CHAPTER IV
DETERMINATION OF SERVICE LIFE TIME OF COMMERCIAL PLASTIC CARDS

4.1 Abstract

Service lifetime of smart card was limiting by the degradation of plastic body. It was related by many affiliate properties such as mechanical properties, thermal properties and physical appearance. The card bodies usually fabricated by either commodity plastic or engineering plastic. The commodity plastic card such as PVC (polyvinyl chloride), PC (polycarbonate), and PETG (polyethylene terephtarate glycol) were tested that define the duration of card. 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 commercial plastic card show the changing in ΔE (color difference) and some change in functionality checking. Then, the surface of each commercial plastic was observed by SEM. And then, the initial thermal properties of each commercial plastic card were also reported in this chapter.

4.2 Introduction

Smart card is the plastic card containing a chip for identification. They enhanced security in various applications. There are several types of commercial plastic used for smart cards such as PC, PETG and PVC. However, the drawback of plastic card is the service lifetime of plastics which is the polymer degradation. The plastic card degradation is the combinations of chemical and physical change occur during storage and use of material and resulting in loss some properties of plastic material. Therefore, the service lifetime of plastic smart card is necessary to guarantee how long the card can be used in daily life.

The purpose of this work is to evaluate and to study the visual inspection, and logical functionality properties of commercial card after testing in any conditions following the standard tests. Finally, the service lifetime of any commercial plastic cards were indicated.

4.3 Materials and Methods

4.3.1 Card material

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

4.3.2 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 2 mission profiles which are C2 and D2 for testing

4.3.3 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 and humidity ageing: follow to ISO/IEC 24789-2

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

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

4.3.4 Define the Test Method From Durability Class and Test Sequence Cycle ; for example, the test method for A1.

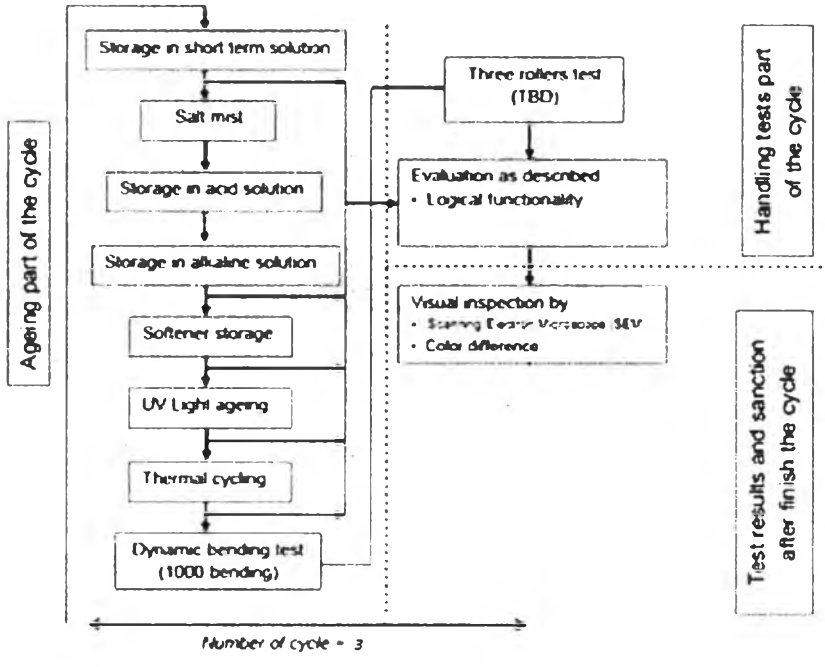

Figure 4.1 Test cycle for determining card service lifetime of commercial plastic card.

4.3.5 Characterizations 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 each cycle.

4.3.6 Characterizations 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.

4.4 Results and Discussions

4.4.1 Thermalstability as Received Card

The degradation temperature of virgin PC plastic card was higher than those of PETG and PVC card and % weight loss of PC was also measured to be lower than those of PETG and PVC. Hence, PC is much more stable at the same operating temperature.

