• Hot Melt Adhesives for IC Cards

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1. Introduction

In recent years, IC cards have been used in various sectors, as exemplified by IC phone cards, JR East's SUICA [1] train ticket, and IC credit cards. Contactless IC cards, which utilize electromagnetic induction to communicate data between IC cards and readers or writers, are increasing, particularly in the transportation sector, where high-speed processing is required, as well as in the distribution sector, where operational ease and expeditious payment are expected. **Figure 1** shows the structure of a contactless IC card. In this structure, an adhesive bonds a circuit board layer with an IC chip and an antenna coil on top of it, and a surface layer substrate material. Polyvinyl chloride (PVC) was traditionally used as the substrate for cards. However, due to environmental concerns, it has been replaced by a resin material called polyethylene terephthalate (PET) or PETG, which is a copolymer of PET and 1,4-Cyclohexanedimethanol. Adhesive materials are required to have adhesion to these substrates and the ability to fill in the irregularities on the IC chip surface, while also maintaining the properties of the card.

Toagosei has released ARON MELT PES, a copolyester hot melt adhesive, with the following characteristics:

(1) Excellent adhesion: Excellent adhesion to plastic materials, such as PET, PVC, and polycarbonate (PC), as well as metal materials, such as aluminum, copper, and iron.

(2) Excellent physical properties: Cohesive, sturdy, and flexible resin.

(3) Excellent electrical properties: Excellent insulation resistance and dielectric strength.

(4) Good workability: Availability in various forms, such as pellets, films, and solutions.

(5) Safety: Environmentally friendly, solvent-free, hot-melt type.

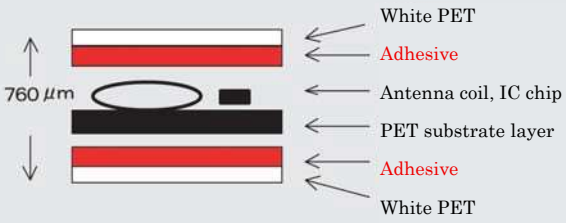

Figure 1: IC card structure

Applying ARON MELT PES technology, we have developed lamination adhesives used for manufacturing IC cards and hot melt adhesives for fixing IC chip modules. This paper introduces the characteristics, performance, and usage of these products.

2. ARON MELT PES

ARON MELT PES is a saturated copolyester-based hot melt adhesive synthesized by an esterification polycondensation reaction using dibasic acid and glycol as the main raw materials. By varying the combination of monomers, various resin properties can be obtained, ranging from crystalline and sturdy resins, such as PET, to amorphous and flexible resins. ARON MELT PES adhesives can be broadly classified into a crystalline hot-melt type and a solution type in which amorphous resin is dissolved in a solvent. Due to crystallization, the hot-melt adhesive has high heat and solvent resistance, as well as excellent electrical properties. It is also environmentally friendly because it is solvent-free. It is processed into shapes suitable for production line applications, including pellets and films. It is primarily used for laminating electrical components, automobile interior materials, as well as for building materials, such as PVC composite [2].

On the other hand, the solution type is used as a base resin for paints, laminating adhesives, and coatings because it allows for thin-film coating and easily mixes with other additives and curing agents.

The hot melt adhesives for IC cards introduced here are crystalline hot melt adhesives customized for them.

3. Adhesives for IC card lamination

There are two types of contactless IC cards: embossed cards, which have embossed characters on their surface, such as credit cards, and non-embossed cards, such as phone cards. Different substrates are used for each type of card. The performance requirements for adhesives also differ depending on the type of card. Table 1 summarizes the performance requirements for adhesives by type.

PET is primarily used for non-embossed, contactless IC card substrates because of its stiffness and recyclability, and adhesives must have adhesion to PET.

