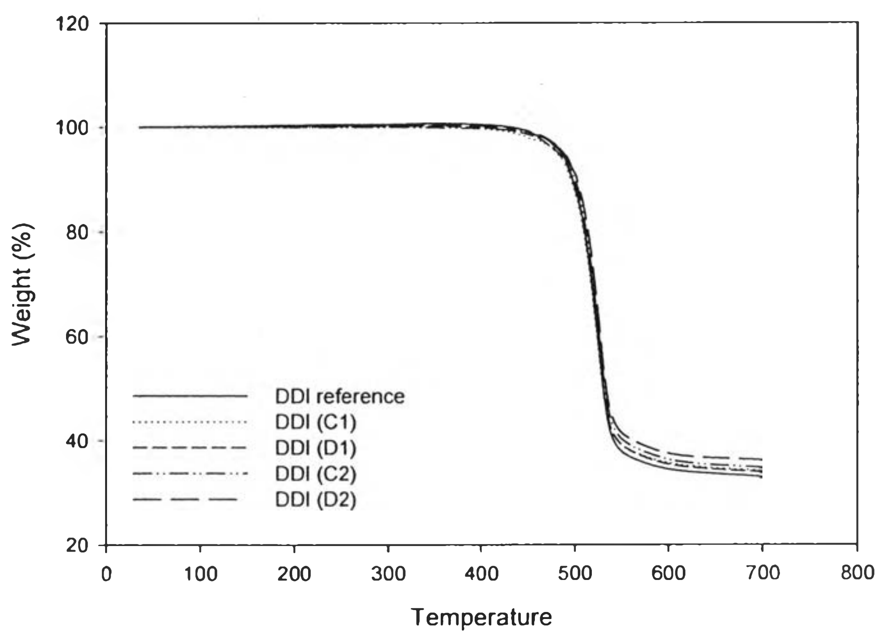


Figure 5.20 Thermogravimetric analysis of PC-DDI.

Firstly the degradation of commercial and engineering plastic cards are studied. The results are presented in Figure 5.3 for PC-STD, PVC, PC-Teslin and PC-DDI series. The heating rate at which the TGA curves were obtained was 10 °C/min.

It is obvious that PVC series can be degraded at much lower temperatures compared to PC-STD, PC-Teslin and PC-DDI series. Its degradation had already started at 200 °C, while for the other polymers the corresponding temperature was above 420 °C. Among the mission profile C1, C2, D1 and D2 of each polymers, the differences were not very strong, with mission profile C2 and D2 being less resistant to decomposition and mission profile C1 slightly better resistance than mission profile D2.

The TGA curve of each plastic card are presented in Fig. 5.17-5.20, where, it can be seen that the TGA curves shifted to slightly lower temperatures with increasing the cycle testing. The decrease in thermal stability with increasing cycle testing could be due to the chain scission along with polymer degradation of plastic material (M.D.H. Beg and K.L. Pickering, 2008) as supported by the reduction of modulus, roughness and/or cracking of each plastic card after cycle testing.

5.4.5 Lifetime Prediction

The lifetime prediction was divided in 2 types. Firstly, the plastic card was guaranteed by visual inspections. The visual inspection was measured on the surface of plastic which observed the cracking or fracture on plastic card. The detail shows in Table 5.12. The results show that the PC-STD and PC-DDI show the good appearance after pass the one and reprocess two cycle testing. However, the cracking of PC-Teslin increases with increase in the cycle testing. Moreover, PVC plastic card presents the initial cracking on the mission profile D2.

So, It can be concluded PC-Teslin (mission profile C1 and D1) didn't pass the one cycle testing after characterize by the appearance. Therefore, the lifetime predictions of PC-Teslin (C1 and D1) are only 1 year. After pass the retested cycle for two time, PVC of mission profile D2 was generated cracking and small void on cards surface. So, the lifetime predictions of PVC were found only 5 years.

In case of PC-STD and PC-DDI cards, they had only some scratch on the card surface hence, the lifetime of PC-STD and PC-DDI can guarantee for 10 years after pass two cycle testing.