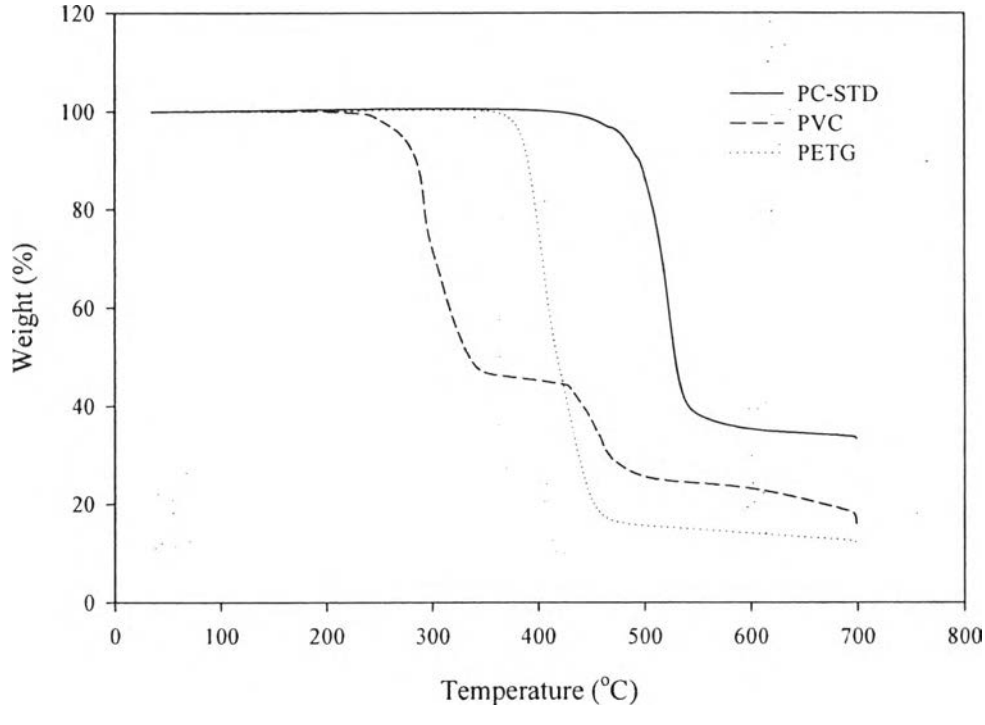

Figure 4.2 Thermogravimetric analysis of virgin commercial plastic card.

Table 4.1 T_d degradation content (weight loss) of virgin commercial plastic card

	T_d (°C)	Weight loss (%)
PC-STD	500.1	65.9
PETG	383.8	87.0
PVC	281.8 and 437.6	53.9 and 21.9

4.4.2 Surface Observation of Plastic Cards

The surfaces of plastic card before and after testing were characterized by FE-SEM. The plastic specimens were then observed on the SEM using an accelerating voltage of 2 kV with 100x.

The results of surface of plastic card were shown in Figure 4.3-4.8. The surface area of each plastic card before testing shows the smooth on surface (Fig. 4.3, 4.5 and 4.7). After 1st cycle testing, the roughness on surface was generated by the UV ray and chemical testing which has an ability to decompose the plastic and leads to enhance the surface degradation

After pass the two retested cycle, the surface of PC cards present the mark and scratch on surface (Fig. 4.4). However, PVC surface (Fig. 4.8) shows the deeper cracks, due to the dynamic testing and the US postal step. In term of PETG, the surface shows voids on the surface of card (Fig. 4.8) which possibly generate the crack on plastic card [G. F. *et al.*, (2002), J. Attwood *et al*, (2006)].

According to the results, the UV light and chemical testing accelerates the increasing the roughness of the plastic card.

In molecular structure, PC-STD (polycarbonate) is the best which has the aromatic inside, causing high mechanical properties but less resistant to caustic solutions and certain solvents. In case of PVC and PETG, PVC is easily degraded molecular structure because of the –Cl inside which can be released by heat and chemical. Finally, the optical and mechanical properties will be dropped. But the PVC was discovered for a long time and was developed for many applications. The plasticizer and additive were used to resolve the problems. So, the PVC cards have better appearances than PETG after pass the cycle testing.

Figure 4.3 The surface micrograph of PC card as received.

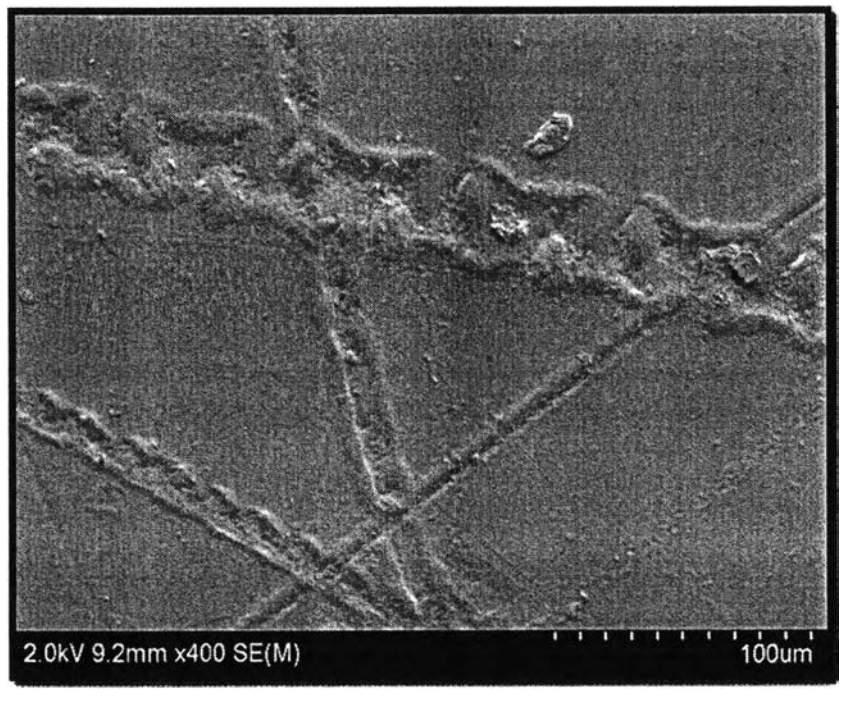

Figure 4.4 The surface micrograph of PC card after testing 2nd cycle.