Table 1: Performance requirements for adhesives for IC cards

Requirement	Non-embossed card	Embossed card
1. Embossability	Not required	No warping after embossing
2. Adhesion	PET substrate material failure	PETG and PVC substrate material failure
3. Adhesive durability	Damp-heat resistance 50°C x 90%RH x 500 h	
4. Chemical resistance In accordance with JIS-K-6305	Immersed in a 5% acetic acid solution at 25°C:	No abnormalities
	Immersed in a 5% sodium carbonate solution at 25°C:	No abnormalities
	Immersed in 60% ethanol at 25°C:	No abnormalities
	Immersed in a 50% ethylene glycol solution at 25°C:	No abnormalities
	Immersed in isooctane-toluene (7:3) at 25°C:	No abnormalities
5. Processing suitability	Die-cutting processability: No burring or adhesion to the blade	

On the other hand, PETG and PVC are primarily used for embossed cards. This is because PET fails to accommodate the stretching involved in embossing, and breaks as a result. Adhesives are necessary to help embossed characters appear clearly without warping the cards.

Other common requirements include adhesion, durability, chemical resistance, and die-cutting processability.

Toagosei has developed adhesives for different types of cards, which will be described in detail.

3.1 Hot melt adhesives for non-embossed cards

We have developed the following new products: a standard-grade ARON MELT PES-111EE as a laminating adhesive for non-embossed, contactless IC cards; PES-111EHW, which prevents adhesive outflow during card forming; and low-melting-point type PES-070EW, which enables bonding at low temperatures (at 100°C or lower) for the purpose of bonding the sublimation-printed card substrate. Table 2 shows the physical property values of each adhesive.

Table 2: Physical property values of hot-melt adhesives for IC card lamination

		PES-070EW	PES-111EE	PES-111EHW
Appearance		White	Milky white	White
Melt viscosity	Pa·s 190°C	98	194	280
Melting point	°C	72	115	110
Glass-transition temperature	°C	-27	-0.5	-8
Tensile strength at break	MPa	3.6	12.2	16.3
Elongation at break	%	300	750	800
Crystallization time	Min	150	120	150

3.1.1 Adhesive performance

The adhesives in these grades contain additives formulated using Toagosei's proprietary technology (Patent No. 2590523) to provide polyester resin with adhesive performance and durability, and are characterized by high adhesion to PET, not found in other companies' hot melt adhesives. **Table 3** shows the results of the adhesive durability test conducted in accordance with JIS-X 6305-1 (2003), "Identification cards - Test methods - Part 1: General characteristics," for which untreated PET was bonded with PES-111EE. As shown in the table, PES-111EE has chemical resistance and its adhesive strength does not decrease after the cold thermal shock test. **Figure 2** shows the relationship between adhesion temperature and peel adhesion strength. The temperature required for adhesion is 80°C or higher for PES-070EW and 115°C or higher for PES-111EE. To obtain sufficient peel strength, however, the ideal temperatures are 100°C or higher for PES-070EW and 130°C or higher for PES-111EE.

Table 3: Adhesive durability test results

	PES-111EE	Competitor hot-melt adhesive
Normal strength at 23°C	5.0 SF	3.0 SF
80°C x 90RH After 1,000 h	3.0 AF	0.8 AF
Chemical-resistant ethanol 60%25°C x 24ht	4.9 SF	3.0 SF
105°C for 1 h → -40°C for 1 h, 300 cycles	4.7 AF	2.9 AF

Untreated PET made by Mitsubishi Chemical: 50 µm
Adhesive: 50 µm 170°C × 30 sec × 1 kgf/cm2
Failure mode: AF = Adhesive interface failure; SF = Substrate failure

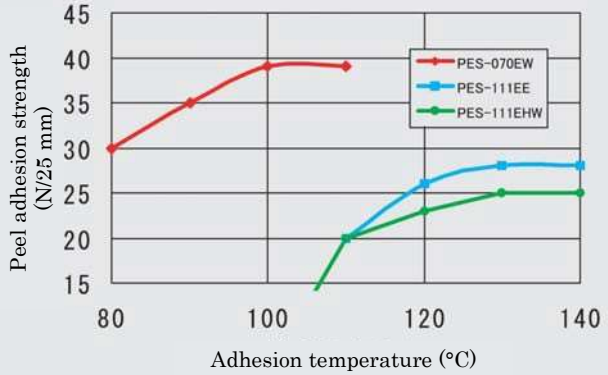

Figure 2: Relationship between adhesion temperature and peel adhesion strength

3.1.2 Electrical properties

Table 4 shows the electrical properties of hot-melt adhesives used for IC card lamination. The required volume resistivity for IC cards is $1 \times 10^{14}\Omega$·cm or higher, and ARON MELT PES-111EE has a resistivity of $2 \times 10^{14}\ \Omega$cm.