Table 5.9 The lifetime prediction of each mission profile by the appearance

Mission Profile	Lifetime Prediction	PC-STD	PVC	PC-Teslin	PC-DDI
C1(normal condition)	5 years	Pass 100%	Pass 100%	Pass* 96%	Pass 100%
D1(severe condition)	2 years	Pass 100%	Pass 100%	Pass* 97%	Pass 100%
C2(normal condition)	10 years	Pass 100%	Pass 100%	Pass* 28%	Pass 100%
D2(severe condition)	3 years	Pass 100%	Pass* 97%	Pass* 10%	Pass 100%

* Sample was observed crack ** Sample was fractured

Secondly, the plastic cards were guaranteed by logical functionality. The logical functionality is the data storage on the chip which measures by RFID (Radio-frequency identification). The detail shows in Table 5.13. It can be concluded that PC-DDI card cannot read the functionality after dynamic bending testing because the chip and antenna coil were separate to each other (call TC poor). Therefore, the lifetime prediction of PC-DDI (D1) is only 1 year after testing. In term of PC-STD, PVC and PC-Teslin cards can be survived the lifetime for 10 years after pass two cycle testing.

Table 5.10 The lifetime prediction of each mission profile by the functionality

Mission Profile	Lifetime Prediction	PC-STD	PVC	PC-Teslin	PC-DDI
C1(normal condition)	5 years	Pass 100%	Pass 100%	Pass* 100%	Pass 97%
D1(severe condition)	2 years	Pass 100%	Pass 100%	Pass* 100%	Pass 83%
C2(normal condition)	10 years	Pass 100%	Pass 100%	Pass* 100%	Pass 75%
D2(severe condition)	3 years	Pass 100%	Pass* 100%	Pass* 100%	Pass 56%

* Sample was observed crack ** Sample was fractured

5.5 Conclusions

Of all above results, it can be concluded that the durability and/or service life-time of plastic cards can be affected by many different environmental factors. After two cycles, the lifetime of each plastic card was predicted. PC-STD was found to have a lifetime of 10 years. In term of PVC were found to have a lifetime 5 years, while PC-DDI and PC-Teslin found to have a lifetime for 1 year. Therefore, engineering plastic shows greater expectation of service lifetime. However, new fabricated materials such as PC-DDI shorter lifetimes was generated from poor process building (TC bond poor), While PC-Teslin, the shorter lifetime was caused from the cracking on surface.

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5.7 References

Adilson Y. Furuse,Kathryn Gordon et al. (2008) Color-stability and gloss-retention of silorane and dimethacrylate composites with accelerated aging, journal of dentistry ,36, 945–952

Bartolomeo P., Irigoyen M, E. Aragon and et al. (2001) Dynamic mechanical analysis and Vickers micro hardness correlation for polymer coating UV ageing characterization, Polymer Degradation and Stability, 72, 63-68

Gulmine J.V., Akcelrud L. (2006) Correlations between structure and accelerated artificial ageing of XLPE, European Polymer Journal,42, 553–562

Heintze SD, Forjanic M and Rousson V. (2006) Surface roughness and gloss of dental materials as a function of force and polishing time in vitro. Dental Materials, 22, 146–65

Lodha P., Netravali A.N. (2005) Thermal and mechanical properties of environment-friendly green plastics from stearic acid modified-soy protein isolate, Industrial Crops and Products, 21, 49-64

Luciano G., Leardi R., Letardi P. (2009) Principal component analysis of color measurements of patinas and coating systems for outdoor bronze monuments, J. Cult. Heritage, 10, 331–337.

Mirabedini S.M., Sabzi M. and et al. (2011) Weathering performance of the polyurethane nanocomposite coatings containing silane treated TiO nanoparticles, Applied Surface Science, 257, 4196-4203

Yuka H., Kobayashi L.S., Delia S. and et al. (2010) Mechanical properties of a degradable phosphate glass fibre reinforced polymer composite for internal fracture fixation, Materials Science and Engineering, 30, 1003–1007