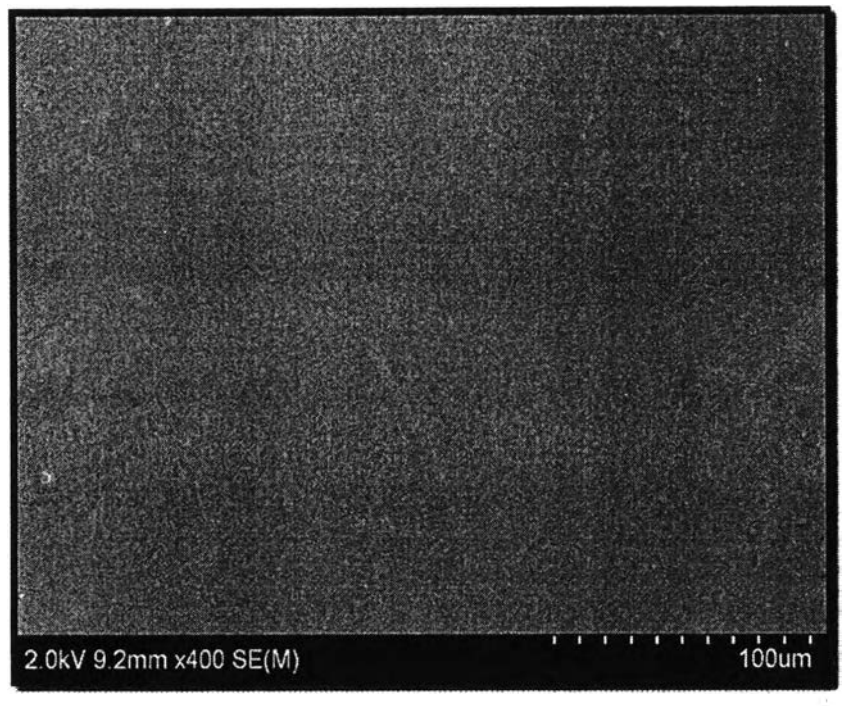

Figure 4.5 The surface micrograph of PVC card as received.

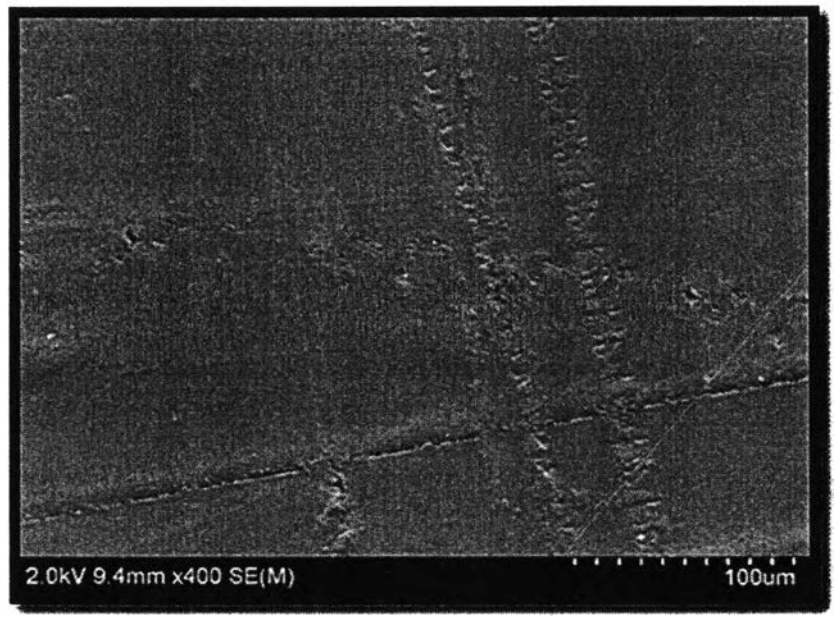

Figure 4.6 The surface micrograph of PVC after testing 2nd cycle.

Figure 4.7 The surface micrograph of PETG card as received.

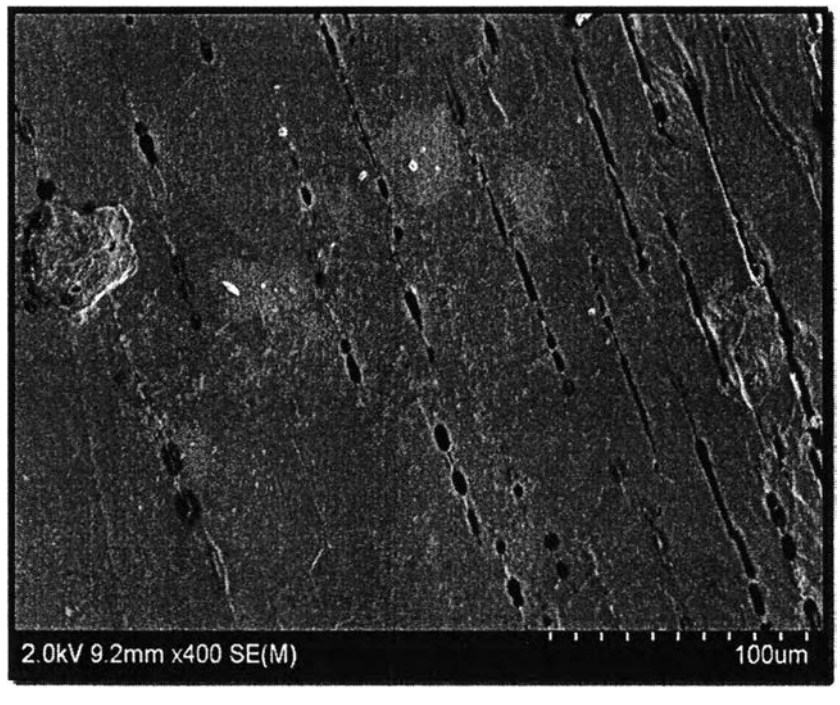

Figure 4.8 The surface micrograph of PETG after testing 2nd cycle.

4.4.3 Service Lifetime Determinations

Three types of commercial materials card including P –STD, PVC, and PETG were tested. 40 cards of each material were divided into tested samples and references as show in Table 4.2.