Table 4: Electrical properties of hot-melt adhesives for IC card lamination

		Unit	PES-111EE
Volume resistivity	ASTM-D-257-66	Ω cm	2×10^{14}
Surface resistivity	ASTM-D-257-66	Ω	2×10^{15}
Breakdown voltage		kV/mm	50

Since the laminating adhesive will be in direct contact with conductors, such as antennas, it must have a low ionic impurity content. **Table 5** shows the ionic impurity content extracted from the adhesive with distilled water at 95°C for 24 hours. All of the ionic impurities are below the detection limit.

Table 5: Ionic impurities in PES-111EE

Na^+	K^+	Cl^-	Br^-	SO_4^{2-}	NO_3^-
<0.1	<0.1	<0.1	<0.1	<0.2	<0.1

Cation: Atomic absorption spectrometry
Anion: Ion chromatography, DINEX DX-300 model

3.1.3 Laminating method

Figure 3 shows an example of the bonding method using an ARON MELT PES film. This is a hot-melt lamination method in which a film of ARON MELT PES hot melt adhesive is placed between the PET film as the surface layer substrate and the circuit board, and heated with a heat roller for lamination. The heat roller temperature is 180-200°C for PES-111EE and PES-111EHW, and 120-150°C for PES-070EW.

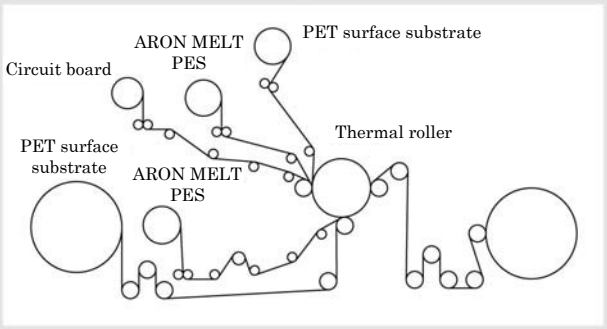

Figure 3: Example of thermal lamination method

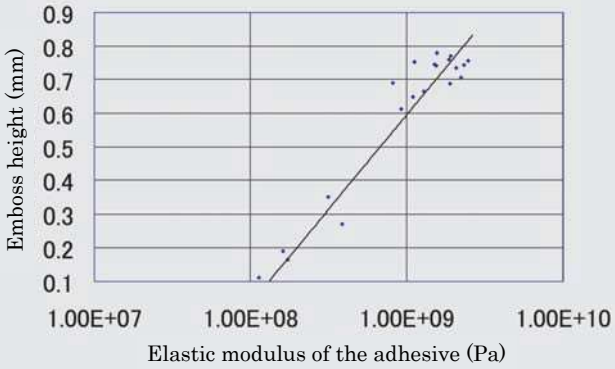

Figure 4: Relationship between emboss height and elastic modulus of the adhesive

The material is then die-cut into the shape of an IC card. Another method is hot pressing, in which ARON MELT PES is cut into sheets, laminated to each substrate, and bonded by a heat press. For IC cards, hot melt adhesives are pre-formed into film shapes using a T-die extruder. **Table 6** shows the film processing conditions using a T-die extruder.