Table 4.2 The samples and references of smart card material

Materials	Tested sample (pieces)	Reference (pieces)	Total (pieces)
PC-STD	30	10	40
PVC	30	10	40
PETG	30	10	40

30 cards of tested samples were divided into 2 groups for mission profile C2 and D3.All tested cards were checked for visual inspection and functionality before testing. The detail is shown in Table 4.3.

Table 4.3 Visual inspection and functionality checking of cards before testing

Materials	Visual inspection	Functionality checking, Max. distance (cm)		
PC-STD	Normal*	4.7	4.8	4.9
PVC	Normal*	5		
PETG	Normal*	5		

*strained and scratched were found on cards as received

After that, all tested cards were tested for each step in the first cycle. The tested cards were checked for visual inspection and functionality after finished each step. The steps start from chemicals resistance, softener storage, treatment with UV light, thermal storage, dynamic bending test, US postal (tensile test), respectively.

1st step: Chemicals Resistance

- *Short Term Contamination*

This part is for determining the effects of chemical contaminants on the cards. It composes of short term test which take the testing time for 1 minute and long term test which take the testing time for 24 hours.

After testing at 1st cycle testing, matted and strained scratch was found in all cards. Consequently after testing at 2nd cycle test, functionality checking distances of all cards were lower compared to those of 1st cycle. The detail is shown in Table 4.4.

1st step: Chemicals Resistance

- *Short Term Contamination*

This part is for determining the effects of chemical contaminants on the cards. It composes of short term test which take the testing time for 1 minute and long term test which take the testing time for 24 hours. After testing at 1st cycle testing, matted and strained scratch was found in all cards. Consequently after testing at 2nd cycle test, functionality checking distance of all cards was lower compared to those of 1st cycle. The detail is shown in Table 4.4-4.5.

Table 4.4 Visual inspection and functionality checking of cards after short term contamination test inspection after 1st cycle

Materials	Defects for visual inspection after 1st cycle					Functionality checking, Max. distance after 1st cycle (Mission profile; C1 and D1)				
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)				$\bar{x}$
PC-STD (C1)	NONE	FEW	FEW	NONE	NONE	4.5	4.6	4.7	4.8	4.61 ±0.06
PC-STD (D1)	NONE	FEW	FEW	NONE	NONE	4.5	4.6	4.7	4.8	4.62 ±0.09
PVC (C1)	NONE	FEW	FEW	NONE	NONE	4.7	4.9	5		4.86 ±0.10
PVC (D1)	NONE	FEW	FEW	NONE	NONE	4.7	4.9	5		4.91 ±0.10
PETG (C1)	NONE	FEW	FEW	NONE	NONE	4.7	4.8	4.9	5	4.84 ±0.09
PETG (D1)	NONE	FEW	FEW	NONE	NONE	4.8	4.9	5		4.79 ±0.13

Table 4.5 Visual inspection and functionality checking of cards after short term contamination test after 2nd cycle

Materials	Defects for visual inspection after 2nd cycle					Functionality checking, Max. distance after 2nd cycle (Mission profile; C2 and D2)					
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)					$\bar{x}$
PC-STD (C2)	ALL	FEW	FEW	NONE	NONE	4	4.1	4.2	4.3		4.13 ±0.12
PC-STD (D2)	ALL	FEW	FEW	NONE	NONE	4	4.1	4.2	4.3		4.18 ±0.08
PVC (C2)	ALL	FEW	FEW	NONE	NONE	3.9	4.0	4.1	4.2	4.3	4.12 ±0.14
PVC (D2)	ALL	FEW	FEW	NONE	NONE	4.0	4.1	4.2	4.3		4.20 ±0.07
PETG (C2)	ALL	FEW	FEW	ALL	NONE	4.5	4.6				4.52 ±0.04
PETG (D2)	ALL	FEW	FEW	ALL	NONE	4.5	4.6				4.51 ±0.03

* Matt from chemicals and softener storage on both side of card,

** Yellowness from UV light on both side of card

- *Long Term Contamination*

This test was divided into 2 parts. There is first test by salt spray test and second by artificial perspiration test.

➢ Salt Spray Test

All cards were tested with the salt spray tester by external laboratory (Calserve Thailand) Co., Ltd.). The photographs of cards before and after testing are shown in Figures 4.9 and 4.10.

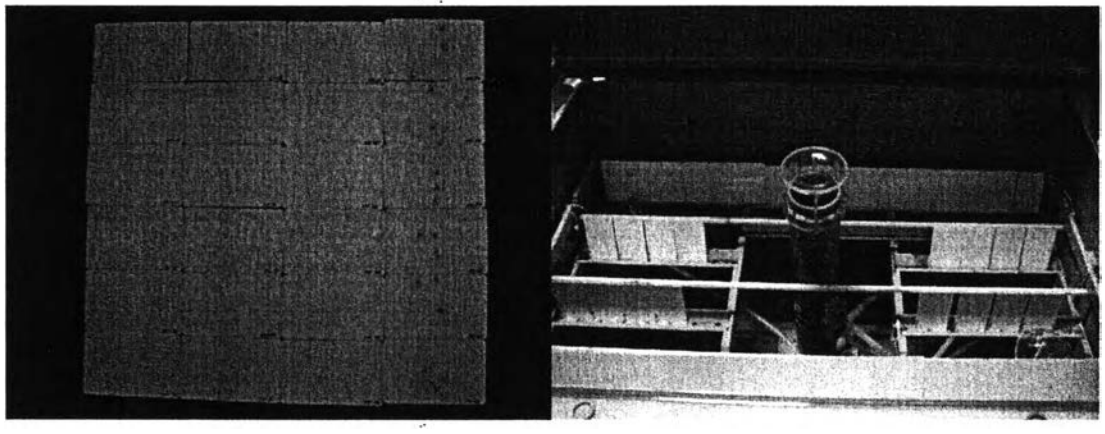

Figure 4.9 Cards before salt spray test.

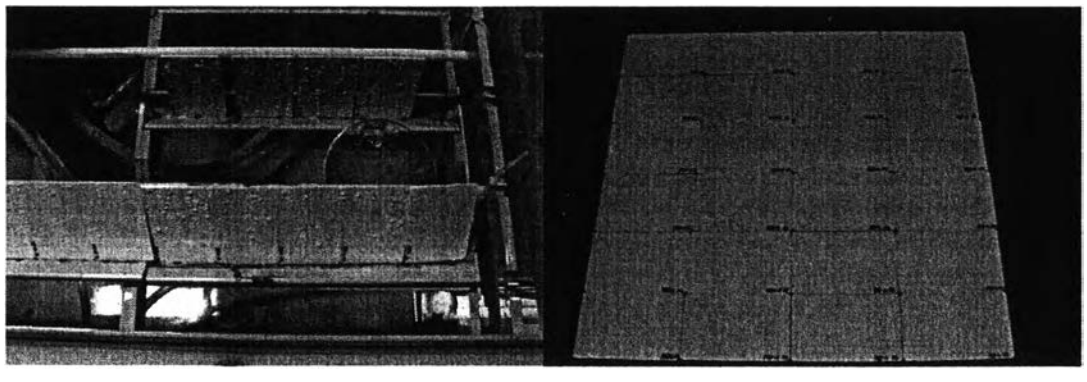

Figure 4.10 Cards after salt spray test.

➢ Artificial Perspiration Test

After salt spray test, the cards were immersed in alkaline solution for 24 hr. and then for acid solution for 24 hr. The detail is shown in Table 4.6-4.7.

Table 4.6 Visual inspection and functionality checking of cards after long term contamination test after 1st cycle

Materials	Defects for visual inspection after 1st cycle					Functionality checking, Max. distance after 1st cycle (Mission profile; C1 and D1)				
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)				$\bar{x}$
PC-STD (C1)	NONE	FEW	FEW	NONE	NONE	4.5	4.6	4.7	4.8	4.59 ±0.03
PC-STD (D1)	NONE	FEW	FEW	NONE	NONE	4.5	4.6	4.7		4.69 ±0.06
PVC (C1)	NONE	FEW	FEW	NONE	NONE	4.8	4.9	5		4.86 ±0.08
PVC (D1)	NONE	FEW	FEW	NONE	NONE	4.7	4.8	4.9	5	4.91 ±0.04
PETG (C1)	NONE	FEW	FEW	NONE	NONE	4.7	4.8	4.9	5	4.82 ±0.08
PETG (D1)	NONE	FEW	FEW	NONE	NONE	4.7	4.8	4.9		4.84 ±0.09

Table 4.7 Visual inspection and functionality checking of cards after long term contamination test after 2nd cycle

Materials	Defects for visual inspection after 2nd cycle					Functionality checking, Max. distance after 2nd cycle (Mission profile; C2 and D2)					
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)					$\bar{x}$
PC-STD (C2)	ALL	FEW	FEW	NONE	NONE	4.1	4.2	4.3	4.4	4.5	4.24 ±0.10
PC-STD (D2)	ALL	FEW	FEW	NONE	NONE	4.2	4.3	4.4	4.5		4.27 ±0.07
PVC (C2)	ALL	FEW	FEW	NONE	NONE	4.4	4.6	4.7	4.9		4.84 ±0.16
PVC (D2)	ALL	FEW	FEW	NONE	NONE	4.4	4.5	4.6	4.8		4.81 ±0.12
PETG (C2)	ALL	FEW	FEW	ALL	NONE	4.6	4.7	4.8	4.9		4.73 ±0.09
PETG (D2)	ALL	FEW	FEW	ALL	NONE	4.6	4.7	4.8			4.81 ±0.09

* Matt from chemicals and softener storage on both side of card,

** Yellowness from UV light on both side of card

2nd step: Softener Storage

This part is for evaluating card resistance to the damaging effects of plasticizers. After testing at 2nd cycle test, functionality checking distances of all cards were lower compared to those of 1st cycle. The detail is shown in Table 4.6.

Table 4.8 Visual inspection and functionality checking of cards after softener storage test after 1st cycle

Materials	Defects for visual inspection after 1st cycle					Functionality checking, Max. distance after 1st cycle (Mission profile; C1 and D1)				
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)				$\bar{x}$
PC-STD (C1)	NONE	FEW	FEW	NONE	NONE	4.1	4.2	4.3	4.4	4.38 ±0.07
PC-STD (D1)	NONE	FEW	FEW	NONE	NONE	4.2	4.3	4.4	4.5	4.37 ±0.09
PVC (C1)	NONE	FEW	FEW	NONE	NONE	4.4	4.6	4.7	4.9	4.80 ±0.19
PVC (D1)	NONE	FEW	FEW	NONE	NONE	4.9				4.90 ±0.00
PETG (C1)	NONE	FEW	FEW	NONE	NONE	4.6	4.7	4.8	4.9	4.77 ±0.05
PETG (D1)	NONE	FEW	FEW	NONE	NONE	4.6	4.7	4.8	4.9	4.82 ±0.08