Table 6: Film processing conditions using a T-die extruder

		PES-070EW	PES-111EE	PES-111EHW
Set temperature (°C)	Cylinder 1	30	90	100
	Cylinder 2	50	120	130
	Cylinder 3	100	150	160
	Adapter	120	140	170
	T-die 1	100	140	160
	T-die 2	100	130	160

Extruder: φ40 mm, single screw, L/D = 25
Compression ratio: 4, screw speed: 45 rpm

3.2 Hot melt adhesives for embossed cards

Embossing, such as on credit cards, is used for payment at stores and is necessary to transfer the card number onto the duplicate slip, as defined in the specifications. The card material must allow embossed characters to appear clearly, and must not warp or crack due to embossing. The character height and card warp are determined by JIS-X-6301 (1998), "Identification cards - Physical characteristics." The height of embossed characters from the card surface must be between 0.43 and 0.48 mm. Regarding warping, the height from the flat surface to the non-embossed surface of the card must be 2.5 mm or less when the card is placed on a flat surface. PVC, PETG, and PETG/PC alloys are primarily used as substrates for embossed cards. PET and acrylics crack during embossing. The use of PETG and PETG/PC alloys has increased in recent years due to environmental concerns, and excellent adhesion to these materials is essential.

Toagosei has developed hot melt adhesives for embossed cards, which boast excellent adhesion and minimal warping, even after embossing.

3.2.1 Examination of embossability

As shown in **Figure 4**, the emboss height correlates with the elastic modulus of the substrate and adhesive. The higher the elastic modulus, the higher the emboss height. The modulus of elasticity must be optimized so that the emboss height falls within the standard.

Therefore, we designed a resin composition with good tensile bond strength without altering the elastic modulus of the resin and developed hot melt adhesives with excellent embossability. **Table 7** shows the physical properties of ARON MELT PES-XP715 and PES-XP727 (the latter of which has improved heat resistance), for embossed card adhesives, as well as the characteristic values of the card tested in accordance with JIS-X-6301 (1998), "Identification cards - Physical characteristics." The test yielded good results: warping of 2.1 mm or less after embossing and an emboss height of 0.45 mm. The chemical resistance test conducted in accordance with JIS-X-6305-1 (2004) "Identification cards - Test methods - Part 1: General characteristics" also shows good results.

Table 7: Physical property values of ARON MELT PES-XP715 and 727, and characteristic values of the card

			PES-XP715	PES-XP727
			Standard grade	Heat-resistant grade
R&B softening point	JIS-K-6863	°C	235	240
Melting point	JIS-K-7121	°C	102	105
Glass-transition temperature	JIS-K-7121	°C	44	48
Melt viscosity	at 230°C	Pa·s	570	740
Tensile properties JIS-K-6734	Tensile yield strength	MPa	30.3	38.2
	Tensile strength at break	MPa	34.7	43
	Elongation at break	%	12.5	5
Embossing characteristics JIS-X-6301	Emboss height Between 0.43 and 0.48 mm	mm	0.45	0.45
	Warping of the card < 2.5 mm	mm	1.6	2.1
Chemical resistance test JIS-X-6305	After immersion in a 60% ethanol solution for 24 h		No abnormalities	No abnormalities
	After immersion in an isooctane-toluene solution (7:3) for 24 h		No abnormalities	No abnormalities
	After immersion in a 50% ethylene glycol solution for 24 h		No abnormalities	No abnormalities

3.2.2 Adhesive performance

Figure 5 shows the peel adhesion strength of PETG/PC alloys bonded with PES-XP715.

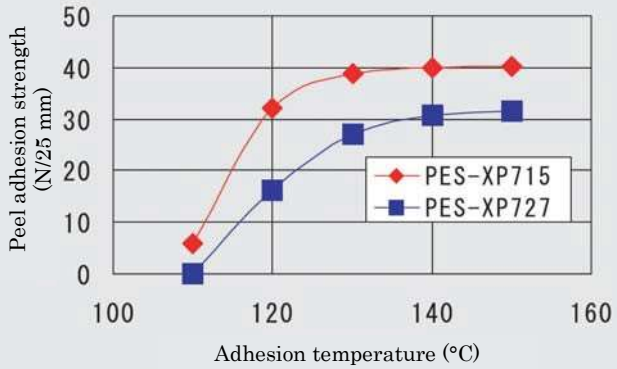

Figure 5: Relationship between adhesion temperature and peel adhesion strength of PES-XP715 and 727

Adhesion condition: Bonding of PETG/PC alloy, 120 μm
Predefined temperature × 30 sec × 0.1 Mpa
Peeling conditions: 23°C, 200 mm/min

Despite its high R&B softening point, bonding with this adhesive can be performed at a bonding temperature of 130°C, offering excellent productivity.