Table 4.9 Visual inspection and functionality checking of cards after softener storage test after 2nd cycle

Materials	Defects for visual inspection after 2nd cycle					Functionality checking, Max. distance after 2nd cycle (Mission profile; C2 and D2)					
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)					$\bar{x}$
PC-STD (C2)	ALL	FEW	FEW	NONE	NONE	4.1	4.2	4.3	4.4	4.5	4.37 ±0.06
PC-STD (D2)	ALL	FEW	FEW	NONE	NONE	4.1	4.2	4.4	4.5		4.39 ±0.07
PVC (C2)	ALL	FEW	FEW	NONE	NONE	4.4	4.6	4.7	4.9		4.82 ±0.17
PVC (D2)	ALL	FEW	FEW	NONE	NONE	4.4	4.5	4.6	4.7	4.8	4.80 ±0.12
PETG (C2)	ALL	FEW	FEW	ALL	NONE	4.6	4.7	4.8	4.9		4.74 ±0.09
PETG (D2)	ALL	FEW	FEW	ALL	NONE	4.6	4.7	4.8	4.9		4.80 ±0.04

* Matt from chemicals and softener storage on both side of card,

** Yellowness from UV light on both side of card

3rd step: Treatment with UV light

This part is for determining the effects from exposure of the cards to ultraviolet light.

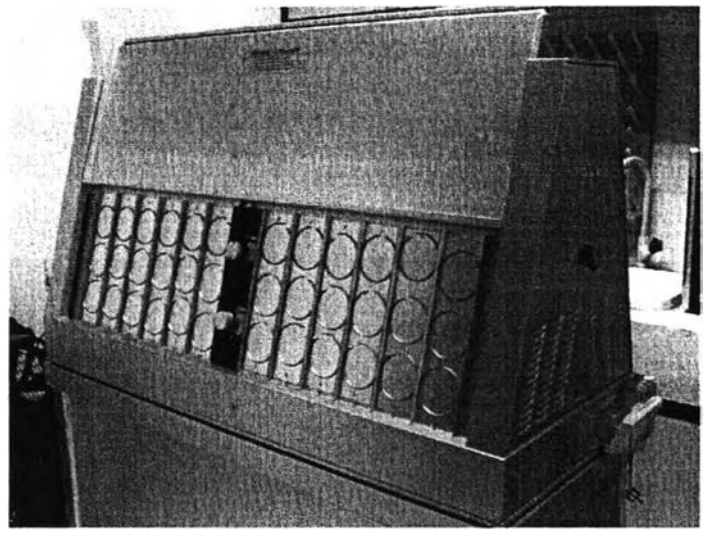

Figure 4.11 QUV tester.

Testing conditions are

- UV light at 313 nm
- Irradiance at 0.68 W/m^2
- Temperature at 35 °C
- Time for 79.19 min

After UV exposure in 1st cycle test, the slight yellowness was found on all PC-STD, PVC, and PETG.After UV exposure in 2nd cycle test any card more yellowness and the functionality checking detail is shown in Table 4.10-4.11.

Table 4.10 Visual inspection and functionality checking of cards after treatment with UV light after 1st cycle

Materials	Defects for visual inspection after 1st cycle					Functionality checking, Max. distance after 1st cycle (Mission profile; C1 and D1)					
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)					$\bar{x}$
PC-STD (C1)	FEW	FEW	FEW	NONE	NONE	4	4.1	4.2	4.3		4.27 ±0.07
PC-STD (D1)	FEW	FEW	FEW	NONE	NONE	4	4.1	4.2			4.24 ±0.09
PVC (C1)	FEW	FEW	FEW	NONE	NONE	4.2	4.3	4.4	4.5	4.6	4.45 ±0.09
PVC (D1)	FEW	FEW	FEW	NONE	NONE	4.2	4.3	4.4	4.5	4.6	4.49 ±0.02
PETG (C1)	FEW	FEW	FEW	FEW	NONE	4.5	4.6	4.7	4.8		4.72 ±0.13
PETG (D1)	FEW	FEW	FEW	FEW	NONE	4.5	4.6	4.7	4.8		4.73 ±0.10

Table 4.11 Visual inspection and functionality checking of cards after treatment with UV light after 2nd cycle

Materials	Defects for visual inspection after 2nd cycle					Functionality checking, Max. distance after 2nd cycle (Mission profile; C2 and D2)				
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)				$\bar{x}$
PC-STD (C2)	ALL	FEW	FEW	NONE	NONE	4.1	4.2	4.3		4.32 ±0.14
PC-STD (D2)	ALL	FEW	FEW	NONE	NONE	4	4.1	4.2	4.3	4.30 ±0.09
PVC (C2)	ALL	FEW	FEW	NONE	NONE	4.7	4.9	5		4.75 ±0.09
PVC (D2)	ALL	FEW	FEW	NONE	NONE	4.7	4.9	5		4.72 ±0.06
PETG (C2)	ALL	FEW	FEW	ALL	NONE	4.3	4.4	4.5	4.6	4.35 ±0.09
PETG (D2)	ALL	FEW	FEW	ALL	NONE	4.2	4.3	4.4	4.5	4.34 ±0.09

* Matt from chemicals and softener storage on both side of card,

** Yellowness from UV light on both side of card

4th step: Thermal Storage and Dynamic Bending Test

The cards were tested for thermal storage at 50±3 °C and 93±3 %RH for 48 hours in oven to establish ageing of the cards at elevated temperature and humidity. After that, all cards were retained in the conditioning environment for 4 hours. And then, the cards were tested for dynamic bending to determine mechanical or functional effects of bending stress in the cards. For the dynamic bending test, a number of bending depends on durability class as shown in Table 4.12.

Table 4.12 Number of bending for each durability class

Durability class	No. of bending
A	1000
B	2000
C	3000
D	4000

Finally, the visual inspection and functionality checking after dynamic bending test and thermal storage test were shown in the Table 4.13-4.14.

Table 4.13 Visual inspection and functionality checking of cards after thermal storage and dynamic bending test after 1st cycle

Materials	Defects for visual inspection after 1st cycle					Functionality checking, Max. distance after 1st cycle (Mission profile; C1 and D1)					
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)					$\bar{x}$
PC-STD (C1)	FEW	FEW	FEW	NONE	NONE	4	4.1	4.2	4.3		4.21 ±0.10
PC-STD (D1)	FEW	FEW	FEW	NONE	NONE	4	4.1	4.2	4.3		4.25 ±0.07
PVC (C1)	FEW	FEW	FEW	NONE	NONE	3.9	4	4.1	4.2	4.3	4.11 ±0.19
PVC (D1)	FEW	FEW	FEW	NONE	NONE	4	4.1	4.2	4.3		4.16 ±0.18
PETG (C1)	FEW	FEW	FEW	ALL	NONE	4.5	4.6				4.55 ±0.05
PETG (D1)	FEW	FEW	FEW	ALL	NONE	4.5	4.6				4.56 ±0.05

Table 4.14 Visual inspection and functionality checking of cards after thermal storage and dynamic bending test 2nd cycle

Materials	Defects for visual inspection after 2nd cycle					Functionality checking, Max. distance after 2nd cycle (Mission profile; C2 and D2)					
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)					$\bar{x}$
PC-STD (C2)	ALL	FEW	FEW	NONE	NONE	4.1	4.2	4.3	4.4	4.5	4.35 ±0.10
PC-STD (D2)	ALL	FEW	FEW	NONE	NONE	4.1	4.2	4.3	4.4	4.5	4.38 ±0.06
PVC (C2)	ALL	FEW	FEW	NONE	NONE	4.4	4.6	4.7	4.9		4.81 ±0.16
PVC (D2)	ALL	FEW	FEW	NONE	NONE	4.6	4.7	4.8	4.9		4.84 ±0.11
PETG (C2)	ALL	FEW	FEW	ALL	NONE	4.6	4.7	4.8	4.9		4.74 ±0.10
PETG (D2)	ALL	FEW	FEW	ALL	NONE	4.5	4.6	4.7			4.79 ±0.08

* Matt from chemicals and softener storage on both side of card,

** Yellowness from UV light on both side of card

5th step: US Postal test (Tensile Test)

The cards were tested for US postal test to determine mechanical effects of bending stress in the cards. The visual inspection and functionality checking after US postal test were shown in the Table 4.15-4.16.

Table 4.15 Visual inspections and functionality checking after US postal test after 1st cycle

Materials	Defects for visual inspection after 1st cycle					Functionality checking, Max. distance after 1st cycle (Mission profile; C1 and D1)					
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)					$\bar{x}$
PC-STD (C1)	FEW	FEW	FEW	NONE	NONE	4	4.1	4.2	4.3		4.18 ±0.12
PC-STD (D1)	FEW	FEW	FEW	NONE	NONE	4	4.1	4.2	4.3		4.25 ±0.08
PVC (C1)	FEW	FEW	FEW	NONE	NONE	3.9	4.0	4.1	4.2	4.3	4.11 ±0.18
PVC (D1)	FEW	FEW	FEW	NONE	NONE	4.0	4.1	4.2	4.3		4.17 ±0.17
PETG (C1)	FEW	FEW	FEW	ALL	NONE	4.5	4.6				4.53 ±0.04
PETG (D1)	FEW	FEW	FEW	ALL	NONE	4.5	4.6				4.52 ±0.04

Table 4.16 Visual inspections and functionality checking after US postal test 2nd cycle

Materials	Defects for visual inspection after 2nd cycle					Functionality checking, Max. distance after 2nd cycle (Mission profile; C2 and D2)					
	Yellowness**	Matted*	Stain Scratch	Warpage	Crack	Distance (cm)					$\bar{x}$
PC-STD (C2)	ALL	FEW	FEW	NONE	NONE	4	4.1	4.2	4.3		4.26 ±0.07
PC-STD (D2)	ALL	FEW	FEW	NONE	NONE	4.1	4.2	4.3			4.25 ±0.09
PVC (C2)	ALL	FEW	FEW	NONE	NONE	3.9	4.0	4.1	4.2	4.3	4.17 ±0.16
PVC (D2)	ALL	FEW	FEW	NONE	NONE	3.9	4.0	4.1	4.2	4.3	4.23 ±0.25
PETG (C2)	ALL	FEW	FEW	ALL	NONE	4.5	4.6				4.52 ±0.04
PETG (D2)	ALL	FEW	FEW	ALL	2 pcs	4.5	4.6				4.51 ±0.04

* Matt from chemicals and softener storage on both side of card,

** Yellowness from UV light on both side of card

4.4.4 Color Difference

The surface degradation of plastic card was characterized by color changing, defined as the color measurement, after testing in accelerated weathering conditions. The tests were performed accordance with ASTM D 65 using a colorimetric spectrophotometer (Miniscan XE Plus, Hunter lab Co.) illuminant D65, in angle 45.

The total color difference value (ΔE) of the reference cards and the tested cards was shown in Table 4.17 and Figure 4.12.