The lamination and heat press methods described in 3.1.3 are used as bonding methods.

4. Adhesives for bonding IC chip modules

The previous section covered adhesives used for contactless IC cards. This section introduces the adhesives used for contact IC cards. A contact IC card has a structure in which a recess is formed in the card substrate to accommodate the IC chip, and an approximately 12 mm square board with an IC chip and electrodes on its top is inserted into the depressed portion and bonded with adhesive. We developed a hot melt adhesive for securing these IC chip module boards. **Table 8** shows the required performance for the adhesive. To achieve high productivity, bonding must be completed in a few seconds and adhesion at low temperatures is also required to avoid thermal damage to the IC chip.

Table 8: Performance requirements for adhesives for IC chip modules

	Performance requirements
1. Adhesive	Excellent adhesion to PETG/PC alloys
2. Low-temperature adhesive	Capable of bonding at low temperatures (bonding temperature of 180°C or lower) in a short amount of time (1 second or less)
3. Adhesive durability	No peeling under the following conditions: Cold storage: -35°C x 500 h Hot storage: 50°C x 500 h Damp-heat resistance: 50°C x 95%RH x 500 h
4. Chemical resistance	No peeling after immersion in a 5% sodium carbonate solution at 25°C No peeling after immersion in 60% ethanol at 25°C No peeling after immersion in a JIS-K-6258 B solution at 25°C
5. Processing suitability	No burring or adhesion to the blade during the die-cutting process

However, low-melting-point hot melt adhesives based on the low-temperature adhesion technology of PES-070EW, which was introduced as a product for contactless IC card lamination, tend to have low crystallinity and softness, making them prone to sticking to the punching die and producing burrs. To address this problem, we developed PES-070IC, a low-melting-point hot melt adhesive.

Table 9 shows the adhesive performance of PES-070IC tested in accordance with JIS-X 6305-1 (2004), "Identification cards - Test methods - Part 1: General characteristics." The die-cutting test results show that there is no burr with PES-070IC.

Table 9: Adhesive performance of PES-070IC

	PES-070IC	Competitor hot-melt adhesive
Initial	16.9 SF	0.5 AF
5% sodium carbonate solution for 24 h	9.9 SF+AF	0.5 AF
60% ethanol solution for 24 h	5.5 SF	7.6 SF+AF
ISO1817B solution for 24 h (isooctane (70%)/toluene (30%))	9.5 SF	2.0 AF
50% EG solution for 24 h	7.4 SF	4.8 SF
Storage at -35°C for 500 h	8.7 SF	1.1 AF
Storage at 50°C for 500 h	6.7 SF	6.3 SF
50°C 90%RH 500 h	5.2 SF	5.7 SF

Unit: N/25 mm
Failure mode: SF = Substrate failure; AF = Adhesive interface failure
Adhesion condition: Bonding of heat-resistant PETG/FR4 substrate
180°C × 1 sec × 0.4 MPa Peeling conditions: 23°C, 200 mm/min

5. Conclusion

Due to their performance, the adhesives for IC cards developed by using ARON MELT PES technology have been adopted for various contactless IC cards, starting with phone cards, and expanding to employee ID cards and membership cards, building up a solid track record.

The IC card market is expected to grow rapidly in the transportation sector, including train tickets, as well as in the public and administrative sectors, including basic resident registration cards[4].

We will continue developing adhesives for IC cards with ARON MELT PES technology as the core. We also intend to further expand the technology cultivated through our adhesives for IC cards to other applications.

Reference

(1) Akio Shiibashi, Card Wave, 3, p.36, (1999).
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