After the 2nd cycle testing, the PVC, PC-STD and PETG cards in mission profile C2have total (ΔE) about 7.7, 4.7 and 3.7, respectively. In term of mission profile D2, PVC has the highest of color difference value ((ΔE ~ 7.6) while PC-STD and PETG have about 4.5 and 3.1, respectively. The reason was that all of plastic card degraded by photolysis to give changed in color difference and they are not inherently UV-stable, meaning they will yellow when exposed to the UV for long periods of time (Mikiya Ito *et al.*, 2000).

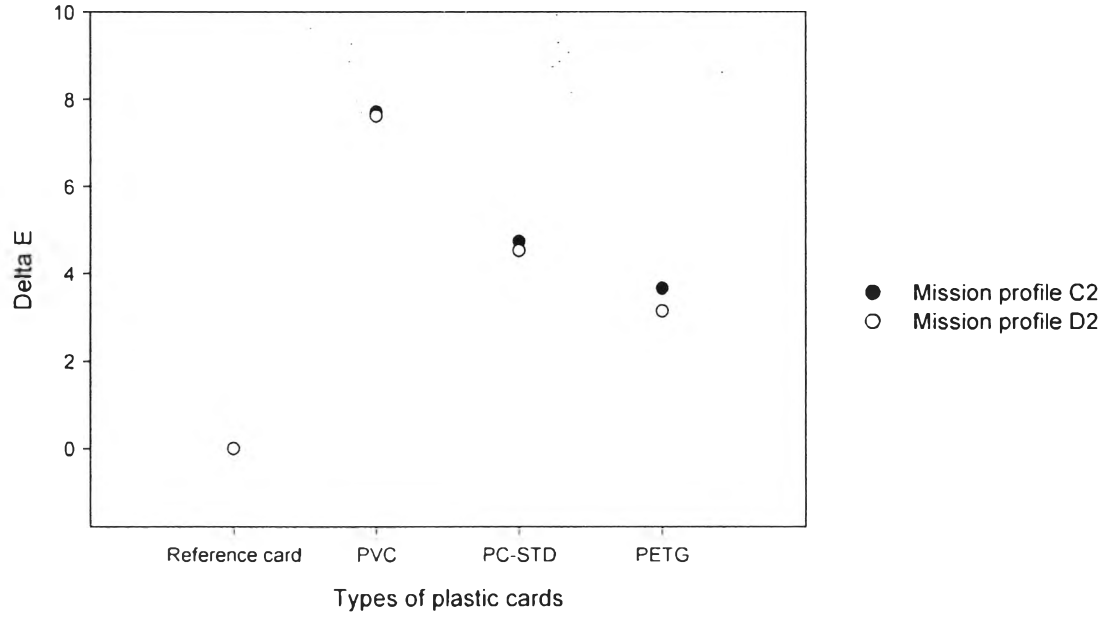

Figure 4.12 The total color difference (ΔE) versus the types of plastic cards.

Table 4.17 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 C2	2	-1.385	-2.108	7.265	7.707
PVC mission profile D2	2	-1.030	-2.098	7.227	7.612
PC-STD reference	-	0	0	0	0
PC-STD mission profile C2	2	-0.634	-1.244	4.530	4.740
PC-STD mission profile D2	2	-0.370	-1.162	4.364	4.531
PETG reference	-	0	0	0	0
PETG mission profile C2	2	-1.878	-0.800	3.042	3.663
PETG mission profile D2	2	-1.442	-0.824	2.674	3.148

4.4.5 Lifetime Prediction

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 4.17.

Table 4.18 The lifetime prediction of each mission profile by the functionality

Mission Profile	Lifetime Prediction	PC-STD	PVC	PETG
mission profile C2	10 years	Pass 100%	Pass 100%	Pass *,** 90%
mission profile D2	3 years	Pass 100%	Pass*100%	Pass *,** 70%

* Sample was observed crack ** Sample was fractured

The results showed the observation of functionality checking of their plastic cards show insignificant changing in functionality checking (max. distance). The plastic card was cracked after testing which also read the functionality until it's fractured.

Table 4.19 The lifetime prediction of each mission profile by the appearance

Mission Profile	Lifetime Prediction	PC-STD	PVC	PETG
mission profile C2	10 years	Pass 100%	Pass 100%	Pass *,** 30%
mission profile D2	3 years	Pass 100%	Pass* 90%	Pass *,** 10%

* Sample was observed crack ** Sample was fractured

The Table 4.19 showed the lifetime prediction of each mission profile by the appearance which decided by cracking on surface of plastic card.

It can be concluded that PETG (mission profile C1 and D1) did not pass the one cycle testing after characterize by appearance. Therefore, the lifetime predictions of PETG (C1 and D1) are only 1 year. After pass the retested cycle for two times, PVC of mission profile D2 was generated the cracking. So, the lifetime predictions of PVC were fallen into only 5 years. In case of PC-STD cards, they can guarantee for 10 years after passed two cycles testing in normal condition. In term of severe condition, only PC-STD was found the lifetime for 3 years.

4.5 Conclusions

All of cards changed in high total color difference value (ΔE) after testing. The PC and PVC image shows the scratch on the surface but PETG shows voids and crack on the surface due to the expose to UV ray and mechanical bending. Thus, PC-STD and PVC cards can guarantee the lifetime of 10 years in normal condition while PETG can guarantee the service life time only 1 year. In term of severe condition, only PC-STD was found the lifetime for 3 years.

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4.7 References

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